



Resilient energy in Europe after the invasion of Ukraine. Comparative analysis on the speed and approach regarding the deployment of wind and solar power generation in the regions of Schleswig-Holstein, Catalunya and Casablanca-Settat

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Our platform is devised as a conduit for participation and influence in social debate. We serve as a bridge between the academic world, civil society and public agents for uniting efforts and contributing to the progress of society.

Our institution is named after Elinor Ostrom, Professor of Political Economy, Professor of the Arthur F. Bentley Chair at Indiana University and the first woman to be awarded a Nobel Prize in Economics.

The Institute includes fellows from very different generations and professional backgrounds, who agree on the need to provide the country with its own, independent and rigorous capacity for analysis. It also seeks to become a connected organization on a European and global scale with leading institutions in the international liberal landscape.

We are members of the Atlas Network, a network of nearly five hundred think tanks around the world, including the Cato Institute and the American Enterprise Institute (AEI) in the United States, the Canadian Fraser Institute; the Adam Smith Institute (ASI) and the Institute of Economic Affairs (IEA) in the United Kingdom; the Timbro Institute in Austria or the Center for Civil Society in India.

About the Friedrich Naumann Foundation for Freedom

Based on the principles of liberalism, the Friedrich Naumann Foundation for Freedom offers political education in Germany and abroad. With our events and publications, we help people to become actively involved in political affairs. We support talented young students with scholarships. Since 2007, the addition "for freedom" has become an established part of our foundation's name. After all, freedom isn't exactly in trend these days. This makes it all the more important to campaign for freedom and to take on the responsibility that goes hand in hand with it. We have been doing this since our foundation on May 19th, 1958. Our headquarter is based in Potsdam, and we maintain offices throughout Germany and in over 60 countries around the world.

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Introduction

Over the recent years, the climate emergency has gained a presence in the public debate. The climate crisis is an issue that concerns an increasingly large portion of the population, not only in Western Europe but also in developing countries. One of the main levers to mitigate the degradation of climate is the replacement of fossil-fuel based energy generation sources by renewable ones, thus making it possible to continue to fulfill today's electricity needs but with a radically lower (or zero) carbon footprint. In addition to the already underlying arguments for a speedy and decisive transition to renewable energy, the Russian invasion of Ukraine in early 2022 acted as a catalyst for change. With Russia being the largest natural gas supplier to the European Union, it was imperative that alternative energy sources were deployed as part of the diplomatic response to the conflict.

Moreover, technical burdens that in previous decades justified a timid rollout of renewable energy are rapidly disappearing: The cost of solar panels has dramatically decreased over the past decade, as technical milestones such as cheaper energy storage options have become readily available. Wind turbines can now produce more than double the energy (MWh per turbine) in a single turbine compared to just years ago. Since technology is now widely available and the return on investment is now acceptable for most use cases, the current major stoppers come down to two: resource availability (land and solar radiation for photovoltaic, acceptable wind speeds for eolic) and policy fit.

Policy is, indeed, conditioning and shaping the strategy and speed of the renewable energy transition in most parts of the world. From specific regulation (i.e. energy transition regulation) to wider legislation (construction permits, power grid connectivity authorizations...), there are many regulatory areas where red tape influences the outcome of such transition.

The purpose of this document is to offer an in-depth overview of the status, approach and milestones of the transition to renewable energy in two very different regions, which are however comparable in some dimensions. Schleswig-Holstein, Catalonia and Casablanca-Settat are all regions with a population of around eight million inhabitants, economic powerhouses of their respective countries (Germany, Spain and Morocco) and a high relative GDP per capita within their countries. Intuitively, the context of those regions in their respective countries would justify them acting as driving forces to push the renewable energy transition forward; however, a careful analysis of the data shows surprising differences which could lead to specific policy recommendations.

While recognising that energy policy (or, for this matter, construction permits and other relevant authorisations) is not a one-size-fits-all issue, a closer look at these three regional experiences can further strengthen the understanding of the energy policy framework, and debunk myths such as those stating that only regions with high resource availability (solar hours, wind speeds) are suitable for leading this new era.

The case of Schleswig-Holstein: strategy and metrics on the deployment of the energy transition

Schleswig-Holstein is a German region that occupies the southernmost part of the Jutland peninsula, shared with Denmark. It is a region of limited size, 15,776 km², with relatively flat orography. It has coastlines in two seas: the North Sea in the west and the Baltic in the east, as well as the Elbe River, which forms a natural border in the southwest. Its capital is the city of Kiel.

2.82 million inhabitants reside in Schleswig-Holstein, with a population density of 179 inhabitants/km², making it the sixth lowest-density state in the country. Its economy heavily depends on the primary sector (agriculture) as well as shipbuilding and maritime transport. The area surrounding Hamburg constitutes an area of first-rate economic growth, as it is the fastest growing port in the European Union.

Schleswig-Holstein is the region in Germany with the largest share of renewable energy installed power per capita. In 2021, 23.2 million megawatt hours (MWh) of electricity were generated from renewable energies in that region. That is 59.1 percent of total electricity production - the majority of the mix, by far. Mathematically, around 160 percent of the electricity consumption in Schleswig-Holstein (around 16.3 million MWh) was covered, according to the North Statistics Office, which means that Schleswig-Holstein is a net exporter of renewable energy to neighboring regions.

