

Review

# The European Union Green Deal: Clean Energy Wellbeing Opportunities and the Risk of the Jevons Paradox

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**Abstract:** After the Great Recession of 2008, there was a strong commitment from several international institutions and forums to improve wellbeing economics, with a switch towards satisfaction and sustainability in people–planet–profit relations. The initiative of the European Union is the Green Deal, which is similar to the UN SGD agenda for Horizon 2030. It is the common political economy plan for the Multiannual Financial Framework, 2021–2027. This project intends, at the same time, to stop climate change and to promote the people’s wellness within healthy organizations and smart cities with access to cheap and clean energy. However, there is a risk for the success of this aim: the Jevons paradox. In this paper, we make a thorough revision of the literature on the Jevons Paradox, which implies that energy efficiency leads to higher levels of consumption of energy and to a bigger hazard of climate change and environmental degradation.

**Keywords:** European Union (EU); Green Deal; wellbeing economics; Horizon 2030; Jevons Paradox; clean energy production; sustainability



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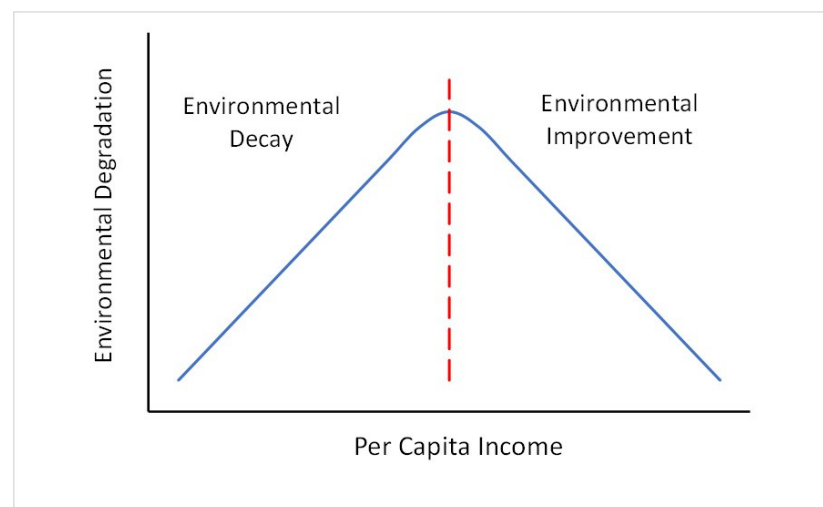
## 1. Introduction

More and more international institutions and forums have now a strong commitment to achieve a climate neutral economy that achieves the people–planet–profit wellbeing [1]. This is the case with the United Nations Sustainable Development Goals (UN SGD) for Horizon 2030 [2], the Economy of Well-Being of OECD [3], the Wellbeing Economy Alliance of WEF and net of transnational corporations [4], the Green Deal of the European Union (EU) [5], etc. The EU Green Deal was passed in 2019 within the Multiannual Financial Framework 2021–2027 [6] with the aim to promote the clean energy production and the wellbeing in Europe [7,8]. Positive externalities derived from the production and use of clean renewable energy are job creation, rural community development, reducing energy poverty and mitigating its negative effects on the environment and public health. Renewable energy jobs were estimated worldwide 11.5 million in 2019, with a growing tendency (in 2018 they were 11 million) [9]. A total of 32% is women employment. Some few countries concentrate most of this employment, but advantages are evident, especially with the use of solar photovoltaic (PV) technologies where 33% of the total renewable energy workforce is found. In 2019, ten countries leading in the production of equipment concentrated 87% of the PV employment. Asia is the continent that takes more advantage of this global trend, with 63% of world jobs in renewables. Production has clearly increased in countries with labour-intensive supply chains such as Philippines, Malaysia and Thailand, and also Brazil and Colombia, whereas a decrease in output in the US and the EU is happening. Not many estimates are available, but there is an upward tendency of the number of jobs in off-grid decentralised renewables. Important linkages on other productive uses are evinced in local

communities, from agri-food to communications, trade or health care. Supply chains are expanding. It is now evident that providing the skills necessary to walk smoothly from fossil fuels to renewables requires more information, training and technology for remote and digital learning [10].

In regards to green jobs composition [9,11], jobs in biofuels expanded to 2.5 million driven by growth of the outputs in 2019: biodiesel grew to 13% and ethanol to 2%. In regards to wind power, there are 1.2 million jobs, 21% of which is women employment. The bulk of the projects are onshore, but 18 countries have now offshore farms, when a decade ago there were only 10. The installed capacity of hydropower is the largest of all renewables, but it grows relatively slowly. Hydropower employs directly near 2 million people, many of them in operations and maintenance.

The promotion of renewables, then, is part of the wellbeing economics agenda, which goal is human satisfaction and social development. Wellbeing economics is based on an interdisciplinary approach that connects economics with other social and physical sciences. It is a choral initiative of cooperative intelligence beyond the traditional bureaucratic model of welfare state economics [12–14], drawing in the collaboration of international institutions, international forums, worldwide think-tanks, global consultant firms, nets of companies and decentralized technologies (e.g., block-chain). All are committed to the construction of healthy organizations under spontaneous cooperation within the digital economy and a dynamic efficiency approach [15]. The ongoing fourth industrial revolution makes technological advances and labour wellbeing exponentially convergent [16–22]. Artificial intelligence is replacing human beings in tedious tasks, something called singularity [23]. Then, more production at lower costs may increase global living standards while improving environment, as predicted by the Kuznets curve [24,25] and shown in Figure 1.



**Figure 1.** The environmental Kuznets curve.

However, for a happy ending of wellbeing economics objectives, a problem emerges: the risk of the Jevons paradox. According to this paradox, clean and cheap energy production could mean higher levels of consumption of energy and a bigger hazard of climate change and environmental degradation. This article is an analytic review in a theoretical and in an ethical way: (1) to understand the alignment of the EU Green Deal with other international initiatives [26]; (2) to explain its origin and development; (3) to reflect on the risk of its success, according to the Jevons Paradox.

The paper is presented as follows. First, a general overview from U.N. to the particular European plan of the economic policies proposed for clean energy production is presented. Second, there is an explanation of the EU Green Deal, its goals and its challenges. Finally, the article pays attention to the Jevons paradox, and there is a proposal to deal with this risk.

## 2. Present Environmental Dangers and Political Economy Proposals

### 2.1. General Overview and Framework

Scientific consensus claims that the Earth is warming [27]. Global climate change is characterized by a statistically significant modification in the mean state of climate or in its variability, which persists for a sufficient period (at least for decades). This trend towards global warming cannot be explained alone by natural causes. Indeed, certain human activities, as the burning of coal and oil, have significantly increased it due to the effect of greenhouse gases in the atmosphere [28,29]. Greenhouse gases let solar radiation pass by but absorbing infrared radiation emitted by the Earth, keeping the heat trapped in the atmosphere. Among these gases, there are the water vapor, the carbon dioxide or the methane. Human emissions of these gases can be due to different activities, such as industrial or agricultural activities or deforestation [30]. Economics has contributed to the analysis of the greenhouse effect [31]. Besides, these greenhouse gas emissions can be removed by vegetal activity. The importance of greenhouse gas emissions removal is such that it has become one of the main environmental concerns for the world population [32–34]. In the mid-to-late 1980s, this issue became a public topic [35]. It was treated by the scientific community up to the late past century [36,37]. A complete review about historicizing climate change can be seen in [38].

