CLIMATE & DEBATES

Insight on the impact on energy security of different climate change pathways in the EU

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This Climate & Debates paper is the follow up of Matteo Le Hérissé's dissertation that Anna Creti supervised last year, for his completion of the master International Affairs and Development at Paris Dauphine University - PSL. The topic of gas security of supply has gained an incredible attention in the last months, amidst the Russian-Ukrainian conflict. This has motivated to complete a broader study that unveils the challenges to correctly measure and monitor gas dependence at the European level. With Gazprom starting to disconnect several countries, among which France, the questions on security of supply deserve sound economic analysis, as this paper illustrates.

This study examines the impact on energy security of different pathways the European Union's energy system may follow, regarding climate change mitigation. As outlined by the current geopolitical, ecological and economical context, energy security has become a key metric and remains at the roots of many high-level decisions in our societies. Also, despite its manifold definitions, it encompasses parameters which reflect crucial matters such as conditions of living of populations. In order to provide an overview of how energy security intertwines with the green transition, this paper proposes an energy security index. If the latter doesn't answer considerations on the comprehensiveness of energy security indexes or on other methodological limitations hindering the definition of a uniquely recognised index, we consider it as a powerful abstraction tool. Indeed, this approach allows to grasp the extent of the observed dynamics in a simple figure and to identify trends. The presented methodology and related index are applied for the evaluation of energy security in the countries of the European Union, allowing for a compilation in a single indicator. We find a close linkage between energy security and the green transition, with projected energy security index pathways indicating the net-zero scenario would have the best positive impact on energy security, whereas the "hot house world" scenario depicts a great deterioration of energy security in the EU.

Jel Codes : Q34; Q38; Q54

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KEYWORDS

Gas | Energy security | Green transition | European Union | Repower UE | Russia

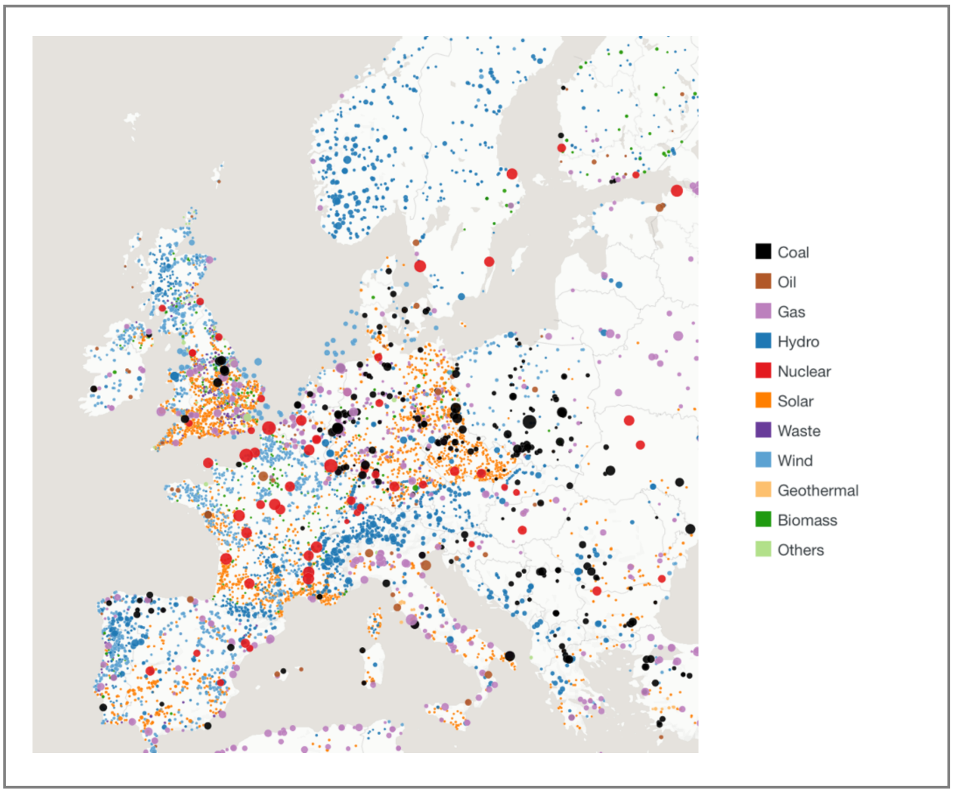
1. The current global context fosters the importance of energy security

1.1. Climate change mitigation and the need for a mutation of the energy system

With already apparent effects and disastrous potential impacts, climate change has now become one of the most urgent matters to be addressed; and it appears energy is at the heart of the solution. Indeed, as the latter represents more than 70% of global greenhouse gas emissions[1], reforming the global energy system would allow for a major step towards the net-zero objective.

Even though we note an important decrease since 1970, the global energy system is still characterised by a deep reliance on fossil fuels. In 2020, 83.15% of primary energy consumed worldwide was from fossil fuels[2]. In the European Union, the figure was slightly better at 71.08%. Nonetheless, we note large heterogeneities in energy mixes among EU Member States. For instance, Poland is an important producer of coal and uses the latter extensively in its energy mix, France has a great nuclear powered energy generation capacity and Norway has massively integrated renewables in its mix. Considering per capita consumption of primary energy, the three countries respective reliance on fossil fuels was in 2019 of 93.78%, 51.48% and 33.23%[3]. That is a 60.55 pp difference in fossil fuels use between Poland and Norway. Chart 1 allows to visualise these European discrepancies by exposing energy production plants. We therefore observe the French dominance on nuclear, the concentration of coal plants in Eastern Europe — and particularly in Poland — or the focus on hydropower in Norway.

Chart 1: Power Plants by Fuel Type and Capacity



Source: Global Energy Observatory, Google, KTH Royal Institute of Technology in Stockholm, Enipedia, World Resources Institute. 2019. Global Power Plant Database v1.2.0.

[1] See Climate Watch and the World Resources Institute data (2020), or the IPCC 2020 report.

[2] Computations based on data from BP Statistical Review of World Energy (2021), considering fossil fuels consumption as the sum of oil, natural gas and coal consumptions.

[3] Figures from Our World in Data (2019).

In order to reach net-zero by 2050, the global and EU energy systems must thus operate a drastic mutation, progressively phasing out fossil fuels in favour of carbon neutral energy generation solutions. As we will demonstrate, this transformation should have an important impact on energy security in the EU.

1.2. Why assessing energy security matters: brief elements of context.

This is a particularly interesting time to study energy security as this increasingly popular concept faces numerous challenges.

(i) First, as previously mentioned, the European Union enters a decisive period that should initiate the transformation of its energy system and mobilise massive capital flows towards new investments in all strata of the energy system: from energy generation, to consumption, including transportation and storage. The European Green Deal detailed, in 2019, this goal of reaching carbon neutrality by 2050 and additional initiatives should support this prospect (e.g., Next Generation EU). Also, we notice a rising interest for climate change mitigation initiatives emerging from European populations, that should spur political leaders to engage in pro-climate activities.