Table 1: Energy mix of Schleswig-Holstein

	2021 (MWh)	%
Fossil-based sources	3.769.565	9,6
Nuclear energy	12.032.352	30,6
Renewable energy	23.228.181	59,1
Residue processing	239.387	0,6
Other sources, non-classifiable	9.694	0
Power extraction (oftakes)	25.840	0,1
TOTAL	39.305.019	100

Source: regional government of Schleswig-Holstein, 2021 energy report

Table 2: Composition of renewable energy generation, grouped by technologies

	2021 (MWh)	%
Hydropower	5.274	0,0
Onshore wind	12.546.849	54,0
Offshore wind	6.069.334	26,1
Solar PV¹	1.492.780	6,4
Other (inc. biogas)	3.113.944	13,4
TOTAL	23.228.181	100

¹ Includes photovoltaic installations in roofs, utility-scale plants and others.

Source: regional government of Schleswig-Holstein, 2021 energy report

As shown on the table above, more than 80% of renewable electricity produced in Schleswig-Holstein is produced by wind turbines, most of which are onshore (installed over land). This corresponds to close to 3.000 wind turbines currently in operation in Schleswig-Holstein, each of which contributes to the creation of three new job listings, on average, according to the statistics of the Business Development and Technology Transfer Corporation of Schleswig-Holstein. As a consequence, Schleswig-Holstein's universities offer the most significant proportion of industry-relevant courses throughout Germany.

The construction of such a large number of wind turbine installations requires significant capital, which could have been a barrier of entry or, at least, a factor slowing down the deployment speed. In this regard, Schleswig-Holstein is well-known for its innovative ownership schemes when it comes to wind turbine projects, since many of them are owned by local farmers; for example, the projects in Ellhöft, Grenzland Vindtved and Neuenkirchen. This formula eases the initial capital requirements thanks to a larger capillarity of shares to minority owners, while flattening the barriers to social acceptance: small towns tend to have a higher acceptance rate for large-scale renewable energy projects if their ownership is not concentrated in large companies but rather distributed amongst citizens of the town. On the other hand, this model creates more complexity in its governance which in the case of Schleswig-Holstein is solved through a more active involvement of the local government, thereby aligning the interests of the various stakeholders and speeding up the process. Similar experiments have failed in other regions around the world, arguably due to a lower degree of involvement of the local institutions.

The *Energieküste* (Energy Coast) in western Schleswig-Holstein is the pioneering region in Germany when it comes to renewable energy. It concentrates a large number of innovative projects that complement the deployment of renewable energy. These projects include heat, storage, sector coupling, hydrogen, mobility and power generation, all considered necessary to achieve decarbonization targets. The west coast produces three quarters of the green electricity generated in the region of Schleswig-Holstein and a tenth percent of the green electricity generated in Germany (*Energieküste*, 2023).

Due to its high levels of renewable energy, Schleswig-Holstein is also a national hub for hydrogen projects. For instance, HH2E, a renewable energy project

developer, has raised 12 million euros in equity from investors, and jointly with other partners have committed investments of up to 500 million across all Germany. The deployment of electrolyzers aims to produce green hydrogen at times of the day when renewable electricity is cheap to fuel vehicles and chemical plants. This can be an important factor to safeguarding industrial competitiveness, which has been severely damaged by the European energy crisis (Guthrie, 2022).

In order to prove its commitment to the energy transition and renewable deployment, the regional government has included the Schleswig-Holstein Renewable Energy Network Agency as one of the six strategic clusters that can foster economic growth and contribute to regional development. This organization helps local firms to find partners that can provide funding and technical support to materialize renewable energy projects, and contributes to raising its social acceptance.

The case of Catalunya: strategy and metrics on the deployment of the energy transition

Catalunya is a region (formally, an "autonomous community") in Spain that occupies the northeastern corner of the Iberian Peninsula, bordering France through the natural border established by the Pyrenees mountains. It is a region of limited size, 31.895 km², but rich in orography: it comprises flat areas by the Mediterranean Sea, as well as pronounced gradients towards the Pyrenees and in several mountainous ranges in the center of the region. It is rich in rivers, many of which are formed towards the Northern part of the country and end in the Mediterranean sea. The Ebre river is the largest one. Its capital is the city of Barcelona.

The Catalan population currently exceeds 7 million inhabitants, with a population density of 242,91 inhabitants/km², making it the second largest state in Spain by population, after the southern region of Andalucia. Catalonia contributes 18.8% of Spain's total GDP, 25.5% of the industrial sector of GDP and 17.5% of the services sector. The industrial sector, and particularly advanced industry, stand out: Catalonia's high-tech exports will represent, in 2021, 34.6%. Catalonia's total exports in relation to Spain as a whole amounted to 26.8% this same year. Of the state's research and development expenditures, 22.8% were made in Catalonia. Catalonia is also the number one tourist destination in Spain.

According to the Energy Outlook of Catalonia (PROENCAT), published by the Catalan Energy Institute (ICAEN), Catalonia generates around 93% of the electricity it consumes, having import needs of around 3 TWh per year. This information is summarized in Table 3.

Table 3: Annual energy generation and demand energy by year

	2018	2019	2020	2021	2022
Generation (TWh)	42,4	45,21	42,96	39,88	41,62
Demand (TWh)	47,4	47,0	44,1	44,7	44,9
Ratio (%)	90%	96%	98%	89%	93%

Source: Institut Ostrom from figures published by the grid operator, Red Eléctrica

It is foreseen to reach a renewable generation share of more than 90% by 2040, which would rise to 100% by 2050 (see Table 4). However, the deployment speed of renewable energy would need to be drastically increased for those goals to be achieved.