The Intergovernmental Panel on Climate Change (IPCC) was set in 1988 as a body devoted to assess the scientific knowledge related to climate change. IPCC was launched by the United Nations Environment Programme and the World Meteorological Organization (WMO) for governments to establish policies of adaptation and mitigation to climate change. IPCC reports are regularly reviewed and they are based on climate change scientific works. IPCC does not carry out its own research, but it identifies points in agreement and disagreement in the scientific community and those points where more research is needed.

IPCC consists of three working groups: the first one is devoted to the physical basis of climate change; another is devoted to impacts, adaptation and vulnerability; the third group is devoted to the mitigation of climate change. The methodology of the IPCC reports has changed in the course of time, starting with the 1994 Guidelines, when a consensus was reached on climate change causes [39,40]. It was replaced by the Revised 1996 IPCC Guidelines. In 2005, this was related to the safeguarding of the ozone layer [41]. The methodology used was published in 2006, which was supplemented in 2013. The risk of extreme events due to climate change has also been studied [42]. A refinement was added in 2019, covering those aspects where the science had sufficiently advanced in the last years (a list of IPCC Methodology Reports can be found in <https://www.ipcc-nggip.iges.or.jp/public/index.html>; page accessed in 18 April 2021 and an account of its importance for the politics of climate change in [43,44]).

According to the Third Assessment Report on climate change 2001, carbon dioxide and methane have increased their atmospheric concentrations about 31% and 151%, respectively, during the period 1750–2000. According to the IPCC Fourth Assessment Report, the following indicators are clearly evidence of climate change: (a) global sea-level has increased about 17 cm in the last century [45] and the rate corresponding to the last decade is nearly double; (b) global temperature has risen: during the past century, the mean global surface temperature raised by 0.6 °C, and since 1860, the decade of 1990 has been the warmest; (c) oceans have also warmed, as they absorb an important part of the warming, so the top 700 m of ocean has suffered warming of 0.16 °C since 1969 [45]; (d) ice sheets reduce their thickness, so Greenland ice sheets have lost between 150 and 250 km<sup>3</sup> of ice per year from 2002 to 2006, while Antarctica about 152 km<sup>3</sup> from 2002 to 2005 [45]; (e) the content of carbon dioxide of the oceans has increased since 1750; this content is now increasing about 2 billion tons per year, so ocean acidity has risen by about 30% [45].

### 2.2. EU Green Deal Framework

The EU is developing ambitious policies devoted to fight climate change [46,47]. Its target is to cut greenhouse gas emissions by 2030 at least 55% and by 2050 to achieve climate-

neutrality. In order to achieve this target, the EU has performed an important package of measures, called the European Green Deal. The main driver of ecoefficiency seems to be economic development, as measured by GDP per capita, so growth and economics seem to be the clue to energy performance [48].

Different initiatives are included in the Green Deal: (a) the European Climate Law, with the 2050 climate-neutrality objective, (b) the European Climate Pact, for citizens to engage in climate action, (c) the 2030 Climate Target Plan, for the reduction of net greenhouse gas emissions by at least 55% by 2030, and (d) the EU Strategy on Climate Adaptation, so that Europe is a climate-resilient society by 2050, adapted to the effects of climate change. The new EU Strategy on Climate Adaptation was adopted by the European Commission on 24 February 2021. By this strategy, the EU can adapt to the impacts of climate change, so member states become climate resilient by 2050. The strategy must make adaptation smarter, faster and more systemic and step up international action for climate resilience [49,50].

The first initiative is the European Climate Law. The aim of the Commission's proposal is to include into this law the goal that EU becomes climate-neutral by 2050. According to this goal, EU countries as a whole should achieve net zero greenhouse gas emissions. The law should encourage that the policies are applied in a socially fair and cost-efficient manner that contributes to the reduction of emissions, the investment in green technologies and the protection of the natural environment. Likewise, all sectors of the economy and society should play their part in this goal. The progress should be monitored by a certain system, so further action is taken if needed. In addition, investors and other economic actors should be able to make predictions, so the transition to climate neutrality is irreversible. Thus, the institutions and the states must adopt the measures to meet the target, at both the national and EU level.

The measures of the European Climate Law are based on the regulation on the governance of energy and climate action, which ensures that EU planning and reporting follow common rules. The climate plans are devoted to five dimensions (and a corollary): first, decarbonization (the reduction of greenhouse gas emissions and the stimulus to renewables), second, energy security (the availability of the resource), third, energy efficiency (cutting down energy waste), fourth, internal energy market (removing barriers within the EU market) and, finally, research, innovation and competitiveness (choosing the best cutting-edge resources). The corollary related to wellbeing economics will be added in this article and it consists of achieving more social and ecological wellness for citizens and in businesses, something common to other international initiatives, such as the Wellbeing Economy Alliance. Likewise, the measures of the Climate Law are based on regular reports emitted by the European Environment Agency and on the scientific evidence on climate change [51–56].

The European Climate Pact is an initiative that searches the participation of people and organizations in climate action in order to build a greener continent. The goal of this pact is to share knowledge and learning about climate change and to develop and implement solutions. Laws and policies are supposed to not be enough alone and awareness and supporting action must be spread [57–59].

Finally, the 2030 Climate Target Plan substantially increases the existing objective of the 1990 plan of the reduction of greenhouse gas emissions, happening to meet the Paris Agreement target of keeping the global temperature increase below 2 °C.

### 3. EU Green Deal Analysis: Development, Goals and Challenges

#### 3.1. Origin and Development

The unofficial origin of the EU Green Deal comes from Rifkin's lectures in Europe during the 2000s decade. At these times, Rifkin (lecturer at Wharton Business School in USA) came to Europe to make some readings of his books, *The Age Of Access* [60], *The Hydrogen Economy* [61] and *The European Dream* [62]. He had the chance to meet some European leaders, especially, Angela Merkel (Chancellor of Germany), who introduced

him to Ursula von der Leyen (former Minister in Merkel's Government and current President of the European Commission). In the following decade (2010s), Rifkin wrote four books, which are the genesis and fundamentals of the EU Green Deal: *Empathic Civilization* [63], *Third industrial revolution* [64], *Zero marginal cost society* [65] and *Green new deal* [66]. Rifkin's influence to promote the Green Deal project has extended to China (Xi Jinping and Li Keqiang in the 13th five-year plan) and USA (Green New Deal, Representative Alexandria Ocasio-Cortez (house.gov)).

