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The wasted energy: A metric to set up appropriate targets in our path towards fully renewable energy systems

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By 2020 Europe has to increase its energy efficiency and share of renewables in 20%. However, even accomplishing these challenging objectives Europe will be effectively wasting energy as we demonstrate in this paper.

In our way towards a fully renewable scenario, we need at least to stop wasting energy in order to guarantee the energy supply needed for growth and comfort. We waste energy when we employ more primary energy than the final energy we ultimately use and this excess cannot be reutilized. In this paper we propose the WE (wasted energy) as a novel metric to measure the performance of energy systems and set up appropriate targets.

The WE incorporates information about energy efficiency and renewable sources. Unlike European legislation, the WE considers them in an integrated way. This approach will help Member States to exploit their intrinsic capabilities and design their optimum strategy to reach their objectives.

Using the information in Eurostat, we calculate the WE of Member States in EU-28 and their evolution. We also analyze illustrative examples to highlight strategies to reduce the WE, study the connection between economic development and WE, and provide a tool to diagnose the potential of improvement of an energy system.

1. Introduction

Energy is key for economic development and comfort. In order to provide us with the required energy, we have traditionally relied on unsustainable sources, i.e., those that we will eventually exhaust. Consequently, in the last decades we have concentrated on creating technology to exploit sources like the sun or the wind that guarantee an unlimited supply, the renewable energy sources. The ideal scenario would then be consuming all our final energy from this type of sources. However, energy systems throughout the world are far away from achieving this perfect situation.

During the transition to a completely renewable energy provision, we need to ensure the supply required for growth and comfort. Even if we could only consume the exact amount of energy we use we will eventually ran out of unsustainable energy sources. But this is not the case. In reality, in every transformation or generation process we lose energy. This extra energy cost may be represented by its energy efficiency, which expresses the ratio between the final energy we produce and the primary energy we consume. Therefore, energy efficiency is key to extend the lifespan of unsustainable energy sources while we create completely renewable systems.

This fact has led administrations to increase in parallel the use of renewable energies and energy efficiency. As an illustrative example, Europe set up specific targets for 2020: (i) a 20% share of the total primary energy generated by renewable sources [1]; and (ii) a plan [2] and specific legislation [3,4] to achieve a 20% increase in energy efficiency as a key path to achieve the environmental and energy goals [5]. Before even reaching 2020, Europe has gone a step further, building a new road map that extends these initiatives up until 2050 in order to construct a competitive low carbon economy [6].

It is evident that these measures have achieved remarkable improvements. However, the underlying problem of covering the supply until we get to the ideal scenario falls beyond efficiency and renewables as separate entities. The core of the problem is how much energy we waste. And even accomplishing its demanding targets, Europe will still be wasting energy, as we will demonstrate further in this paper.

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From a political rather than a thermodynamical perspective, we understand that we waste energy due to the inefficiency that is not compensated with renewable energy sources. Consider two extreme and conceptual scenarios: (i) if we were completely efficient, we would be using just the energy that we effectively use, thus we could not say we were wasting any energy; (ii) on the other hand, if we were completely inefficient but all the energy we were consuming came from renewable sources, we could say that we were not wasting it as it could be renewed in the environment and we could reuse it.

Consequently, we need a metric, obtained from empirical data, which expresses the wasted energy in an energy system and integrates its efficiency and share of renewable sources. This integrated metric would provide a better representation of the actual performance of that energy system.

Given this need, in this paper we propose the WE (wasted energy) as a novel metric to define more appropriate targets to guarantee the energy supply until we reach a fully renewable system. The WE incorporates information about energy efficiency and the production of renewable sources in a single numeric value. In this sense, the WE reflects the misuse of energy, expressed as the percentage of one primary energy unit that was not transformed into final energy units, and cannot be replaced in the environment.

In the remainder of this work, we will demonstrate that employing the WE to define energy and environmental targets, we actually impose a more restrictive objective than those based on efficiency and share of renewable sources. At the same time, this new objective will more precisely reflect the actual needs of both environment and Society.

2. Related work

This paper aims at contributing to alleviate the waste of energy along the path towards a fully renewable scenario. This ideal situation would result in positive effects on economy, employment, exports, and other externalities like health [7].