Table 4: Evolution of renewable energy installed power, grouped by technologies (MW)

	2020	2030	2040	2050
Hydropower	1.825,3	1.825,8	1.825,8	1.825,8
Onshore wind	1.271,1	5.234,2	16.939,0	23.136,0
Offshore wind	0	1.000,0	1.500,0	3.500,0
Solar PV	344,5	7.156,6	22.431,5	33.152,3
Other	116,7	191,8	270,9	247,4
TOTAL	3.557,6	15.408,4	42.967,2	61.861,4

Source: Prospectiva Energètica de Catalunya (PROENCAT)

Table 5: Gross renewable electricity generation in Catalonia (GWh)

	2020	2030	2040	2050
Hydropower	5.209,6	4.282,6	4.068,4	3.854,3
Onshore wind	2.637,2	13.652,3	36.395,8	45.955,1
Offshore wind	0	4.100,0	6.059,6	13.285,6
Solar PV	484,1	11.407	35.291,5	51.228,1
Other	416,6	892,5	1.321,7	1166,8
TOTAL	8.747,6	34.334,3	83.137,0	115.489,8

Source: Prospectiva Energètica de Catalunya (PROENCAT)

PROENCAT's scenario is exclusively committed to renewable energies, which implies the abandonment of fossil and nuclear generation technologies. These ambitious plans to deploy new capacity and renewable energy generation contrast with the rates achieved to date. Thus, during the 2021-2023 period, a total of 94 MW have been installed, at an average rate of 31.3 MW per year. This means that, in order to achieve the established wind power target by 2030, current rates would have to be multiplied by a factor of 17.6.

Catalonia has three of the seven reactors currently operating in Spain: Ascó I, Ascó II and Vandellós II. These generation units annually produce more than 50% of the total electricity generation in Catalonia. The National Integrated Energy and Climate Plan 2021-2030 (PNIEC 2021-2030), currently under review, provides for an orderly closure of the nuclear park over a time horizon of about 14 years. In the Catalan case, the first cessations of nuclear activity will occur throughout the year 2030 and 2032, when the reactors of the Ascó nuclear power plant, which already have extension authorization to be able to

operate for their last ten years, will stop operating, while the Vandellós reactor will cease its activity in 2035.

The implications of the cessation of nuclear activity for Catalonia's electricity dependence are relevant, since in a not very long time horizon, more than 50% of the electricity generation capacity will be lost. If the renewable deployment objectives do not meet the ambitious objectives, there would be, in the short term, an increase in electricity import needs to very high levels, that could reach 40%.

Table 6: Total electricity generation by source in Catalonia (TWh)

	2019	2020	2021	2022	%
Hydropower	3.5	5.1	3.4	2.7	8.6%
Pumped-storage hydro	0.1	0.2	0.2	0.3	0.4%
Nuclear	23.6	23.9	23.4	24.0	55.9%
Combined Cycle Gas	8.8	5.3	4.8	7.9	15.8%
Onshore wind	3.1	2.6	2.6	2.5	6.3%
Solar PV	0.4	0.4	0.4	0.4	0.9%
Solar Thermal	0.0	0.1	0.1	0.1	0.1%
Cogeneration	5.4	5.1	4.6	3.4	10.9%
Other	0.4	0.4	0.4	0.4	1.0%
TOTAL	45.2	43.0	39.9	41.6	100.0%

Source: Institut Ostrom from figures published by the grid operator, Red Eléctrica.

As shown in Table 6, wind and solar energy account today for less than 8% of total electricity generation. Even including hydro and other renewable sources, the full share only reaches 16%. The time series of total generation and installed capacity shows that there has been very little progress, especially considering the ambitious objectives analyzed in previous sections. This can be directly attributed to the strict regulatory framework that has impeded the deployment of new renewable projects. In particular, available evidence based on both quantitative evaluation and conceptual analysis suggests that the Decree 147/2009 which established the administrative procedures for implementing new wind and solar installations severely retarded the deployment of solar-PV and wind energy projects in the region (Sinha, 2021).

The case of Casablanca-Settat: strategy and metrics on the deployment of the energy transition

Casablanca-Settat is a region of Morocco towards the Northern side of the country, bordering the Atlantic Ocean. It has a minimal size of 20,166 km² and a flat orography, without any relevant mountains. Its capital is the city of Casablanca, the largest city in Morocco and the country's economic and business center.

It is the most populated region of the country, with 6,861,739 inhabitants and a density of 340/km² in 2014, which corresponds to 21% of the national population. It replaces the former Greater Casablanca region by bringing together the provinces of El Jadida and Sidi Bennour from the former Doukkala-Abda region, as well as the provinces of Settat, Benslimane and Berrechid from the former Chaouia-Ouadigha region after the administrative reform of 2015. Casablanca-Settat had a gross domestic product of 290 billion Moroccan dirhams in 2013, accounting for 32% of Morocco's GDP, with an economy primarily based on services and industry.

Casablanca's intense interest in the deployment of renewable energy started in 2009 with King Mohammed VI's announcement that renewable energy for Morocco as a whole would have to reach a 42 percent share by 2020. With Casablanca being the industrial powerhouse of Morocco, it absorbed many of the efforts towards that goal. The initiatives were overseen by the Moroccan Agency for Solar Energy (MASEN), with the landmark projects being a major solar energy scheme near Ouarzazate (160MW) partially financed by the World Bank and launched in 2015, and a tender of 1000 MW (aggregate total) onshore wind projects. Despite the participation of international funding in many of those major projects, the Casablanca regulations approved an official requirement to include local participation of up to 30 percent of the total investment. This decision acted as a clear impulse from the renewable energy tenders for the local renewables industry.