According to the EU Consilium or Council of the EU, the official timeline announced in press headlines is the following (Fleishman Hillard, 2021):

- 2019: The strategic agenda was presented: EU leaders called for a climate-neutral, green, fair and social Europe (European Council, 20–21 June). EU leaders endorsed the 2050 climate neutrality objective (European Council, 12–13 December). An exchange of views on the EU environment and climate policy was proposed for the next term (Environment Council, 19 December).
- 2020: Ministers debated financial and economic aspects of the Green Deal (Economic and Financial Affairs Council, 21 January 2020). They also discussed agricultural aspects of the Green Deal (Agriculture and Fisheries Council, 27 January 2020). Competitiveness Council discussed the transition to climate-neutral EU (Competitiveness Council, 27–28 February 2020). Environment and climate ministers exchanged views on the European Green Deal (Environment Council, 5 March 2020). Agriculture ministers welcomed EU Biodiversity and Farm to Fork strategies (video conference of agriculture ministers, 8 June 2020). EU energy ministers discussed the EU Green Deal and economic recovery (video conference of energy ministers, 15 June 2020). According to the environment ministers, the European Green Deal should guide the recovery towards green growth (video conference of environment ministers, 23 June 2020). The council agrees its position in support of the initiative of the European Year of Rail 2021 (press release, 24 June 2020). The council agrees on its partial negotiating position of the Just Transition Fund (press release, 24 June 2020). EU chooses more ambitious options to calculate offsetting requirements for aviation emissions. The EU confirms its participation in the CORSIA voluntary phase from 2021 and chooses the more ambitious option to calculate its offsetting requirements (press release, 25 June 2020). EU leaders discuss the EU's climate ambition for 2030 (European Council, 15–16 October 2020). The council prioritizes actions for sustainable food systems and make some conclusions on the Farm to Fork strategy (press release, 19 October 2020). The council agrees its position on the public sector loan facility with a just transition towards climate neutrality (press release, 21 October 2020). Environment ministers reach partial agreement on the EU climate law and adopt conclusions on biodiversity (press release, 23 October 2020). The council adopts conclusions on the EU biodiversity strategy for 2030 (press release, 23 October 2020, Environment Council, 23 October 2020). The EU and member states' contributions for the climate finance continued to increase in 2019 (press release, 29 October 2020). EU leaders endorsed a new binding climate target (European Council, 10–11 December 2020). The council endorses the political deal with the parliament for the just transition fund. The resources will come from the 2021–2027 multiannual financial framework (EUR 7.5 billion) and the next generation EU instrument of EUR 10 billion spread over three years (press release, 16 December 2020). The council gives a general approach on the European climate law proposal (press release, 17 December 2020).
- 2021: Finally, the council approves the conclusions on the EU chemicals strategy for sustainability (press release, 15 March 2021). Council and parliament reach provisional agreement on the European climate law (press release, 21 April 2021). A public sector loan facility to support just climate transition is accepted in a provisional agreement (press release, 26 April 2021). EU ambassadors approve a compromise text on the EU climate law (press release, 5 May 2021).

### 3.2. Goals and Challenges

As mentioned, five dimensions are covered by the EU climate plans. However, these five strategic tools for the fight against climate change raise certain problems and at least one contradiction. Some of the problems in each dimension are:

- (1) **Decarbonisation:** In 2019, different countries and big corporations expressed their commitment to a net zero carbon pathway. Renewable technologies have reduced their costs so much that they have become the most economical option [67]. The sector where the decarbonisation process is the easiest is perhaps electricity generation. Globally almost three-quarters of annual net electricity capacity already come from renewable energy. However, a full decarbonisation still requires investments in the sector. Indeed, the main problem of renewable technologies is uncertainty and intermittency, so different strategies must be considered in order to remove, or at least reduce, this problem: a combination of diverse renewable sources, such as solar and wind, the storage of energy and the use of zero-carbon base-load power [68,69]. Though decarbonisation in the electricity generation sector can be addressed with the necessary investment, only around a quarter of global greenhouse gas emissions is caused by this sector. In Figure 2, the composition of energies for electricity generation is shown. However, the decarbonisation of other sectors is much more difficult. For instance, the case of transportation is paradigmatic, as there are less than one percent of electric vehicles. The still high price of these vehicles, together with the reduced number of charging points, explain such a low percentage [70,71]. In the case of the EU, in [72] the necessary energy system transformations and the costs to meet the decarbonisation objectives established in the EU Roadmap 2050 are analysed by seven large-scale energy economy models (also [73]). The emissions reduction target can be achieved with technological options, which entail less than 1% of GDP during the period 2015–2050. The delay in reducing emissions until 2030 increase the energy system costs and makes the objective of decarbonisation difficult [74].

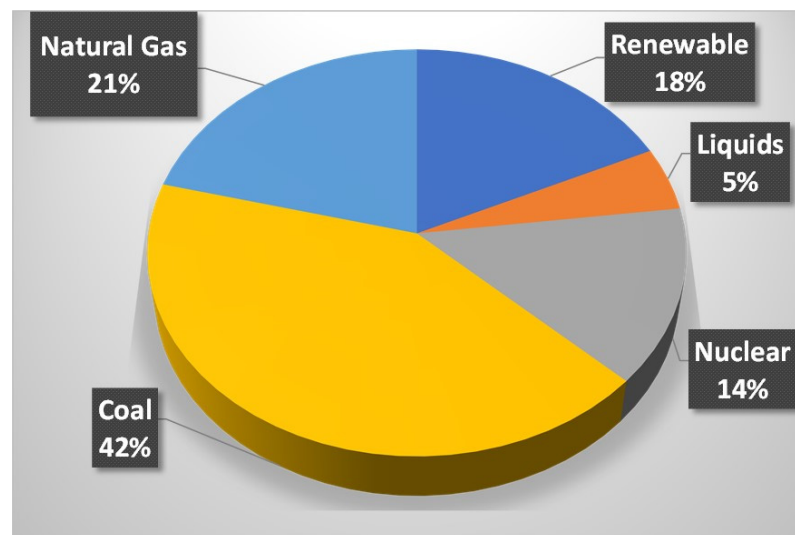


Figure 2. Worlds' electricity generation [75].

- (2) **Energy security:** The definition of this term is complex [76] as it has implications in very different fields: economic, social, technical, political, etc. In [77], the distinction between “security of supply” and “security of demand” is stressed. This security implies that production and consumption of energy need to be in accordance, and a balance of supply and demand is needed. This balance depends on geopolitics, on the availability and affordability of energy through domestic production or imports and on the diversification of energy sources. At the end of the last century, studies

about energy security focused on supply [78], so the main concern for policymakers was getting a non-intermittent flow of energy supply [79]. Currently, the concept of energy security is part of a broad interdisciplinary field including dimensions such as energy efficiency, sustainability, reduction of greenhouse gas, energy poverty, equitable access to energy, energy education, etc. [80,81]. Some scholars, such as [82], add the concept of “cultures”, as different subjects can perceive the energy security in different ways, according to their culture (national, political, economic, professional and epistemic). The IEA defines energy security as the uninterrupted availability of energy sources at an affordable price. To achieve long-term energy security, timely investments are needed to ensure the availability of energy in agreement with the environmental needs and the economic developments. Short-term energy security is referred to the need of the system to react rapidly to sudden shifts in the balance between supply and demand [83]. This issue needs then to be addressed in the scope of different regions [84–89].