(ii) Second, the post-Covid-19 pandemic rebound of the European economic activity has translated in a rise in energy demand. The IEA estimates a 0.5% push in global energy use for Q1-2021, compared to pre-pandemic levels[4]. Given the current state of play of the energy system, global economic recovery has led to a 'golden age' of fossil fuels that seems to defy the green transition: "59% of the electricity demand rise in 2021 was met by coal generation alone"[5].

(iii) Third, the European Union has been experiencing rising prices of energy products since late-2021. On 21 December 2021, European gas prices peaked at EUR 175 per MWh, a 400% increase over the last six months. The conjunction of economic, meteorological and geopolitical factors explains the sharp increase. In September 2021, the restart of the European economy translated in a shock of demand on energy markets. The long-lasting cold weather has lessened natural gas reserves that have not been fully replenished in time. This important increase of energy prices, additional to the current inflationary context, cuts in household income and fuels a rise of social tensions.

(iv) Fourth and related to the latter, the resurgence of populism exacerbates tensions on energy security in all its forms. Drivers of these tensions may be political stances and proposals such as:
  - questioning free trade
  - exit from the European energy market
  - a hasty exit from nuclear power
  - counter-intuitive "pro-purchasing power" positions that comfort the fossil fuel system
  - tendency to reverse the state of affairs with abrupt reforms favouring instability and economic underperformance

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[4] Global Energy Review, IEA, 2021
[5] Ember, Global Electricity Review 2022.

(v) Fifth, on 24 February 2022, Russian troops crossed the Ukrainian border while missiles struck locations across the country (including the capital city Kyiv). The start of the war is the peak of regular escalades in tensions between the two countries and adds up to disagreements notably on NordStream2 that were already exerting pressure on gas supply. This war at the borders of the EU brings up major concerns on energy sovereignty (see section *2.2.iii)*.

2. Energy security

2.1. An ambiguous term

Despite its importance in policymaking and its ubiquitous use, the notion of energy security lacks a universal definition. Indeed, this notion remains ambiguous, and many definitions exist (Ang & al. identified 83 definitions existing in the literature, in a 2015 study[6]). The most common one refers to managing risks, most of which are related to possible disruptions in energy supply:

- For Willrich Mason, energy security can be defined as the "assurance of sufficient supplies to permit the national economy to function in a politically acceptable manner"[7].
- The International Energy Agency (IEA) defines it as "the uninterrupted availability of energy sources at an affordable price."
- The European Commission defines energy security as "the uninterrupted physical availability of energy products on the market, at a price which is affordable for all consumers (private and industrial), while respecting environmental concerns and looking towards sustainable development".

In order to provide an insight on the impact of the transition of the European energy system towards carbon neutrality, we will choose to focus on a wholistic definition of energy security, with an extension towards sustainability. For this purpose, we consider The World Energy Council's definition of energy sustainability that constitutes an 'Energy Trilemma' on the basis of three core dimensions: *Energy Security*, *Energy Equity*, and *Environmental Sustainability* of energy systems.

2.2. Defining and discussing indicators

Regardless of concerns that may be expressed on the numerous limitations in the use of indexes to measure energy security — limitations which would hinder the definition of a unique comparative scale for energy security — we could argue this type of index remains a powerful abstraction tool. This approach to energy security indeed allows to grasp the extent of the observed dynamics in a simple figure; something particularly useful when focusing on such a complex and broad topic.

[6] Ang, B.W. & Choong, W.L. & Ng, T.S., 2015. "Energy security: Definitions, dimensions and indexes", Renewable and Sustainable Energy Reviews, Elsevier, vol. 42(C), pages 1077-1093.
[7] Willrich, M. (1976). Energy & World Politics. Page 67. The American Society of International Law

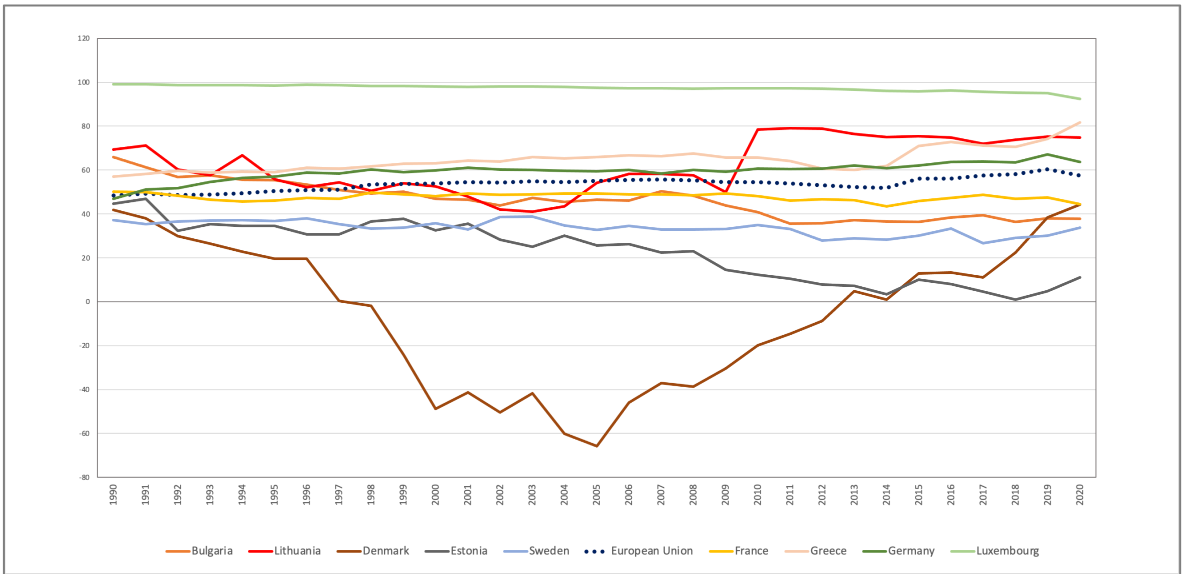
Having reviewed the polysemic nature of energy security and the multitude of indicators that may be used in its measure (more than 320 indicators are identified by Mukherjee and Sovacool[8]), we will focus on four sub-indexes to assess the intricate relationship between energy security and the green energy transition: $Energy\ dependency$, $Country\ context$, $Equity$, and $Environment$.

(i) <u>Energy dependency</u>.

Energy import dependency has always been regarded as a meaningful indicator for sovereignty, and overall, for energy security. Energy may be considered as a regular commodity: inserted among others in our global economy of exchanges, subject to the laws of the markets and to decisions based on comparative advantages and other international trade theories. Nevertheless, geopolitical and military conflicts remind us energy can be used as a socio-political and economic weapon too, making dependency a key issue for energy security. The 2006 and 2009 gas crises and recently started Russo-Ukrainian war are example of this.

In 2020, the European Union imported 57.5% of its gross available energy (53.7% on average over the 1990-2020 period)[9]. However, it is important to note the EU presents important trade balance discrepancies (see Chart 2 below). For instance, in 2020, Greece, Luxembourg and Lithuania respectively imported 92.47%, 81.78% and 74.91% of the energy they consumed. On the other hand, Estonia imported only 11.05% of the energy it consumed for the same year; 33.86% in Sweden and 37.88% in Bulgaria. Looking at previous years, Denmark appears as an outlier: from 1998 to 2021, the country was net exporter of energy. In 2005, the gap between Denmark's negative imports (i.e., exports) and Malta's imports was of 165.3 pp.