The substantial contribution of renewable energy projects to the local economy paved the way for a strikingly high support rate for such initiatives amongst the Casablanca population. According to citizen polls (El Assal, 2023), 96% of the polled population expressed interest in using renewable energy, while more than 89% of locals affirmed they were "ready to support" large-scale energy transition projects in Casablanca. That context contributed to speeding up the deployment of such initiatives, as there was close to no opposition.

The Government of Morocco does not publish official data on the aggregate electricity production by regions. However, a broad vision can be drawn by observing the country-level data and the specific large-scale projects identifiable in the region of Casablanca-Settat.

Table 7: Total electricity generation by source in Morocco (TWh)

	2019	2020	2021	2022	%
Hydropower	3.33	2.28	2.14	0.91	0,4%
Solar	4.17	3.99	4.76	3.77	1,5%
Wind	12.39	12.06	13.36	13.96	5,4%
Gas	10.13	7.87	7.90	2.33	0,9%
Coal	77.49	77.80	85.42	77.67	30,2%
Oil	156.34	136.37	154.73	158.23	61,6%
TOTAL	263.85	240.37	268.31	256.87	100.0%

Source: Statistical Review of World Energy (2023)

As shown in Table 7, Morocco as a whole falls behind the countries of Germany and Spain respectively when it comes to the current state of the deployment of renewable energy. However, by contrasting those figures with the pool of identifiable renewable energy projects in the region of Casablanca-Settat, it is possible to conclude that the region leads the generation of renewable energy in the context of Morocco and features a multi-fold advantage in the share of decarbonised electricity generation in contrast with the Moroccan average.

- The Khalladi wind farm (120MW, launched in 2017), the Safi power plant (200MW, launched in 2021) and the Oualidiya wind farm (36MW, 2020) are all inside the perimeter of the Casablanca-Settat region

- The wind farms of Amougdoul (60MW, 2007), Jbel Hdid (200MW, 2021) and Tanger 2 (100MW, 2022) are connected with dedicated transport lines to the Casablanca-Settat region

The investment in wind farms from 2020 to 2022, either inside the Casablanca-Settat region or outside but connected to it with dedicated transport lines, was above 2.200 million dollars, with an addition of 1.566 MW of power in that time window on top of the pre-existing 1.220 MW, totalling more than 2.700 MW of wind power in the region or directly connected to the area (Haidi et al, 2020).

Regulatory state of affairs

In order to foster the deployment of renewable energies it is essential to have a regulatory framework that follows some good regulatory principles.

First and foremost, ensuring a transparent and efficient regulatory framework is crucial, as it can help streamline the approval process, reduce barriers, and encourage investment in renewable energy. Besides, creating a clear, consistent, and stable regulatory framework is also important to provide certainty to all the stakeholders involved in the deployment process (developers, investors, etc.). Hence, it is important to avoid unforeseen and unwarranted regulatory changes.

Moreover, establishing a streamlined permitting process that simplifies the approval procedures for renewable energy projects is something worth implementing. This can reduce delays and costs associated with project development. Another good practice is to create specialized offices that serve as a single point of contact for all permitting and regulatory needs for renewable energy projects. This simplifies interactions with regulatory authorities and reduces bureaucratic costs. Regulators must also set clear and predictable timelines for the processing of permits and approvals. Delays can increase project costs and uncertainty, making it less attractive to investors.

It must also be ensured that the regulatory framework addresses grid connection and necessary infrastructure upgrades to accommodate renewable energy projects, promoting grid integration and stability.

Following some of these principles, the European Union has passed several emergency measures to improve the existing regulatory environment. For instance, Regulation (EU) 2022/2577, of 22 December 2022 laying down a framework to accelerate the deployment of renewable energy states that "The planning, construction and operation of plants and installations for the production of energy from renewable sources, and their connection to the grid, the related grid itself and storage assets shall be presumed as being in the overriding public interest and serving public health and safety when balancing legal interests in the individual case".

This same regulation imposes a maximum deadline of 3 months to all installations of solar energy equipment and co-located energy storage assets, including building-integrated solar installations and rooftop solar energy equipment. For the permit-granting process regarding the installation of solar energy equipment, including for renewables self-consumers, with a capacity of 50 kW or less, the absence of a reply by the relevant authorities or entities (administrative silence, that is, the failure to issue a ruling within the fixed term) within 1 month following the application results in the permit being considered as granted.

Finally, it has imposed an exemption from the requirement, if applicable, of being subjected to a determination whether the project requires an environmental impact assessment. It has been proven fundamental to strike a balance between promoting clean energy and safeguarding environmental and social interests through well-crafted regulatory procedures.

Similar grounds on regulatory requirements have recently been passed in the case of Morocco. The Moroccan Government has undertaken a wide-ranging reform of the legal framework governing the renewable energy sector, including a new regime for self-generation. The Reform has introduced an option for distribution network operators to acquire up to 40% of the total electricity produced annually by renewable energy electricity generation facilities which is supplied to customers within the jurisdiction of the relevant distribution network operator. The Reform has also introduced an obligation on each renewable energy operator to apply the principle of national preference, that is, prioritize Morocco-based suppliers in the construction and service contracts.

The new regulatory framework in place in Morocco now allows the administration - fundamentally, the Ministry of Energy Transition - to grant an authorisation to build installations for the production of renewable energy following a call for projects, under specifications defined in a call for proposals formally referred to as "cahier des charges". This allows the Government to act proactively when it comes to pushing specific renewable energy projects and opportunities.