- (3) Internal energy market. The EU internal energy market is referred to the integration of gas and electricity markets of EU members into a single market based on the free movement of goods, services, people and capital [90]. The construction of the EU itself had as the principal aim the emergence of an internal energy market. This project began in the Treaty of Paris in 1951 when the European Coal and Steel Community was created to achieve supranationalism in energy supply, and the creation of the Euratom in 1956, which afterwards led to the Treaty of Rome in 1957 when the European Economic Community began with the first six member states. EU’s internal energy market has been harmonised and liberalised by certain measures adopted since 1996. These measures are devoted to achieve a more competitive, flexible and customer-centred electricity market, by addressing aspects such as the transparency, the regulation, the consumer protection, the energy poverty, the supply of electricity, gas and oil or the creation of trans-European networks for energy [91]. Thus, the removal of certain trade barriers, the convergence of pricing and tax policies, and the adoption of environmental and safety regulations are required. The legal basis for these measures is contained in Article 194 and Article 114 of the Treaty on the Functioning of the EU (TFEU). Along the years, different directives about the liberalisation of gas and electricity markets (energy packages) have been adopted. The First Energy Package for electricity was adopted in 1996 and for gas in 1998; the Second Energy Package was adopted in 2003; the Third in 2009; finally, the Fourth Energy Package was adopted in 2019. On the other hand, the Commission put forward several legislative proposals in 2016. The ‘Clean Energy for all Europeans’ package promotes the design of an electricity market, of the security of electricity supply and of governance rules for the Energy Union [92,93]. The proposal COM(2016)0864 for the internal market in electricity proposes that the price at which electricity is supplied to consumers and member states is based on a price competition between suppliers, ensuring the protection of vulnerable households. Now, the goal is to achieve a fair competition in the energy sector. That is, consumers must freely choose the supplier who can provide electricity and gas freely across borders. Fair competition entails harmonized national regulations and the absence of dominant players in the market [94,95].
- (4) Research, innovation and competitiveness in energy. According to the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions [57,58], the National Energy and Climate Plans (NECPs) do not pay sufficient attention to research and innovation needs with respect to climate and energy objectives. The national budgets devoted to research and innovation in the clean energy sector have suffered an overall decrease and the national objectives and funding targets are not sufficiently established [96]. Thus, a new approach to research and innovation and competitiveness in clean energy is needed to achieve climate neutrality. Research and innovation policies, both in the

European and national level, along with funding and national industrial strategies, must be aligned with the climate and energy objectives. These policies must be carried out through NCEPs. However, circular ecoinnovations do not imply higher growth rates of small- and medium-sized enterprises, SMEs, which need to be engaged for policies to be neutral with the size of the firm [97].

- (5) Energy efficiency. In the 2012 directive, amended in 2018, rules are set and obligations are established in order to achieve the EU's 2020 and 2030 energy efficiency targets. Among the measures promoted to achieve these objectives, they are worth mentioning: making buildings more efficient, promoting cogeneration of heat and power, labelling and ecodesign rules, calling for private financing for investments based on energy efficiency or launching a heating and cooling plan in order to provide the energy consumed by the building and industry [98].

From all this, a wellbeing corollary can be drawn that needs to be aligned with the other international initiatives mentioned: into the EU Green Deal announcement in 2019 [7], there was an explanation not only for energy issues, but also for a bigger commitment with social and ecological wellness [99]. The EU Green Deal is the framework to lead to a low-carbon economy and guarantee affordable energy for all consumers; to make the EU's energy supplies reliable; to make the EU less dependent on energy imports; to encourage growth and job creation and to bring wellbeing benefits. In this way, to improve wellness, there are long-term strategies and projects with sustainable, smart and friendly cities; the support to business committed with the welfare of the whole stakeholders, etc. [100]. Instruments should be used to avoid that the lower income citizens are not in a disadvantageous position compared to more wealthy people who could still spend as much energy as they want regardless of the higher green taxes imposed.

For instance, as shown in [101], there are many potential synergies of energy transition with sustainable rural development, but these combined actions are often undervalued. Sustainability contributes to rural well-being and development, leading to energy security and rural mobility. Rural areas face common environmental problems: for instance, biodiversity loss and pollution due to a non-friendly with the environment management of natural resources and waste disposal. These areas are often depopulated, suffering from physical isolation, while they have high proportions of natural resources and agricultural land. Absence of public services and remoteness creates higher car dependency. Local development strategies should be long-term and as diverse as rural areas, with specific natural endowments. Many studies link biodiversity and well-being [102–105].

As shown in [106], a just ecological transition implies giving special attention to these rural areas. They are more vulnerable due to the scarce diversification of activities and lower incomes and educational opportunities, with high rates of unemployment and aging dependent population. Many of them depend on transition-inconsistent sectors such as manufacturing and mining. Thus, energy transition may imply jobs and income losses for them, which must be compensated. Particular attention is needed for coal and carbon-intensive regions. Citizen participation in the energy transition is also of critical importance to ensure social acceptability of the transition measures, including farmers and local retailers, and to foster community ownership. Many energy developers give 'community benefits' for their developments. This implies restructuring food value chains and creating new opportunities for farmers [107]. Climate change could also endanger these areas, making water scarce or increasing flooding, coastal erosion or the frequency and intensity of wildfires increase.

However, according to the study carried out in 16 rural regions across North America and Europe [108], renewable energy does not automatically generate employment in rural areas and the economic growth that occurs is usually much lower than expected. Indeed, the economic growth in these regions requires setting the appropriate local conditions within a coherent policy framework. Renewable energy policies usually pursue overly ambitious targets with very high incentives that tend to cause distortions. The stimulus encourages rent-seeking behaviours, and the trade-off between renewable energy installations



and other activities is not always taken into account. For that reason, local communities sometimes ward off and reject these types of projects. Thus, according to [109], incentives that do not take into account the space must be avoided, implementing flexible policies that consider the needs and development of the places where renewables are introduced. Different opportunity costs within rural economies should be considered, along with backward and forward linkages to other industries such as manufacturing, agriculture or forestry. Besides, different stakeholders should be drawn to the scenario and intermediate institutions should foster collective action in rural economies.

To support these long-term strategies of wellness by introducing clean energies, and also to stop climate change, there is an institutional and scholar turn of the literature linked with wellbeing economy alliance [110–112]. However, in the EU Green Deal strategy, there is a paradox, linked to energy efficiency, which European laws need to tackle with, and that is stressed in the rest of the article: the Jevons Paradox.