<u>Chart 2:</u> Share of imported energy in the EU27, net, in % of energy use.



<u>Source:</u> Own authors computations with World Bank data

[8] Benjamin K. Sovacool, Ishani Mukherjee, Conceptualizing and measuring energy security: A synthesized approach, Energy, Volume 36, Issue 8, 2011

[9] Eurostat data.

The European energy transition should lessen by 2050 the continent's dependency by phasing out fossil fuels (crude oil is imported at 90%, gas at 75% or coal at 40%[10]). However, an opposite dynamic occurs concerning critical raw materials (that are mostly imported from China). The fact natural gas would be used as a transition energy (something reconsidered by the new European energy strategy, namely *REPower EU*[11]) also questions the *in fine* impact of the transition on energy dependency and energy security.

Our study will incorporate this notion of energy dependency with the $share\ of\ imported\ energy\ (\%\ of\ energy\ use)$, computed as $Energy\ net\ imports = energy\ use - energy\ production$.
Thus, we have:

$$Energy\ dependency = Eu - Ey$$

with $Eu \equiv energy\ use$ and $Ey \equiv energy\ production$.

(ii) Country context.

This second sub-index focuses on the notion of *accessibility*, considering the national environment in which the energy system takes place. We then assume a favourable macroeconomic environment alleviates pressure on energy security. In order to assess this, we will use the sum of three metrics:

$$Country\ context_{i,t} = MIs_{i,t} + DBs_{i,t} + FHs_{i,t}$$

First, to assess the macroeconomic stability of a given country (i), we will compute a score based on the $Misery\ index$ for each year (t). The latter, theorised by A. Okun, qualifies the economic condition of a country. We will use an extended version defined as the sum of the $unemployment\ rate$ (u) and the $inflation\ rate$ (r), minus the $economic\ growth\ rate$ (δ)[12]: $MI = u + r - \delta$. The assumption is that the lower the index is, the more favourable economic conditions are. Once the Misery index computed, we define a score as: $MIs_{i,t} = \frac{MI\ rank_{i,t}}{number\ of\ countries}$ so that a poor macroeconomic stability of a country translates into a low rank (the scale is inverted, with 1 being the worst).

Second, to consider the performance of the national regulatory environment, we will use the $ease\ of\ doing\ business\ index$ provided by the World Bank. We also insert this index as a score defined by: $DBs_{i,t} = \frac{Doing\ business\ index_{i,t}}{100}$. The European Union scored an average of 79.3% in 2020, with a relative low dispersion: Denmark ranks first in term of *Doing Business score* with 85.3%, Malta the last with a score of 66.1%.

[10] Ristori, D., « Enjeux et défis de la politique énergétique en Europe », Géoéconomie, 2015.

[11] See 2.2.(iii) for extended comments.

[12] Data on inflation are from the IMF; unemployment rates are from the ILOSTAT database; GDP per capita growth data are from the World Bank.

Third, using the Freedom's House[13] global freedom index, we assess the political stability and security of the national environment. A high $FH\ score$ is associated with an increased energy security, and incorporated in our $country\ context$ index as: $FHs_{i,t} = \frac{Freedom\ House\ score_{i,t}}{100}$. We note the European Union's environment is politically stable and secure as the EU28 2020 average $FH\ score$ of 91.5% is higher than the third world quartile (90%). Also, it appears the lowest scores are concentrated in Eastern Europe, despite limited discrepancies within the European Union. Only 8 countries scored below 90 in 2020; e.g., Poland (82%), Bulgaria (78%) and Hungary (69%).

(iii) Equity.

This third sub-index considers the issue of the *affordability* of the EU energy system. The World Energy Council defines the latter as the "ability to provide universal access to reliable, affordable and abundant energy for domestic and commercial use"[14].
The matter of the affordability of energy is a key issue given the fact that in the short and medium term, the energy transition would translate into rising energy prices. Indeed, the transformation of the energy system requires massive investments. A risk is then to see a repercussion of private investment plans (i.e., the replacement of amortised capital by new unamortised capital) into the price of energy. Also, as highlighted by I. Schnabel[15], while the shift towards carbon-neutrality for the global energy system will take time, a rising carbon price, increased costs for fossil fuels production and supply, and relatively inelastic energy demand may result, during the transition period, in persisting upward pressure on energy price. In addition, the equipment needed for the energy transition and trends such as electrification, digitalisation and technology progress are pressure on scarce resources.
Affordability is a major criterion to be incorporated in energy security concerns (as shown by its extensive coverage in the literature), and many metrics may be used to incorporate this. In our sub-index, we grasp this issue through households' purchasing power of energy products. We thus subtract the energy prices inflation ($\Delta p^E_{i,t}$) to the change in wages ($\Delta w_{i,t}$) for a given country:

$$Equity_{i,t} = \Delta w_{i,t} - \Delta p^E_{i,t}.$$

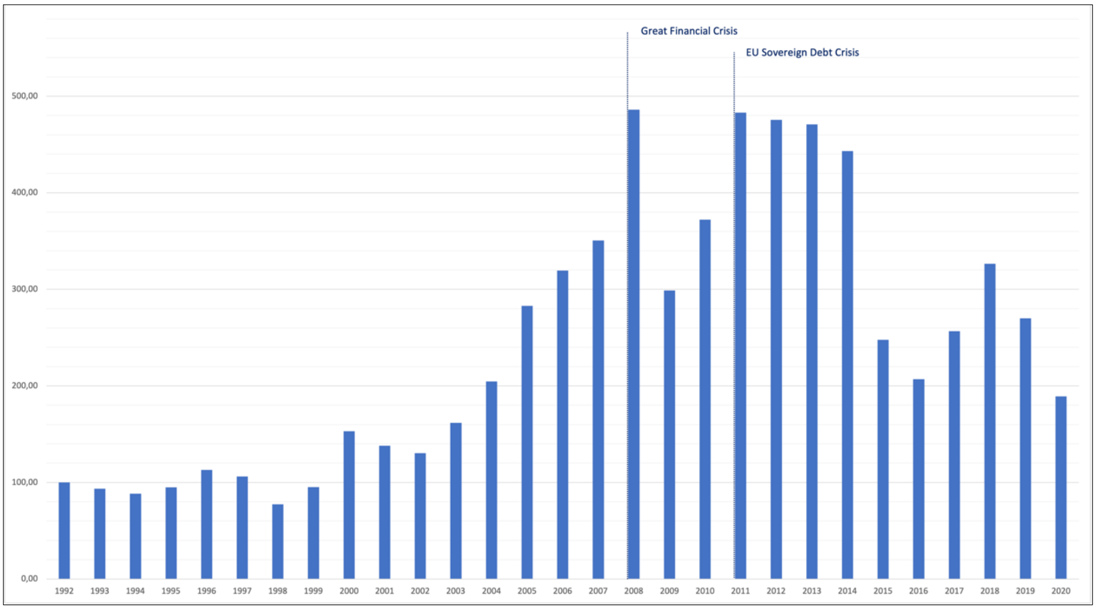
We note Eastern European countries' households have experienced the most important increase in earnings over the ten last years (see Chart 3 below); which is consistent with the development of their economies. For instance, wages in Lithuania rose by 105.7% from 2011 to 2020. Over the same period, Greece is the only country in the EU where wages have declined (by 6.6%).