Causal analysis on the speed of the energy transition

As discussed in the previous chapters of the present report, there are significant differences in the speed of deploying renewable energy power between regions, which are relatively close geographically and with comparable land size and population. There are several hypotheses that could explain such differences.

The first of those hypotheses would be the notable differences in natural resource availability between those regions. For instance, it might be that the solar radiation is not comparable between the regions, or that the wind resource availability (hours of wind compatible with turbine generation) is also significantly different between them. In such a scenario, a correlation could be drawn between solar radiation and energy produced in photovoltaic parks, as well as a correlation between wind frequency and speed and wind turbine generation, in megawatts-hour. The presence, or lack of, of those cause-effect relationships will be tested in this chapter.

Another hypothesis that could potentially explain the existence of notable differences between the studied regions is a potential causal relationship with financial capability. In such an event, there would be a linear or geometric relationship between the gross domestic product per capita and the share of renewable energy in the grid. This could be explained by the relatively costly nature of this transition, which requires significant initial investments. Again, the presence of such a relationship or lack thereof will be put to test in the present document.

Finally, the third potential explanation of the differences could be purely policy-related: differences in regulatory layout - i.e. the processes and itinerary needed to obtain the permits to build renewable energy projects - as well as the set of incentives, both positive incentives - i.e. tax reductions, direct transfers, specific funding lines at low rates or other favorable conditions - or negative incentives - i.e. the loss of rights, access costs which make for an ineffective return on investment or other barriers of entry related to poorly designed public policy. The current regulatory framework in each region will also be assessed in the current chapter.

Contrast between renewable energy deployment speed and GDP per capita

The transition from a fundamentally fossil-fuel based energy system to a power grid layout which integrates a majority of renewable powered technologies is a process which requires historically high upfront investments. Renewable energy, versus traditional power generation schemes, has very limited operational costs - for instance, solar radiation is a free resource as well as wind availability. However, the cost per produced megawatt hour is not free nor close to free, since the depreciation of the initial investment for those installations needs to be recovered, and that is not a small sum albeit it is quickly being reduced due to economies of scale and improvements in the production processes of the involved utilities.

According to a study published in 2022 by the insurance company Allianz, the estimated total cost of deploying the necessary renewable energy infrastructure throughout Europe to meet the official 2050 decarbonisation targets is 2.3 trillion euros. The same study states that 75% of that cost would need to be assumed by private capital sources. Such intensive upfront investment needs make for a scenario in which countries with different investment capabilities could have varying levels of complexity in unlocking those private funding opportunities, unless foreign investment is considered.

Private investment is complex to evaluate as an intrinsic vector; however, it is usually a product of the gross domestic product (GDP) of each country or region. With that in mind, it is appropriate to analyze the GDP per capita of each region whose renewable energy approach and speed have been previously outlined.

Table 8: Nominal GDP per capita by region, euros

	2015	2016	2017	2018	2019	2020	2021	2022
Catalonia	28.742	29.778	30.876	31.976	32.793	29.111	31.590	34.534
Schleswig-Holstein	29.809	30.488	32.007	32.790	34.032	33.452	36.094	38.274
Casablanca-Settat	N/A	N/A	N/A	4.560	N/A	4.605	N/A	4.610

Sources: Institut Ostrom from figures published by IDESCAT and CEIC

As shown by the previous data, a potential correlation between speedier renewable energy deployment and higher GDP per capita (involving potentially easier access to private investment to cover the upfront costs and thus overcome the financial barrier of entry of renewable energy projects) could possibly make sense in the comparison between Catalonia and Schleswig-Holstein. However, that would be a weak link: Schleswig-Holstein GDP per capita is 14,7% higher than that of Catalonia even though its renewable energy deployment speed is more than double. However, this hypothesis becomes irrelevant when looking at the contrast between the region of Casablanca-

Settat and Catalonia: Casablanca-Settat's GDP per capita is just 13,7% that of Catalonia and, despite that strong divergence, its renewable energy deployment speed is much higher than Catalonia's.

Those findings are consistent with the qualitative observations that all three regions object of the present study have previous experiences with raising funds for renewable energy projects from international parties; including, but not limited to, the following experiences:

- The Rethwisch's large wind farm in Schleswig-Holstein, one of the largest in the region, was promoted and invested by the MDP Group based in South Africa ([Rethwisch \(Schleswig-Holstein\) \(Germany\) - Wind farms - Online access - The Wind Power](#))
- The Norwegian-based Statkraft has filed for permits for five solar photovoltaic projects of 50MW each in Catalonia ([Les renovables eviten el Govern i tramiten projectes catalans a Madrid \(ara.cat\)](#))
- The Italian Enel Green Power conglomerate is currently building a large, 280MWp wind turbine project neighboring the Casablanca-Settat region, in Jbel Lahdid, and connected to Casablanca's electricity grid ([Marruecos | Enel Green Power](#))

Therefore, it is reasonable to infer that the local availability of funding to push the execution of renewable energy projects is not a relevant barrier since the studied regions have shown a consistent capacity to attract foreign investment for their projects. That phenomenon also explains where there is a clear lack of correlation between the GDP per capita and the speed of deployment of renewable energy projects in the areas studied in this report.