#### 4. The Jevons Paradox and Its Risk

The Jevons paradox has long been established since 1865. In the book *The Coal Question*, the English economist William Stanley Jevons witnessed the increase of British consumption of coal after the introduction of the James Watt steam engine, which boosted the efficiency of previous designs such as Thomas Newcomen's engine. Watt's steam engine was widely introduced in different industries, increasing the total coal consumption. As Jevons literally says in page 140: "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. As a rule, new modes of economy will lead to an increase of consumption according to a principle recognised in many parallel instances" [113]. Jevons cited the example of the Scottish iron industry, where a decrease of coal consumption, per quantity of iron, of more than two thirds, led to a tenfold growth in total consumption, besides the indirect effect of boosting other coal consuming sectors due to the availability of cheap iron.

Jevons idea must be understood within his criticism to classical economists, who considered that the cost of production is the source of the value of goods. According to Jevons, it is not the cost of production but marginal utility (the last unit consumed) that gives value to commodities. Finally, the author defended the Jevons "catena": The cost of production affects supply, supply affects the final degree of utility and the final degree of utility affects value. More precisely, the exchange ratio of two commodities is the reciprocal of the ratio of the final degrees of utility of the quantities of commodity available for consumption after completing the exchange. This implies that resource efficiency, when reducing the cost of production, will decrease the marginal utility of the commodities that use the given resource, increasing directly the consumption of those commodities and indirectly the consumption of other commodities with which they are exchanged. Then, resource efficiency is not a good path to the lesser use of resources: the reduction in the cost of production will make producers use the resource more while consumers increase their consumption. As coal is a non-renewable energy resource, Jevons was raising the question of the limits to growth or energy return on energy input (EROEI). As demand grows exponentially, while supply is limited, Jevons was also arguing the problems of overpopulation and that prosperity would find its limits sooner than was commonly realized. This is shown in Figure 3, the actual diagram depicted by Jevons in [113]. With this, Jevons came back to the classical economics idea of the stationary state [114], a concept that emerged long ago, in the period of the Scottish Enlightenment [115]. Obviously, Jevons underestimated the relevance of coal substitutes such as hydroelectric power, petroleum or renewable resources [116].

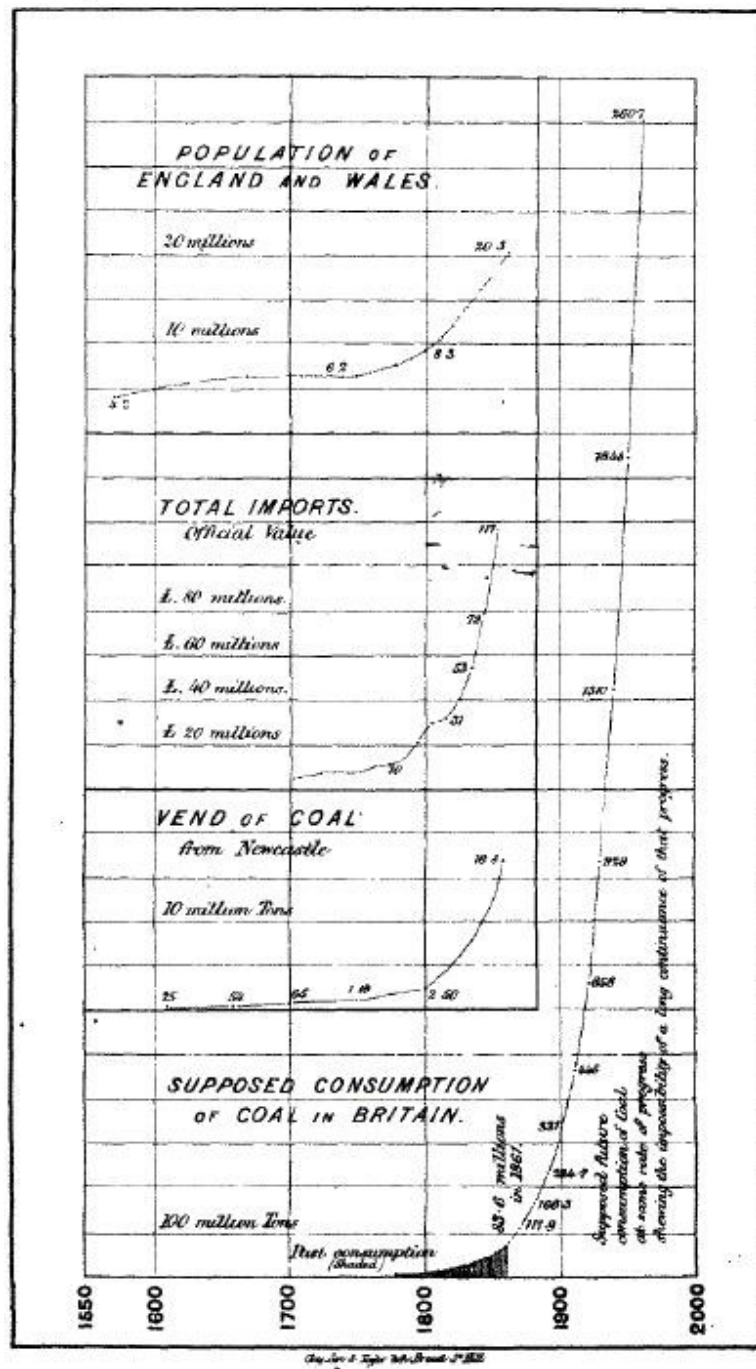


Figure 3. Digitalized image of the diagram depicted by Jevons to represent the rebound effect [113].

This Jevons paradox (sometimes Jevons effect) implies a reduction in the amount of input needed for a certain use, but an increase in the rate of consumption due to increasing demand [117]. Then, technological progress does not reduce the consumption of inputs [118,119]. Technological advances would increase the rate at which the coal deposits of England were depleted, and could not solve the stationary state problem [120]. The Jevons paradox is perhaps the most widely known paradox in environmental economics [121]. The difficulties of calculating the recoverable reserves of a resource that is theoretically finite are discussed in detail in [122].

With these considerations, Jevons initiated an original research program not fully developed until the late twentieth century: the area of econophysics. Along with his paradox, Jevons had a “sunspot” theory of business cycles further extended by H.L. Moore [123].

In this case, Jevons sought a causal link between economic activity and meteorological conditions and in particular an influence of periodic solar activity on agriculture. Jevons found a correlation between the degree of sunspot activity and the price of corn. In his book *Investigations in Currency and Finance* [124] he presents three essays; “The Solar Period and the Price of Corn” (1875) where he finds that the prices of the produce of agriculture have an eleven year cycle (actually, the sunspot cycle average length) [125]. In a second essay “The Periodicity of Commercial Crisis and Its Physical Explanation” (1878) with “Postscript” (1882), the claim by Jevons is that weather patterns have a strong relationship with business activity in basically agrarian societies such as India and Africa, which is to say, in arid and semiarid lands [126]. The third essay entitled “Commercial Crisis and Sun-Spots Part I” (1878) and “Part II” (1879) proposes some policies to make the contraction of the business cycle smoother [127,128]. Jevons stresses the influence of the solar cycle on consumer spending and confidence. This random variable, as shown in [129,130], determines expectations.