Concerning energy prices, it appears global energy prices peaked in 2008 and, before 2021, have never returned to such high levels. Since 2000, global energy prices have never decreased; their lowest growth was in 2020 (+30.38% compared to 1992). Also, as previously mentioned, a Covid-19 crisis' aftermath is the current inflationary environment: as of April 2022, inflation in the OECD area reached the average value of

[13] Freedom in the World, Freedom House
[14] Trilemma Index, World Energy Council, 2021.
[15] I. Schnabel (ECB), Interview with Le Monde, published on 22 December, 2021

9.2%. Concerning energy price inflation, it surged to 32.5% (yoy), after reaching its highest rate since 1980 in March (33.7%)[16].
The Russo-Ukrainian conflict has further exacerbated the pressure on energy prices. Indeed, Russia remains a major supplier for fossil fuels in the EU: in 2021, 40% of total gas consumption, 27% of oil imports and 46% of coal imports of the European Union originated Russia[17]. In addition to disruptions of supply, the war has been condemned by the EC, leading the latter to impose successive series of sanctions on Russia. Among embargos and other economic sanctions, the European Commission published on 8 March 2022, its *REPower EU* plan, "outlining measures to drastically reduce Russian gas imports from its 2021 level of 155 bcm before the end of this year – and reach complete independence from Russian fossil fuels well before the end of the decade."[18]
This change in the European strategy for energy will have still unknown impacts of the structure of energy prices, but for the moment, adds-up to the stress of the energy market.

Chart 3: Change in global energy price index (%, base 100 in 1992)



Source: Own author computations with FED data

(i) Environment.

Finally, we incorporate the environmental aspect of energy security in our analysis, as:

$$Environment_{i,t} = a\left(\Delta CO2_{i,t}\right) + b\left(\Delta CO2_{i,t}^{target}\right) + c(CNEM_{i,t})$$

The first term in the construction of the sub-index considers the reduction in GHG emissions ($\Delta CO2_{i,t}$) for a country at a given year. Then, we add as the second term the target of emissions reduction the country has committed to ($\Delta CO2_{i,t}^{target}$), considering the target holds until it is changed. The last term of this sub-index is the share of carbon

[16] Data from OECD, 2 June 2020 and 4 May, 2022 updates.
[17] Data from the European Commission, April 2022.
[18] EC, April 2022.

neutral energy in the mix of the country ($CNEM_{i,t}$), in which we include nuclear power and renewables.
In order to consider for a differentiated impact of these metrics, we weight them with the following factors: $a = \frac{3}{6}$; $b = \frac{2}{6}$; $c = \frac{1}{6}$.

3. Index

3.1. Computing the index to assess energy security in the EU

We must acknowledge the previously detailed sub-indexes do not impact energy security to the same extent. Paravantis & Kontoulis[19] conducted in 2020 a survey of a "small panel of engineering, economic, and geopolitical energy experts" in which they were asked to rate the dimensions of energy security that were presented to them. Following their insight, we associate their assessed dimensions with our sub-indexes, and convert their marks (out of ten) in weights (in percentage). These weight variables are detailed in the Table below, and allow us to shape a more realistic index of energy security.

	Rate given by the panel (out of 10)	Corresponding percentage	Weights
Energy dependency	8.8	28.76	α_1
Country context	8	26.14	α_2
Equity	8	26.14	α_3
Environment	5.8	18.96	α_4
	Total:	100	

Source: Own author computations with data from Paravantis & Kontoulis (2020)

Thus, the index (I) we have constructed to assess the impact on energy security, of the transition of the EU energy system towards carbon neutrality, is defined by:

$$\boxed{\boldsymbol{I = \alpha_1 * Energy\ dependency + \alpha_2 * Country\ context + \alpha_3 * Equity + \alpha_4 * Environment}}$$

Or in details:

$$I_{i,t} = 28.76\% * Energy\ dependency + 26.14\% * Country\ context + 26.14\% * Equity + 18.96\% * Environment$$

$$\Leftrightarrow \quad I_{i,t} = 28.76\% * \left[1 - Energy\ net\ imports_{i,t}\right] + 26.14\% * \left[MIs_{i,t} + DBs_{i,t} + FHs_{i,t}\right] + 26.14\% * \left[\Delta w_{i,t} - \Delta p^{E}_{i,t}\right] + 18.96\% * \left[\frac{3}{6}\left(\Delta CO2_{i,t}\right) + \frac{2}{6}\left(\Delta CO2^{target}_{i,t}\right) + \frac{1}{6}\left(CNEM_{i,t}\right)\right]$$

$$\Leftrightarrow \quad I_{i,t} = \frac{28.76}{100} * \left[1 - (Eu - Ey)\right] + \frac{26.14}{100} * \left[\frac{(u + r - \delta)_{i,t}}{number\ of\ countries} + \frac{DB\ index_{i,t}}{100} + \frac{FH\ score_{i,t}}{100}\right] + \frac{26.14}{100} * \left[\Delta w_{i,t} - \Delta p^{E}_{i,t}\right] + \frac{18.96}{100} * \left[\frac{3}{6}\left(\Delta CO2_{i,t}\right) + \frac{2}{6}\left(\Delta CO2^{target}_{i,t}\right) + \frac{1}{6}\left(CNEM_{i,t}\right)\right]$$

[19] J. Paravantis and N. Kontoulis, "Energy Security and Renewable Energy: A Geopolitical Perspective", IntechOpen, September 2020.