Contrast between solar deployment speed and solar hours and sun radiation intensity

Once discarded the possibility that financial barriers of entry might explain the differences in the speed of renewable energy deployment, we can assess whether the availability of natural resources differs between the analyzed regions. In the case of solar photovoltaic installations, the aforementioned availability corresponds in fact to the solar radiation in each of the regions. As it is quite obvious, solar radiation is not identical in different latitudes and thus differs between the three regions.

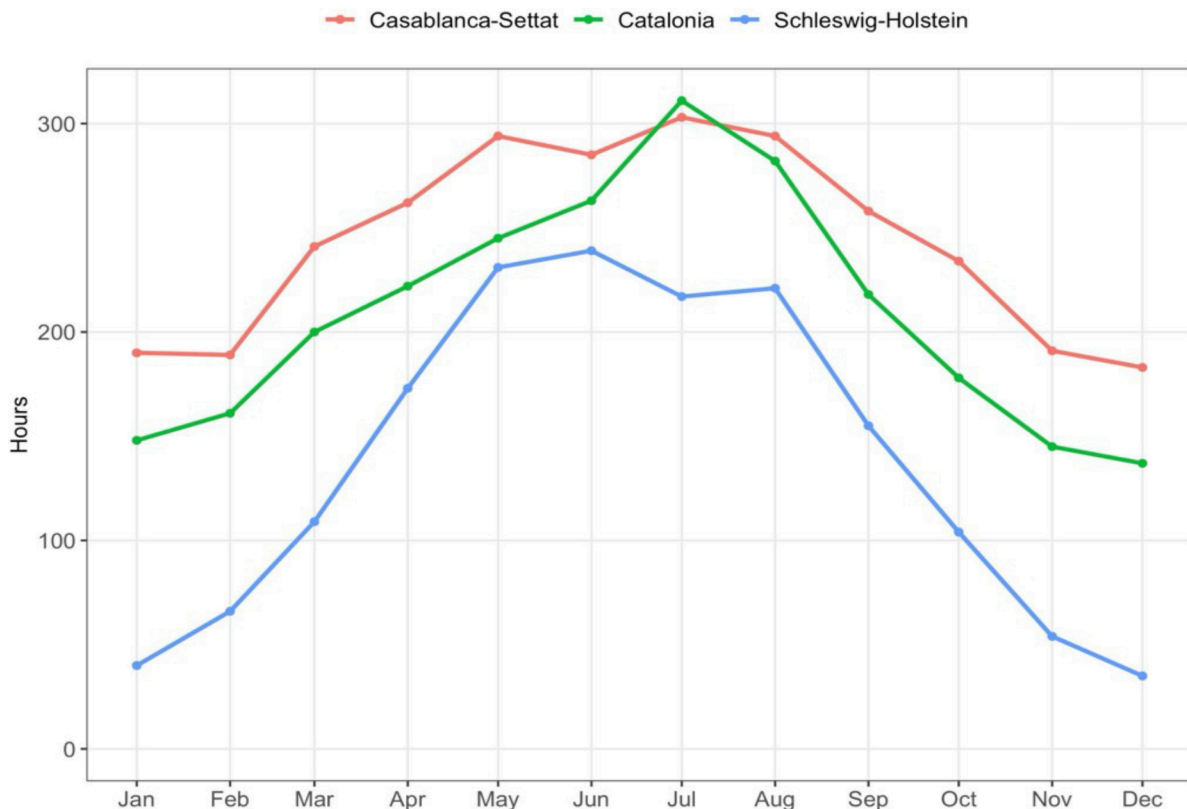
As can be seen in table 8, Casablanca is well above the mean of monthly solar hours with respect to Catalonia and Schleswig, with the latter being the region with less solar hours. The results are consistent with the intuitive fact that latitudes further from the equator have poorer solar radiation than those closer to the equator.

Table 9: Monthly solar hours by region

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Catalonia	148	161	200	222	245	263	311	282	218	178	145	137
Schleswig-Holstein	40	66	109	173	231	239	217	221	155	104	54	35
Casablanca-Settat	190	189	241	262	294	285	303	294	258	234	191	183

Source: Institut Ostrom from figures published by Weather and Climate

Graph 1: Monthly solar hours by region



Source: Institut Ostrom from figures published by Weather and Climate

However, the previous results are not consistent with the hypothesis that a higher degree of solar installations would be present in regions with higher radiation - in fact, Schleswig-Holstein's installed power of all solar photovoltaic parks combined is higher than that of Catalonia, and more so on a per capita basis. That is despite Schleswig-Holstein's solar radiation being significantly lower than Catalonia's throughout the year and more sharply in the months of September to April.