The first question is then: Is it possible to reach 100% renewable energy systems? Fortunately the answer is "yes" as Lund and his collaborators have demonstrated. The set of technological changes we require to reach this objective, like energy savings in demand, efficiency in production, and replacement of fossil fuels, are feasible in a foreseen future [8]. In fact, in Ref. [9] he provides a software, namely EnergyPlan, to model different approaches to integrate renewable energy sources into existing systems in order to design viable approaches. EnergyPlan has been used to construct specific paths adapted to the particular conditions in different countries like Denmark [10], Ireland [11], and Macedonia [12] to reach 100% renewable systems in 2050.

On the basis of this achievable fully renewable scenario, we now need to find ways to maintain economic growth and comfort, which are intimately related to energy consumption. The key is to avoid wasting energy. As the IEA (International Energy Agency) indicates, nowadays we waste energy in every sector (buildings, transportation, industry, etc.) [13]. The fundamental strategy is simply to prevent consuming more energy than you strictly need; as expressed in Ref. [14] "If you don't need it, don't use it"; the authors demonstrate that applying this principle they could save 56% of the energy commercial buildings use in South Africa and Botswana. In addition, the IEA establishes that cable TV set-top boxes in the United States of America consumed 18 TWh of electricity in 2010; saving this energy would have avoided the annual generation of six 500 MW coal-fired power plants [15].

Unfortunately wasting energy is not only linked to behavioral aspects that we can correct. Generation processes and distribution also include a share of energy that is not ultimately employed. Considering this wasted energy as a new resource for other processes opens a new set of sustainable approaches that fall into the so-called Industrial Ecology [16]. Following this approach, there are technologies that aim at re-using sub-products like heat in power and industrial plants [17] or redesigning the energy distribution networks using effective approaches like district heating [18–20].

Being certain that we can achieve 100% renewable energy systems and that, along the path, we must find ways for reducing the wasted energy, we now require to design specific policies to articulate this transition [21]. As indicated by Fiona Hall, Member of the Committee on Industry, Research and Energy of the European Parliament, "We need to develop, enact and eventually implement an integrated 2030 framework with binding targets for carbon reduction, energy efficiency and renewables". This integrated framework is not fully achieved yet although during the last decade, Europe has developed an extensive set of directives focused on significantly reducing both GHG emissions and energy consumption.

In 2006 the European Commission created the Renewable Energy Road Map [22]. This communication established the target of raising to 20% the share of primary energy that come from renewable sources in 2020. Although the target is to be accomplished by Europe as a whole, the Commission remarks that it needs the contribution of every Member State and has to be applied to every consuming sector. This target became mandatory with Directive 2009/28/EC [23].

In addition, the "20 20 by 2020" communication [1] extended the stated renewable energy aim to a specific environmental target measured in terms of GHG emissions. In particular, it added a second objective to reduce at least 20% in GHG emissions by 2020. These two targets are evidently connected given that all renewable sources except some biofuels are non-emitting or carbon neutral.

In order to empower the tools to accomplish these objectives, the European Commission opened a new legislative path focused on energy efficiency [5]. It fixed an additional target of saving 20% of the projected primary energy [2] in 2020. This target was officially established through Directive 2012/27/EU [3] and implies a reduction of 1474 million tons of oil equivalent (Mtoe) of primary energy or 1078 Mtoe of final energy by 2020. These targets were updated after the accession of Croatia to the EU to 1483 Mtoe primary energy and 1086 Mtoe of final energy [4].

These targets open a set of issues revolving around how to monitor their actual accomplishment. Energy efficiency is usually audited through its inverse, the PEF (primary energy factor), defined as the ratio between the primary and the final energies of a specific transformation or generation process. Thus the PEF reflects the efficiency of a process or a whole energy system (taking in this case the overall values of the primary sources and final forms in a country or region). However, it presents an inherent issue regarding the calculation of PEFs. Current legislation, technical standards, and scientific works use fixed or estimated values. We can solve this issue constructing an empirical and dynamic approach to the PEF as indicated in Ref. [24]. Even overcoming this problem, the PEFs do not carry information about the share of renewable sources employed in the mix.

Consequently, each target is monitored in a separate way, thus failing in constructing the desired integrated framework where a measure of the energy we waste would be key to extend the lifespan of the energy supply in our way towards fully renewable energy systems.

3. The wasted energy

Thermodynamics states that energy can be neither created nor destroyed (first law) and that entropy always increases in