3.2. Results and implications on policies

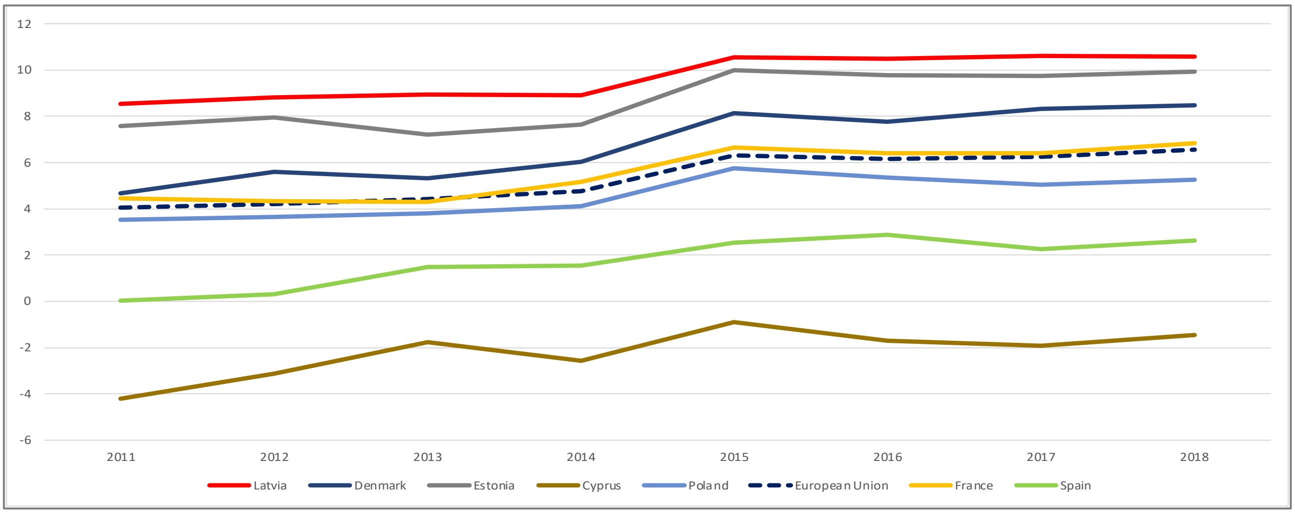
Computing the above detailed index only yields a figure to be compared in time, or between countries. For instance, the fact the index takes the value of 3.68 in Austria in 2016 ($I_{Austria,\ 2016} = 3.68$) doesn't provide any information by itself. Also, the index doesn't provide a maximum (or minimum) value that would correspond to the best (worst) situation possible; it is only to be compared.

We first estimate the index for each EU Member State (UK included), from 2011 to 2018.

This time period aims to provide an overview of energy security in the EU before the implementation of the European Green Deal, and to have reference dynamics by country. Chart 4 below presents the values of I for selected countries over the period.

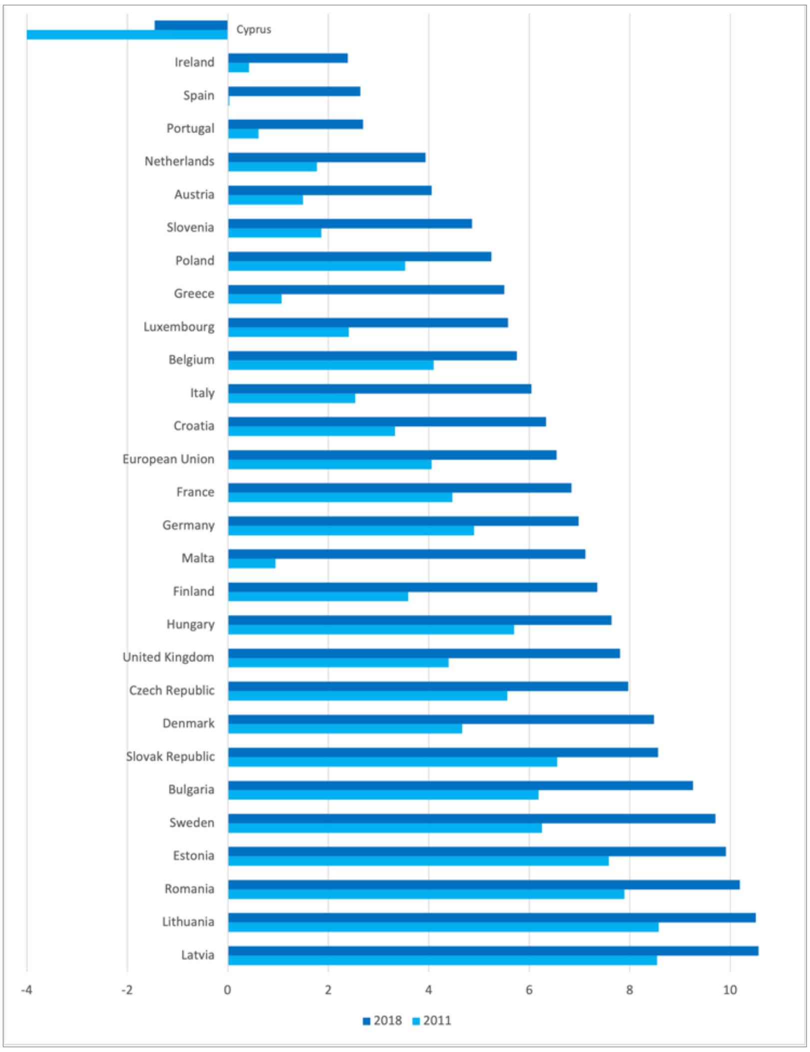
As highlighted by Chart 5, it appears no country in the EU has experienced a deterioration of its energy security (on average between 2011 and 2018).
It is nonetheless interesting to note that Cyprus appears to be an outlier, with a very fragile energy security. Our assessment of energy security in the country assigns negative values for the entire period (from $I = -4.21$ in 2011 to $I = -1.46$ in 2018). On the opposite, Latvia and Lithuania share the strongest position over the period (with a maximum value for Latvia in 2017 at $I = 10.60$).

Chart 4: Index, overview of energy security for selected countries in the EU prior to the EU Green Deal



Source: Own author computations

Chart 5: Energy security index in the EU28, 2011 vs 2018

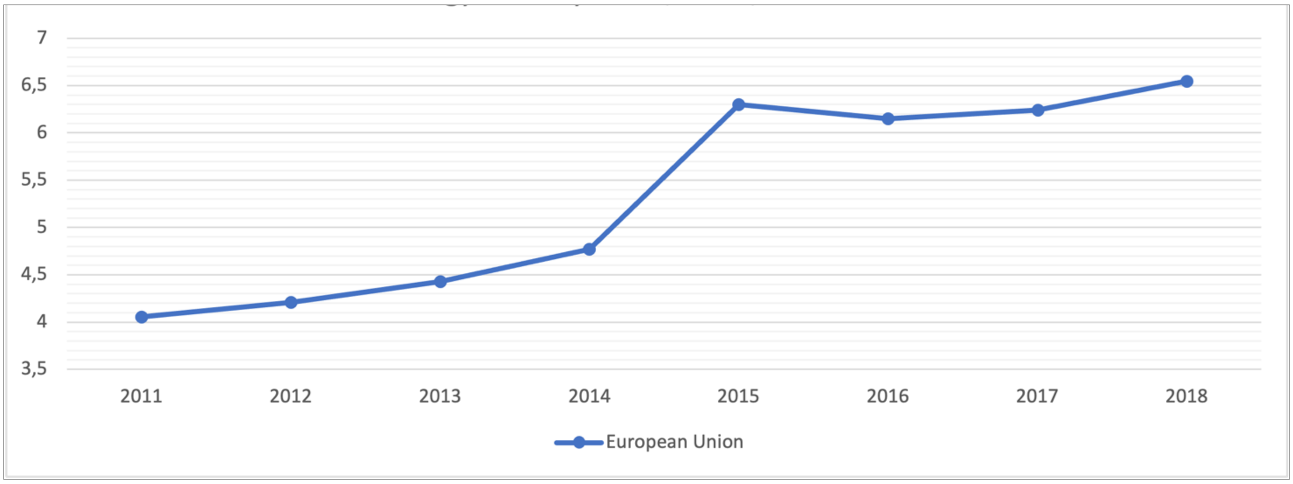


Source: Own author computations

Then, we consider the index for the European Union (EU28).