William Stanley’s son, H. Stanley Jevons, continued the work of his father on sunspots. After publishing in 1909 in *The Contemporary Review* the article “Changes at the Sun’s Heat as the Cause of Fluctuations of the Activity of Trade and of Unemployment”, he circulated it in the monograph entitled *The Sun’s Heat and Trade Activity* [131,132].

## 5. Discussion

### 5.1. The Debate on the Rebound Effect

Energy economics has established a long-running debate on the nature, causes and consequences of the rebound effect introduced by Jevons [133]. Improved efficiency intends to reduce the amount of resource needed for a given use, lowering its relative cost, but can also increase the quantity demanded. Additionally, it improves real incomes and economic growth, and in so doing it further increases the demand for resources. All this implies counteracting (to some extent) the use diminution due to improved efficiency. The Jevons paradox appears when the effect of the increased demand outreaches the lesser cost, and the speed at which resources are used increases.

Modern economists have re-examined the consumption rebound effect from improved energy efficiency [134,135]. In the 1980s a debate started on the ratio between the energy price and energy efficiency [136–138]. Jevons touches on energy depletion concepts recently revisited by writers dealing with the peak oil problem. Capital costs of energy services are determinant of the variations in energy prices, so energy efficiency may be an endogenous variable with opportunity costs [139,140].

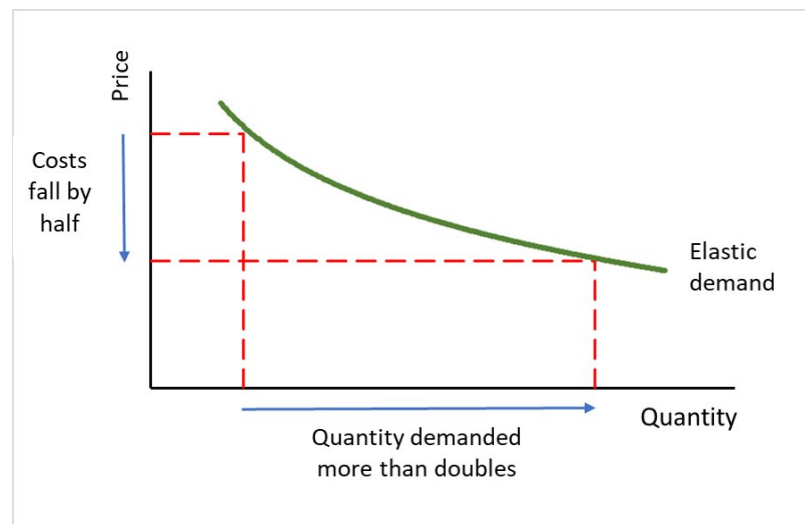
In microeconomic terms, the rebound effect is due first to the substitution effect. When energy is cheaper, people consume more of it. Second, it is affected by the income effect, as lower energy prices lead to higher disposable incomes. Microeconomic studies estimate empirically price elasticity or substitution and income effects derived from price changes [141–144].

The macroeconomic growth rebound effect is energy overspending, which is the difference between the optimal and the actual economic growth [145]. Additionally, macroeconomic models are used to simulate the effects on consumption behaviour [146–149].

### 5.2. Direct and Indirect Rebound Effect

The law of demand predicts that, generally speaking, lesser costs (or price) of a good or service increase the quantity demanded. If the cost for travelling is lesser, people will travel more, making the demand for fuel increase. This direct rebound effect may offset the initial drop in the use of fuel due to increased efficiency. The Jevons paradox happens when there is a rebound effect greater than 100%, offsetting the initial efficiency gains [116]. However, the size of the direct rebound effect depends on the price elasticity of demand for the good [150]. As shown in Figure 4, the greater the demand elasticity, the greater the rebound effect. In a market under perfect competition and assuming that fuel is the sole input, if the price of fuel is constant but there are double efficiency rates, travelling would

have halve the effective price (consumers can buy twice as much travel). However, the assumption of only one type of input is quite unrealistic (labour, machinery, etc., must be included), and there are other factors besides input cost that can affect price. These factors make the Jevons paradox less likely to occur, reducing the rebound effect.



**Figure 4.** The effect of the elasticity of the demand on the rebound effect.

Saunders in [151] argues that neoclassical growth theory broadly supports the Jevons paradox, and increased energy efficiency usually increases the consumption of energy by two means: first, the use of energy is made relatively cheaper, encouraging its consumption (the above mentioned direct rebound effect [133]) and real incomes and economic growth increase, which implies higher energy use for the whole economy. At the microeconomic level of an individual market, although the rebound effect may happen, energy efficiency usually reduces energy consumption, causing the rebound effect to be less than 100%. Saunders argues that, considering both microeconomic and macroeconomic effects, energy efficiency improvements due to technological progress tend to increase total energy use [152,153]. Jorgenson in [154] assumes that technical change happens at a fixed rate and direction, but more complex models suggest that technical change have different magnitude and sign between types of capital and sectors and in the course of time [155,156]. In [154,157], contrary to usual assumptions, technical change has been energy-consuming, increasing energy intensity over time. There is a dynamic relationship between technological efficiency, consumption and the use of resources. The savings due to resource efficiency are eventually overrun by increases in consumption that draw to a net increase in the use of the resource [158].

However, there is also an indirect rebound effect. For example, the money that is saved on motor-fuel consumption may be spent on other goods or services that also have energy requirements. There are many types of indirect rebound effects, summarised in [159]: re-spending and output effects, embodied energy effects or energy market and composition effects [160]. However, improved fuel efficiency can still be worthwhile although the Jevons paradox occurs: it leads to greater production and increased material quality of life [161]. For example, the improved steam engine allowed cheaper transport and contributed to the development of the Industrial Revolution. Hertwich shows different types of the rebound effect from an industrial ecology perspective [162]. Additionally, the rebound effect has been extensively studied in the case of residential energy demand and transportation [163–171].

There are different methods for calculating the direct and the indirect rebound effect, such as risk and vulnerability rebound indicators or energy input–output coefficients [135,172], which calculate the rebound effect in a range from 0 to 30%. Such estimates

are different across countries and across sectors: commercial, industry, residential and transport. Other studies determine a high global rebound effect in 2040 on the use of energy (70%) and related emissions (90%), with determinants such as induced supply and movement of labour among economic activities, and substitution elasticity between energy and other goods [173]. Besides, limited evidence come from developing countries, where the rebound effect is assumed to be higher [174].