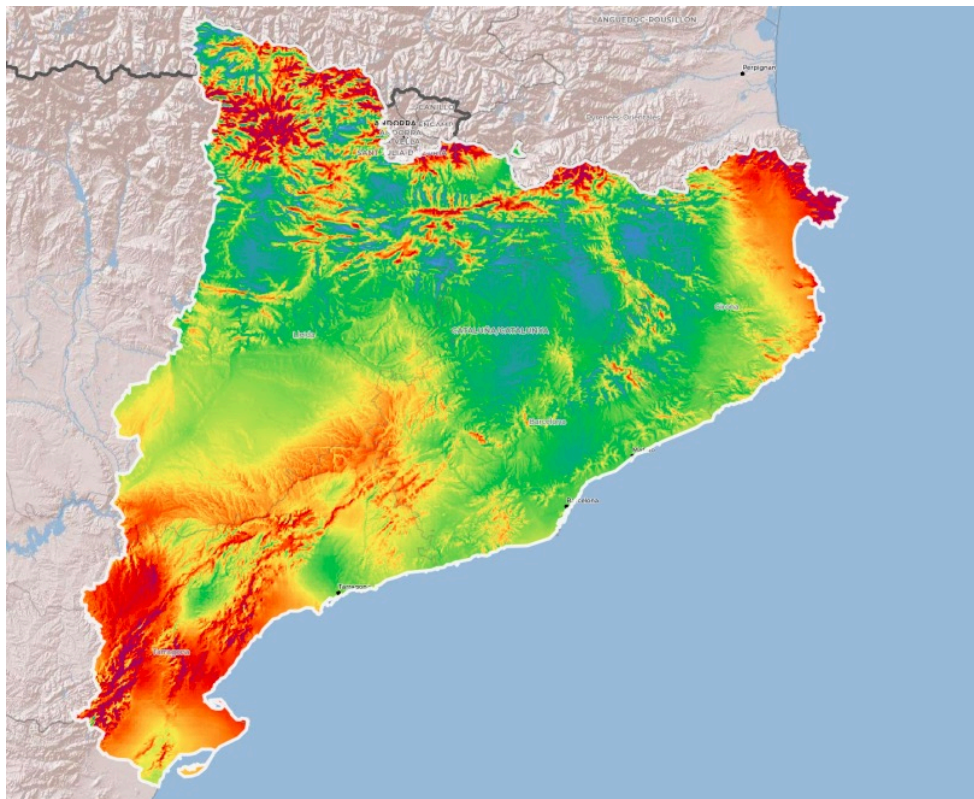
Therefore, it is possible to conclude that the underlying causes for the different degrees of renewable energy implementation do not seem to be related to the availability of the natural resource, in this case solar radiation.

Contrast between eolic deployment speed and wind resource availability

While the previous exercise was useful to determine or discard a potential linear relationship between solar radiation and volume of solar power per capita, that observation does not necessarily imply that the situation will be equivalent in the case of wind turbines - it is necessary to again reevaluate a potential correlation between the installed wind power per capita versus the availability of wind, and more specifically, wind speeds. In order to assess wind availability, we use mean wind speed maps from the Global Wind Atlas by region.

In the case of Catalonia, wind availability is concentrated in the three extremes of the region. Geographical distribution of wind installed capacity shows that the resource is not always located where it could be more useful and maximize its efficiency. For instance, the province of Girona, located in the northeast part of the region, is one with the highest wind resource availability, but has systematically opposed the deployment of wind generation, with no significant progress in the last years. However, it is foreseen that Girona will host one of the biggest offshore wind projects in Spain.

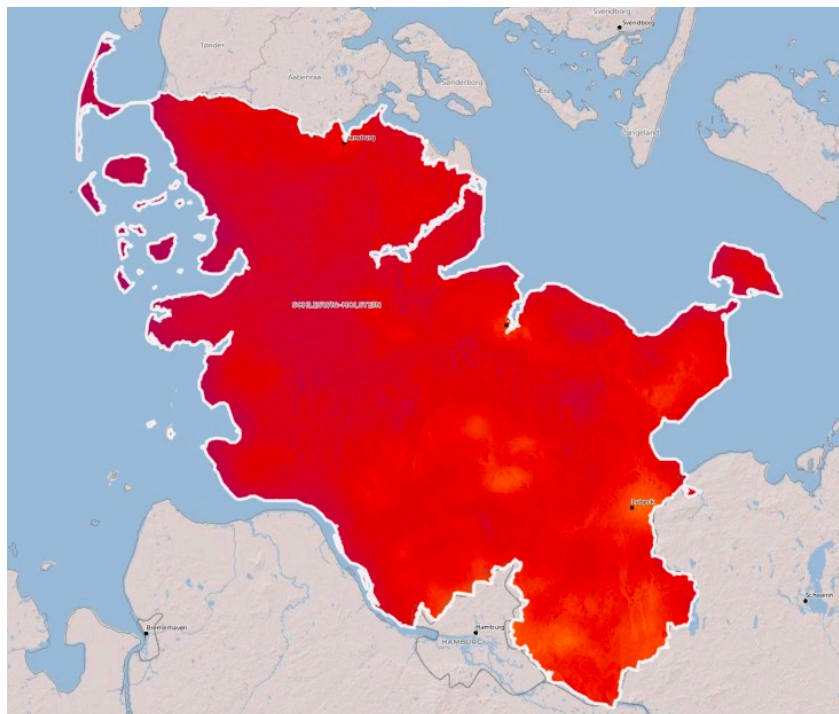
Map 1: Catalonia's mean wind speed



Source: Global Wind Atlas

The map for Schleswig-Holstein shows much higher and homogeneous rates of wind availability across all the region's geography. This is consistent with generation data from Table 2, which shows high levels of electricity generation from wind, both onshore and offshore.