Adopting an aggregated scope allows to better identify non-linearities in the evolution of the energy security index. Indeed, we note an important step between 2014 and 2015: from $I_{EU28,2014} = 4.77$ to $I_{EU28,2015} = 6.30$ (that is a 32% increase, which is ten times the average year-over-year change in the period). We may identify two reasons for such an important change. First and foremost, the end of 2014 marks the approval of the EU's framework for energy and climate; GHG emissions reduction targets rose from 5% (Kyoto Protocol) to 40%. The 2015 Conference of Parties' Agreement then ratified the target in NDCs. This sharp increase of the climate target translates in a 64% rise in the value of the environmental sub-index we use. The $Equity$ sub-index we use also drastically changes: it decreases by 57% between 2014 and 2015, due to an important slowdown of global energy inflation. The increase of global energy prices was almost halved (a 44% decline) between the two years. This comes as the second reason for the upward change in energy security in the EU28 over the period.

Chart 6: Energy security index in the EU28, 2011-2018



Source: Own author computations

4. Long term results of the index

4.1. The variety of pathways impact the metrics in their own respective way

In the previous section (*3.*), we have used the index computation to assess where we stand in the EU28 — in 2018 — in terms of energy security. Now, it is interesting to use the tool we have created to take a look at the massive transition period that is to come: towards 2030 and 2050.

Our study on the post-2018 period is largely fed by the work the *Network of central banks and supervisors for Greening the Financial System* (NGFS) has done since 2017, for outlining the different pathways our global economy may embark in until 2050[20]. Accounting for socio-economic assumptions and economic outlooks, the NGFS has shaped six scenarios. Following its insight, we define four main pathways we wish to confront our index endeavour to.

These four scenarios are based on unique conservative assumptions that impact our metrics differently; policies and objectives are strictly applied. For instance, the fist pathway (*no climate policies*) implies $\Delta CO2_{EU28}^{target}$ takes the value of 0% from 2018, whereas in the fourth (*net-zero*) the metric takes shifts to -55% in 2030 and -100% in 2050.
For each scenario, we then apply different prevision methods on the metrics we use (see Annex 1), so that it yields dynamics that are consistent with the assumptions of the scenario we defined, the NGFS' approach and the literature.
Four metrics we use: $\Delta\, energy\, prices$, $\Delta CO2^{emissions}$, $\Delta\, CO2^{target}$ and $CNEM$, are greatly affected by the different assumptions of the scenarios (see Annex 2).

[20] See for instance: NGFS, Climate Scenarios for central banks and supervisors, June 2021.

Considered scenarios are the following:

(i) No climate policies

Because we consider GHG emissions reduction target have a strong impact on energy security, we ought to study this first scenario which assumes current climate change mitigation objectives are deemed null and void. Therefore, GHG emissions would rapidly grow; we project GHG emissions would grow by more than a three-fold between 2018 and 2050. With a deeply carbonated energy mix, energy prices would continue to increase at a fast pace. This pathway would thus be associated with a 'hotter house world' than the most business-as-usual NGFS scenario.

(ii) Current climate policies

This second pathway considers no additional policies on climate change mitigation are taken from 2018. GHG emissions would remain high and follow a slightly decreasing trend towards 2050. The NGFS describes "severe physical risks" associated with the 3°C increase in temperatures. We consider renewable energy generation technologies would continue to be implemented at a slow pace and GHG emissions would decrease according to the current trend. Inflation for energy would remain strong from the current stand.

(iii) Paris Pledge

Regarding climate neutral energy generation and GHG emissions reduction, the Paris Pledge is comparable to the Current climate policies scenario. Nonetheless, it assumes COP15 objectives hold and, by 2030, shifts the GHG emissions reduction objective to 'net-zero'. As described by the NGFS, "climate policies are introduced immediately and become gradually more stringent". GHG emissions are then contained, so are energy prices.

(iv) Net-zero

This pathway considers net-zero CO2 emissions are reached globally, thus limiting global warming under the 1.5°C threshold. This ambitious scenario assumes climate change mitigation policies are taken rapidly and result in the transformation of the economic landscape towards decarbonised technologies. The deployment of carbon neutral technologies is drastically increased to generate clean energy by 2050. The phase-out from fossil fuels, advanced interconnections and efficiency contribute to maintain energy prices to similar levels.

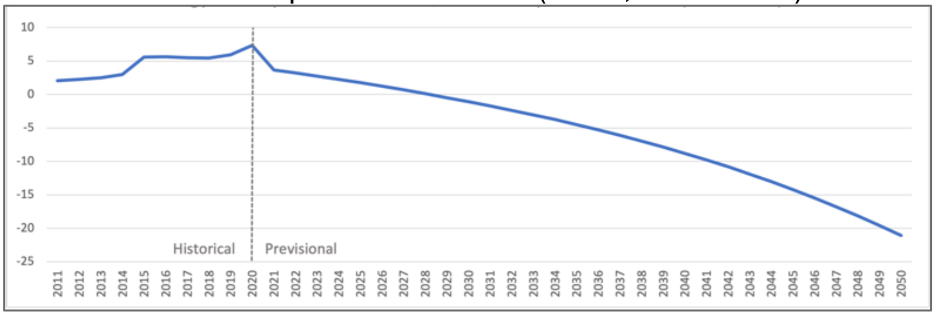
4.2. The variety of pathways yields divergent results for the aggregated index of EU energy security

Thus, computing the index for energy security in the EU28 over the 2011-2030 period yields four different results, that depend on the considered pathway.

(i) No climate policies.

We note our energy security index rapidly engages in a very sharp downward dynamic when no climate change mitigation action is undertaken. Between 2020 and 2050, the value of the index plunges by 388% (from $I_{EU28,2020} = 7.32$ to $I_{EU28,2050} = -21.07$); by 115% over the 2020-2030 period.

Chart 7: Energy security index,
no climate policies scenario (EU28, 2011-2050)

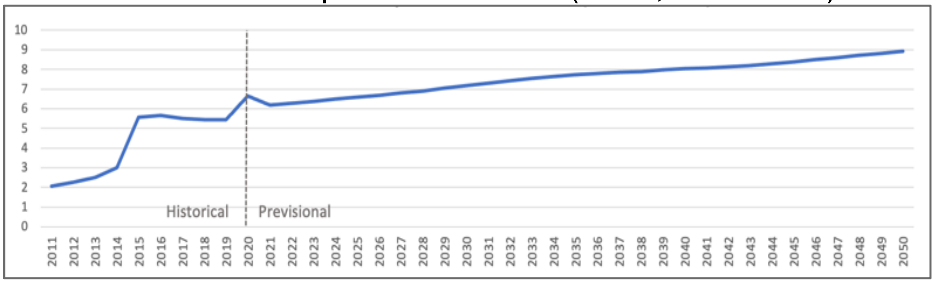


Source: Own author computations

(ii) Current climate policies.