In mature markets such as markets for oil in developed countries, there is usually a small direct rebound effect, so that increased fuel efficiency reduces resource use *ceteris paribus* [175]. However, even if there was not a reduction of the total amount of fuel used, there are other benefits associated such as the mitigation of price increases, disruptions and shortages in the global economy related to peak oil [176].

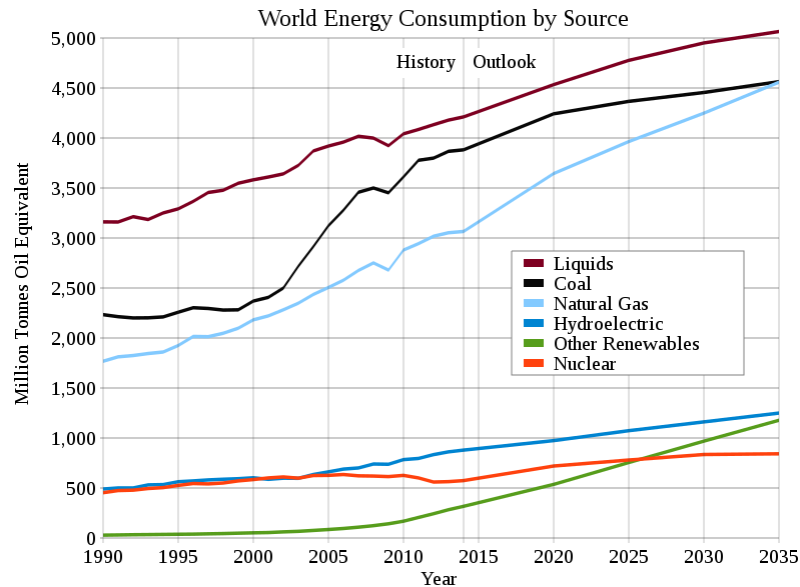
### 5.3. Economic Growth and Energy Efficiency

As previously commented, there are many studies that demonstrate strong correlations between production and energy consumption, but it is unclear the extent to which growth in the economic output can be taken as a cause of the increased energy consumption, or vice versa. A synergistic relationship between the two seems to underlie, each being the cause of the other within a positive feedback mechanism [177]. Neoclassical and 'endogenous' growth theory considers that expansion in energy inputs do not play a major role in economic growth, due to the fact that energy accounts for a small share of total costs in relative terms [178–181]. The increase in energy inputs result from the combination of increased labour and capital, improvement in the quality of inputs and in the total factor productivity, which frequently are referred to as 'technical change'. Ecological economists contest this view and argue that the main driver of economic growth over the last two centuries has increased availability of 'high quality' energy inputs [182–184]. According to these authors, energy carriers are different both in their capacity to make useful work (embodied in the thermodynamic concept of 'exergy') and in economic productivity—reflected by differences in price per kWh [185].

Sorrell finds a synergistic relationship between energy consumption and economic growth [159]. In [186], a circular feedback process is identified with increasing time lags: a rapid response (the direct rebound), a slow mechanism (the indirect rebound) and a restructuring process of the overall economic structure in the long-term (the general equilibrium effects). In [177], the consumption of resources is considered as both a stimulus and a consequence of growth, stressing the existence of a positive feedback cycle between the consumer demand, industrial investment and lower unit costs and prices for consumers. In [187,188], the aggregate economic growth is shown to offset all efforts toward dematerialization.

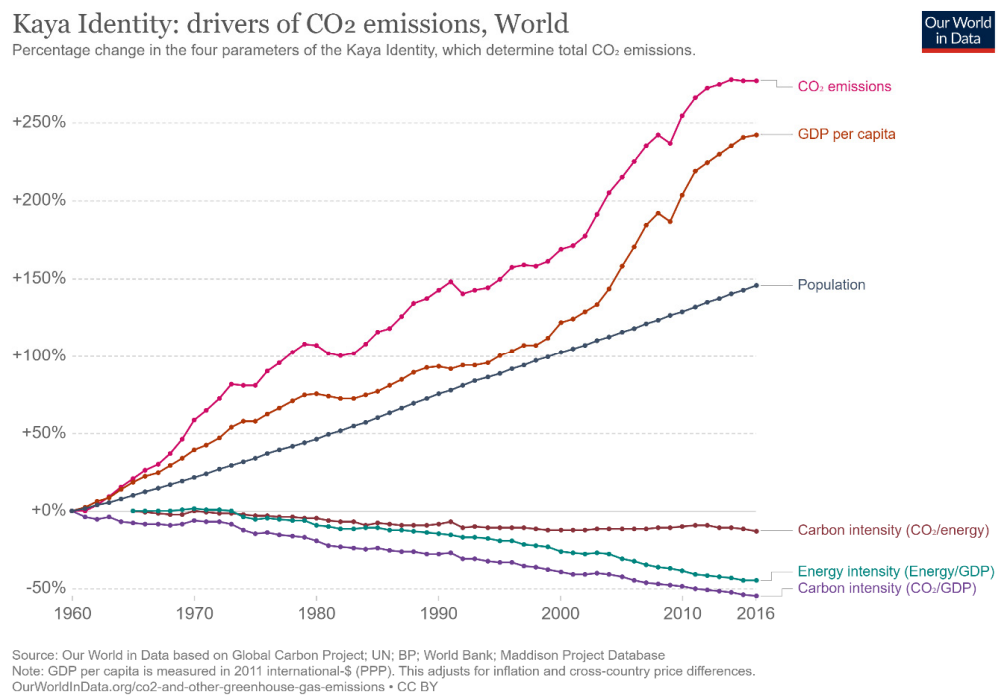
Actually, there is little support in history for the claim that increases in income lead to declining energy consumption [189–191]. Historical evolution of energy consumption according to different energy sources is displayed in Figure 5. In [192], economic activity alone (GDP growth) is not the variable that explains the increases in CO<sub>2</sub> emissions in Europe. What explains the increases in emissions is economic growth when energy intensity is high [193,194]. Energy intensity is defined as the ratio of primary energy consumed over GDP [195]. It is sometimes taken as an inverse of the energy efficiency, although, as predicted by Jevons, factors that influence energy intensity sometimes offset, or even augment, energy efficiency gains, such as GDP per capita, real prices or the composition of output [196]. Therefore, economic activity is important to understand the growth of CO<sub>2</sub> emissions in economies in which expansions throughout the economic cycle are sustained over energy-intensive sectors. Here, two representative country patterns have been found: the case of Germany, Belgium, France, Holland, Great Britain, Sweden and Switzerland, in which per capita CO<sub>2</sub> emissions and economic growth have moved in different directions over the last 40 years. In the literature this phenomenon is known as decoupling. On the contrary, the case of Spain, Austria, Greece, Italy, Portugal, but also Denmark, Finland and Norway, where the synchrony in the movements of GDP per capita and CO<sub>2</sub> emissions is enormous. So, for them growth is sustained by intensive energy sectors, and there is

a trade-off between growth and energetic neutrality [195]. Certainly, the two groups of countries might not be at the same level of growth in the first place, so path dependence might influence the relationship of energy and CO<sub>2</sub> emissions.