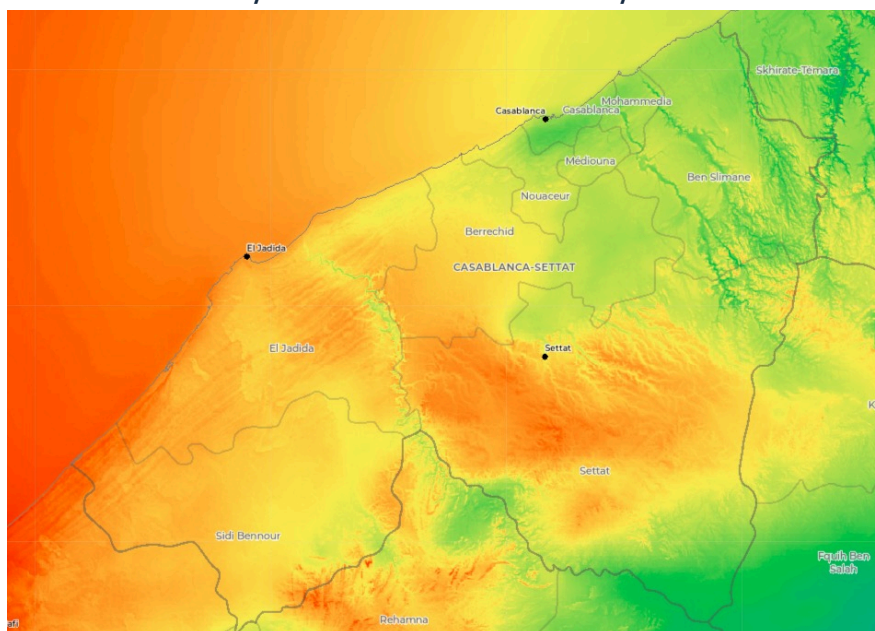
Map 2: Schleswig-Holstein's mean wind speed



Source: Global Wind Atlas

It is also clear that the wind resource is less abundant in Casablanca-Settat compared to Catalonia and Schleswig-Holstein.

Map 3: Casablanca's mean wind speed



Source: Global Wind Atlas

Based on those findings, it is not possible to establish a solid correlation between the intensity and frequency of wind speed and the total deployment of renewable energy power per capita, as the order of precedence of the regions by renewable energy per capita does not match that of the wind availability and speed.

Conclusions and policy recommendations

Despite the limitations on data availability for renewable energy deployment, particularly in the case of the Casablanca-Settat region, it is clear that the speed and intensity of the deployment of renewable energy projects - fundamentally solar photovoltaic parks and wind turbine projects - are not equally distributed amongst regions, even if they might have some contextual attributes in common such as a similar geographical positioning, a comparable relative weight over their respective countries and relatively similar population. On the other hand, a context where geopolitical tensions are increasingly strong, the effects of global diplomacy over the energy availability and cost are significant: for instance, the situation of mainland Europe after the sudden shutdown of the North Stream gas pipe during the development of the Ukraine invasion by Russian troops has had a clear negative influence over the gas - and, for extension, electricity - pricing.

Therefore, the regions where the switch to on-site renewable energy sources is faster will enjoy a larger degree of resilience and independence, while those regions lagging behind in the energy transition will suffer the consequence of global geopolitical tensions more intensely, so much that their industries might have challenges to compete in the global market due to significant cost increases.

In order to strengthen the aforementioned resilience, energy sovereignty and industrial competitiveness, it is necessary to address the underlying causes for which the speed of the energy transition is uneven between relatively comparable regions. In this report, several hypotheses have been evaluated: first, if the gap might be caused by differences in GDP per capita which could harm the investment capacity needed to execute such a transition. This hypothesis has been discarded since there is no observable correlation between GDP per capita and deployment speed of renewable energy projects. A second theory focused on the availability of resources; that is, solar radiation and wind frequency and speed. Again, it has not been possible to validate this hypothesis since the regions with higher solar radiation and wind speed are not deploying more renewable energy projects.

The remaining reason that could justify the observed differences is their regulatory approach. In fact, it is possible to conclude that an adequate energy policy can accelerate the speed and intensity of installed renewable energy power - and, thus, of energetic resilience and independence, and industrial competitiveness - even if the natural context (availability of resources such as sun radiation and wind speed and frequency) and the socioeconomic context (GDP per capita) is not favorable. This is, for instance, the case of Schleswig-Holstein, which does not enjoy particularly good solar radiation figures and, despite such reality, has been able to multiply by orders of magnitude the installed solar photovoltaic power per capita of Catalonia, with a significantly better solar availability.

With that in mind, it is of particular importance to observe and replicate the successful regulatory reforms that have been implemented by those regions that show positive results, including:

- The participation of the local population in the ownership scheme of large-scale energy projects is observed in Schleswig-Holstein and Casablanca-Settat. This is also featured in the current legislation in Catalonia, but few projects have been implemented in that region since the passing of such regulation. While complex to verify empirically, it is intuitively possible to trace a link between such schemes and the proportionally lower burden of local opposition to large-scale projects in Schleswig-Holstein and Casablanca-Settat versus Catalonia.
- It has been possible to identify that both the Government of Morocco and the local Government of Schleswig-Holstein have established the public goal and willingness to lead the way of power decarbonization in their respective countries. This ambition has not yet been observed in the region of Catalonia where the ruling party has publicly expressed skepticism with regards to the need of generating renewable energy in Catalonia versus doing so in the neighboring areas *Energia i paisatge* - Miquel Puig (ara.cat)¹.
- The approach of large-scale projects has been prioritized by both the regions of Casablanca-Settat and Schleswig-Holstein. Such an approach has had a two-fold effect: first, it has paved the way for a faster energy transition by adding large sums of renewable Gigawatts of power. This has maximized the ratio of project evaluation/authorization timescale to additional renewable power to the grid. Second, since large-scale projects feature their own evacuation lines, it has reduced the risk of facing poor connectivity, a challenge that otherwise smaller projects often face. This scenario contrasts to the one in Catalonia, where the government has been prioritizing small-scale projects.

¹ Miquel Puig. "Energia i Paisatge". *Diari Ara*, January 21, 2021.

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