When only 2018 climate policies hold, climate change mitigation isn't sufficient enough to limit the rise of temperature and other adverse effects. Nonetheless, it allows the EU energy security to maintain its current state of play. We even note a slight increase: +8% by 2030 and +34% by 2050.

Chart 8: Energy security index,
current climate policies scenario (EU28, 2011-2050)

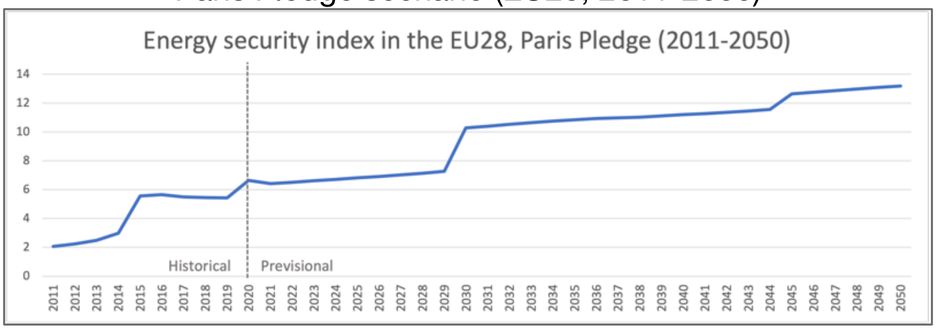


Source: Own author computations

(iii) Paris Pledge.

This third scenario assumes that objectives of the COP15 Paris Pledge hold, translating in a rise of the GHG emissions reduction target from -55% in 2030 to -100% in 2050. We note these new targets lead to energy security improvements: as visible with the step in the curve in 2030 (from $I_{EU28,2029} = 7.28$ to $I_{EU28,2030} = 10.28$, a 41% increase). Overall, this pathway yields a 54% increase of our energy security index by 2030 and 98% by 2050.

Chart 9: Energy security index,
Paris Pledge scenario (EU28, 2011-2050)

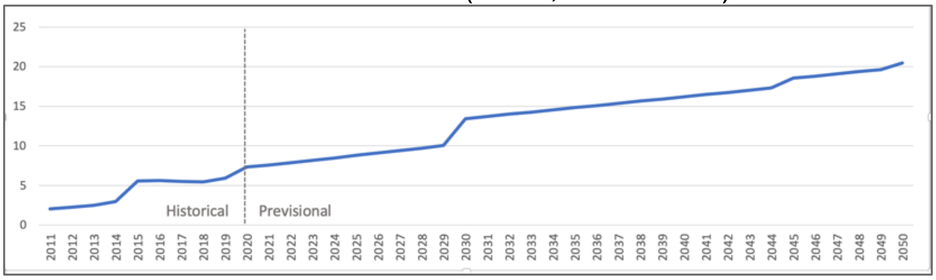


Source: Own author computations

(iv) Net-zero.

Finally, we note the net-zero scenario generates the most important increase of our energy security index: +83% by 2030 and +179% by 2050.

Chart 10: Energy security index, net-zero scenario (EU28, 2011-2050)



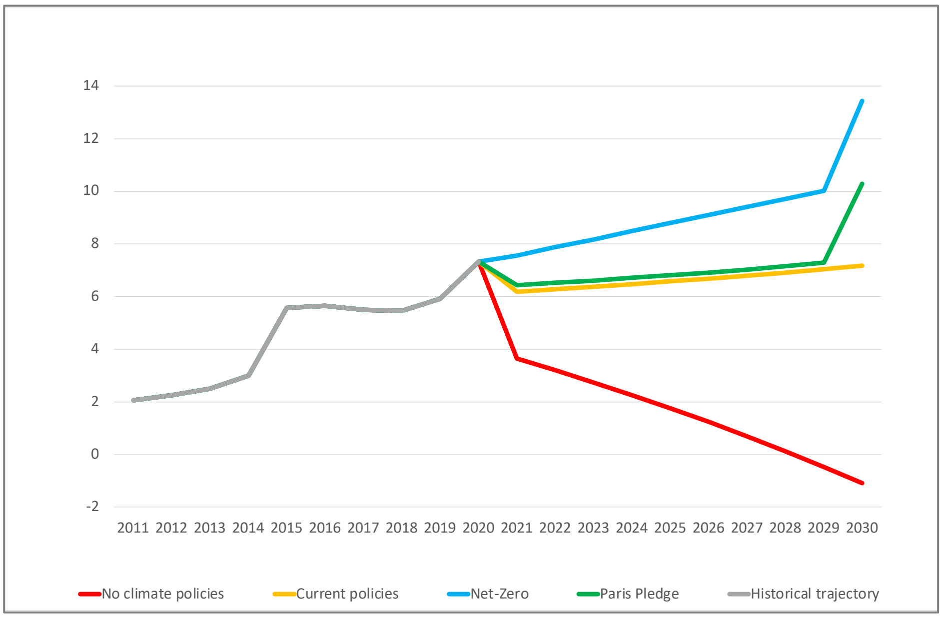
Source: Own author computations

We may combine these four charts in one.

On the one hand, the resulting chart (see Chart 11) allows to appreciate the important spread between the most ambitious climate mitigation scenario (*net-zero*) and the less ambitious (*no climate policies*). Indeed, the gap is widening by the years — because of the opposite dynamics of the pathways, and of the exponential form of the energy security index curve for the *no climate policies* scenario. In 2025, the gap is of 7.04, 14.53 in 2030 and 41.52 in 2050; following an almost linear tendency.

On the other hand, this aggregated chart provides curves that could be compared to the climate scenarios (see Annex 3, to be considered with y axis inverted for comparison). It may confirm our intuition that the more effective the green transition to carbon neutrality is, the more it yields energy security gains.

Chart 11: Energy security index, all climate scenarios (EU28, 2011-2030)



Source: Own author computations

We shall note the very long-term horizon of the previsions invites us to consider their fiability with precaution. Indeed, if the tendencies might prove to be correct, the exact value of the energy security index could vary with new variables. As highlighted by the Russo-Ukrainian war and the related new EC energy strategy (March 2022), shocks may shift political action and greatly impact the metrics we use. Thus, previsions to the 2030 might be considered to be the safest.

5. Conclusion and key recommendation

Recent geopolitical events in Eastern Europe have brought energy security to the forefront of political and media discourse. The Russo-Ukrainian war disrupts multiple aspects of energy security, from availability to affordability and accessibility. However, this new momentum for energy security only adds up to the decisive stance it holds in the transformation of the European energy system towards net-zero.

Through this paper, we have proposed an index that may be used as a single metric for assessing the interlinkages between energy security and the European green transition.
Even though limitations relating to the very own building methodology of the index should be considered, we found that climate change scenarios have very strong impacts on energy security parameters. As a result, we can conclude that initiatives increasing the probability of achieving the net-zero target contribute to building a favourable environment for energy security. Including environmental parameters in the assessment ensures the relationship should be true in the opposite direction too.

Thus, and in times when preoccupations around energy in Europe are at their highest, we strongly call for an alignment of efforts. Taking measures on energy security without considering environmental parameters would be pernicious. The adoption of new energy supply sources and more globally of the new *REPower EU* plan should then be monitored closely for that matter.