**Figure 5.** World energy consumption outlook 2015 ([https://commons.wikimedia.org/wiki/File:World\\_Energy\\_Consumption\\_Outlook\\_2015.svg](https://commons.wikimedia.org/wiki/File:World_Energy_Consumption_Outlook_2015.svg), accessed on 8 July 2021).

According to the Kaya identity, there are four drivers of the emissions across different countries, and over time: GDP per capita, population, energy intensity (the energy per unit of GDP) and carbon intensity (CO<sub>2</sub> per unit of energy) over time. However, the increase in GDP was a stronger driving force than the increase in population, as shown in Figure 6.



**Figure 6.** Kaya Identity: Drivers of CO<sub>2</sub> emissions, World. Source: Maddison Project Database, version 2018 [196].

#### 5.4. Rebound Effect and Energy Policies

In general, to counteract the rebound effect, human behaviour when modifying prices must be studied and consumption patterns must be accounted for [197–199]. A better feedback and analysis of energy bills, that is, a better understanding of the consumption of energy and the costs of actions taken at households, can lead to up to 10% savings in the consumption of electricity for heating in cold climates [200]. Short-term mechanisms that give the appropriate incentives to economic agents to avoid trade-off growth-emissions and rebound effects must be introduced. The increase in carbon taxes, with adequate counterweights (carbon dividends) for those who are in a weaker position to face them, or a regional convergence in energy intensities must be encouraged. In the short term, we cannot subtract growth from the most cyclical sectors, which pull the rest of the economy. This means that carbon taxes and subsidies on clean technologies must be cyclical—or countercyclical if we adopt a Schumpeterian approach.

Conservation policies that make the cost of use more expensive (such as trade barriers or green taxes, or even physical caps like quotas or rationing) have also been proposed to control the rebound effect [201–203]. In this sense, to counteract the paradox, efficiency gains need to go along conservation policies that maintain or increase the cost of use [204]. Higher fuel efficiency will not reduce, by itself, the rate of depletion of fossil fuels. For the falling of resource use, efficiency gains should go with other policies that limit the use of resource [205].

Other research shows the relationship between consumption and resource use. For instance, [206] shows that the ICTs invested in transport have a rebound effect that increases traffic and, possibly, energy consumption. A direct correspondence is found in [207] between freight transport volumes and national material flow.

So, sustainable energy policy could rely on government interventions that reduce demand [201,208,209]. Environmental economists point out that the use of fuel will unavoidably decrease if more efficiency is coupled with an intervention that maintains or increases the cost of fuel use (e.g., a fuel tax) [210]. The ecological economists Mathis Wackernagel and William Rees suggest that any cost savings from efficiency gains must be taxed away or removed from further economic circulation. They suggest that these savings are captured for reinvestment in natural capital rehabilitation [204].

Other researchers critique government energy efficiency policy as a counterbalance for the Jevons' Paradox, such as Brookes [211–214]. More liberal policies of establishing higher emissions standards could be applied. The volume of tradable CO<sub>2</sub> emission rights is equivalent to 57% of the emissions, the rest being allocated free of charge to companies in sectors at risk of relocation due to carbon leakage. Therefore, an increase in the demand for emission rights, derived from a higher demand for electricity or industrial production associated with economic growth, translates into an increase in the price of electricity, whereas the reduction of prices due to an increase in supply also implies an increase in the volume of emissions. As the price of electricity is established within a marginalist market, an increase in the price of emission rights increases the price of electricity consumed. This also means that lower-cost technologies due to already amortized installations obtain windfall profits to which a correction tax could be applied. Besides, emission rights only affect the costs of generating electricity from fossil energy sources (coal or natural gas), not renewables.

## 6. Conclusions

In this article, the policies of the European Union (EU) to fight climate change have been reviewed with a critical approach. The European Green Deal is an important package of measures whose main driver of ecoefficiency is the level of economic development, as measured by GDP per capita, being growth the clue to energy performance. However, the wellbeing Green Deal objectives might be at risk due to the Jevons paradox, so wellness challenges and risks of environmental policies should be stressed. To make the transition to climate neutrality irreversible, people and institutions must participate into the environ-

mental turn, and investors and other economic actors should be able to make economic predictions. Hence, the importance of linking energy physics with economics.

In the Green Deal, there are five strategic tools for the fight against climate change. We have shown that these tools imply opportunities, but also carry with dangers. For instance, decarbonisation goes along with the challenge of being able to tackle with uncertainty of renewable technologies. Energy security not only implies “security of supply”, but also “security of demand”. To achieve an internal energy market, free and fair competition in the energy sector is needed. Research, innovation and competitiveness in energy imply that growth rates of small- and medium-sized enterprises need to increase. Finally, as previously mentioned, energy efficiency entails an important paradox for long-term strategies of wellness: the Jevons Paradox or rebound effect. Jevons showed that energy efficiency may lead to an increase of consumption. The resource will be overused, although the last unit consumed will have decreasing levels of utility. In limited, non-renewable energy resources, Jevons paradox raises the question of wellness, sustainability and the limits of growth. Then, technological progress does not reduce the consumption of inputs, it shortens the relative cost of using a resource, which leads to increases in the quantity demanded and in real incomes and accelerates economic growth, boosting once more the increase in the demand for resources.

A direct and indirect rebound effect may happen, the first being the law of demand for which a decrease in price increases the quantity demanded, the second due to the fact that money saved on consumption may be spent on other goods and services with new energy requirements. Different methods try to calculate the direct and the indirect rebound effect, such as risk and vulnerability rebound indicators or energy input–output coefficients. Such estimates broadly vary across sectors. However, there are very different correlations between economic output and energy consumption depending on the theoretical background used: according to neoclassical and ‘endogenous’ growth theory, having more energy inputs play a relatively minor role in economic growth; according to ecological economists, the increased availability of energy inputs of ‘high quality’ has been the main driving force of economic growth over the last two centuries. However, these energy carriers have different capacity to perform useful work and economic productivity. In general, to counteract the Jevons paradox it is necessary to gain a better understanding of the behaviour of consumers of energy and the costs of actions taken at households. Efficiency gains need to go with conservation policies that maintain the same (or higher) cost of use.

Energy efficiency policies try increasingly to counterbalance the Jevons’ paradox. Actually, climate change policies are now going beyond energy efficiency. In particular, they avoid carbon intensity to take into account other technological processes that may accelerate a transition to low carbon economies. Some of these policies are based on the interventionism paradigm, such as the establishment of barriers that can take the form of tariffs or green taxes, physical caps like quotas or rationing, etc. Other policies are based on the liberal paradigm, such as the appeal to the cooperation of international and national institutions, the promotion of digital and knowledge-based economy or the establishment of higher emissions standards. As shown in this paper, more self-regulatory policies should be implemented for aiming at the wellbeing of humanity in the long run. Then, we could make the most of the greater concern for the environment that people and institutions are assuming now.

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