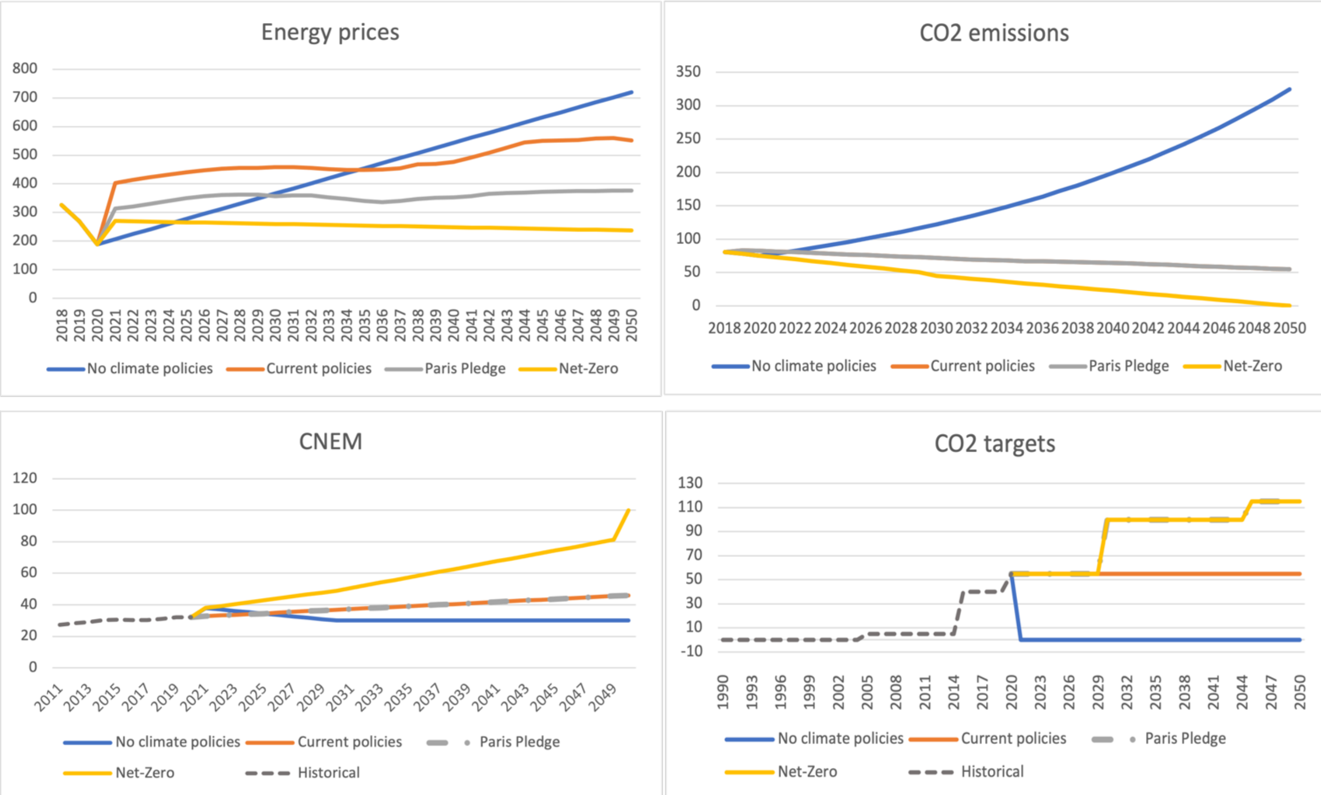
Annex

Annex 1: Prevision methods by metrics and pathways

	No climate policies	Current policies	Paris Pledge	Net-Zero
$Energy\ net\ imports$	linear prevision	linear rising prevision	linear rising prevision	linear rising prevision
MIs	unchanged	gradually and slightly rising prevision	gradually and slightly rising prevision	gradually and slightly rising prevision
DBs	unchanged	gradually and slightly rising prevision	gradually and slightly rising prevision	gradually and slightly rising prevision
FHs	unchanged	gradually and slightly rising prevision	gradually and slightly rising prevision	gradually and slightly rising prevision
$\Delta\ wages$	linear prevision	linear rising prevision	linear rising prevision	linear rising prevision
$\Delta\ energy\ prices$	strong rise (linear projection based on historical data from 1992 to 2020)	linear rising prevision	20 years average with 5% increase	progressive inverted tendency, slight and finally strong decrease (-33% in 2050)
$\Delta\ CO2$	tendency inverted with a 5% stronger dynamic	linear rising prevision	linear rising prevision	same than target
$\Delta\ CO2^{target}$	none	-55% targets in 2030 and 2050	-55% target in 2030 and -100% in 2050	-55% target in 2030 and -100% in 2050
$CNEM$	unchanged	linear rising prevision	linear rising prevision	strong linear rise (49% in 2030 and 100 in 2050)

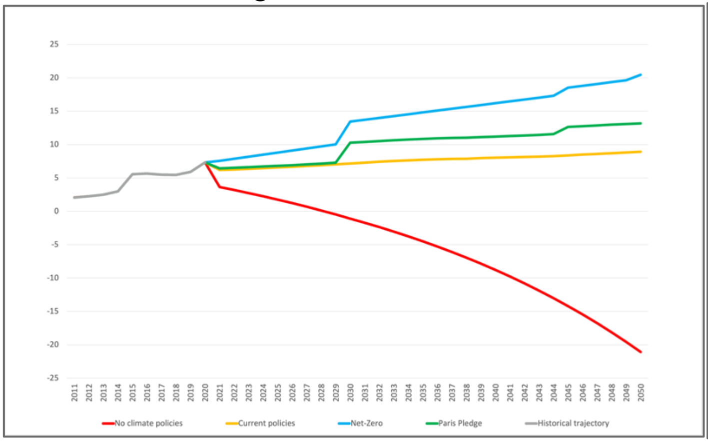
Source: Own author

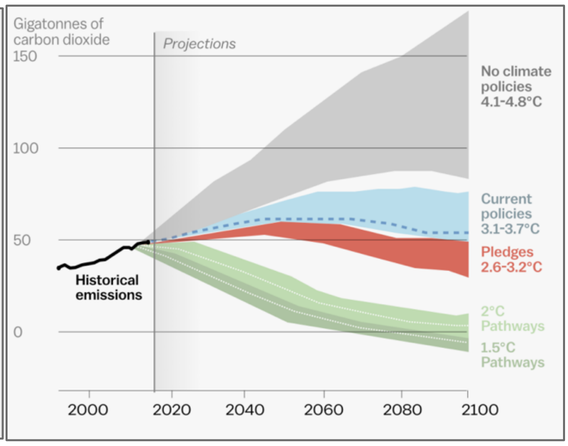
Annex 2: Impact of the different scenarios on key metrics



Source: Own author computations with FED, Eurostat, World Bank data.

Annex 3: Matching tendencies with climate scenarios





Source, left chart: Own author computations
Source, right chart: Carbon Action Tracker, Vox

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