

Analysis of the renewable energy evolution in Europe: 2000-2018

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Abstract: Renewable Energy points the way towards the energy transition and towards the sustainability and responsible increase in energy consumption that occurs each year. It is true that a large percentage of the primary energy consumed is from fossil sources and, therefore, it generates emissions that pollute the planet and its natural resources. However, more and more nations are becoming aware of this fact and investing in RE. Europe is one of the regions of the world where more has been invested in renewable energies in recent years, therefore the main purpose of this article is the analysis of the evolution of different RE in Europe during the period between 2000 and 2018. From this analysis it will be possible to obtain conclusions on investment and RE capacity in Europe and in their countries, and also on the different technologies used to obtain primary energy from RE sources.

Key Word: Renewable Energy; Primary Energy; Capacity; Wind Power; Solar Energy; Marine Energy; Hydropower; Bioenergy.

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I. Introduction

We can define as a primary energy source that which is available in nature before being converted or transformed. This kind of energy source should be assumed as the input used in an energy system. One of the most common forms of energy consumption, and therefore of measuring the capacity or energy consumption of a country, is electricity. The study of the evolution of the use and consumption of energy all over the world is a topic of great interest to the community due to its importance in terms of its energy sources. As indicated in¹, primary energy from renewable sources suffers a global stopless, which implies a contribution to the consumption of primary energy, standing at 10.8% of the total, and as the fourth energy source worldwide. The use of fossil sources reaches the 84.7% of the total primary energy consumed worldwide standing in the first three positions, so that coal, oil and natural gas are distributed in the following way: oil (33.6%), coal (27.2%) and Natural gas (23.9%), and finally the consumption of nuclear energy represented 4.4% of the whole. With these data, there is a growth in global energy consumption of 2.9% in the year 2018, which implies that the growing trend results of the energy generation must be optimized, as well as the reduction of conventional energy and an increase in renewables sources to mitigate the negative impact on the environment.

Figure 1 shows a graph with the distribution of primary energy consumption worldwide, showing that Renewable Energy (RE) come to ranks fourth.

Focusing on Europe in 2018, RE represented 15.5% of the primary energy consumed, implying an increasing of 7.8% compared to the previous year. As in the rest of the world, fossil energies occupied the first three places in the consumption of primary energy, with the variation that natural gas ahead of coal: oil (36.2%), natural gas (23%) and coal (15%), thus representing 74.2% of the primary energy consumed, and finally the contribution of nuclear energy is 10.3%.

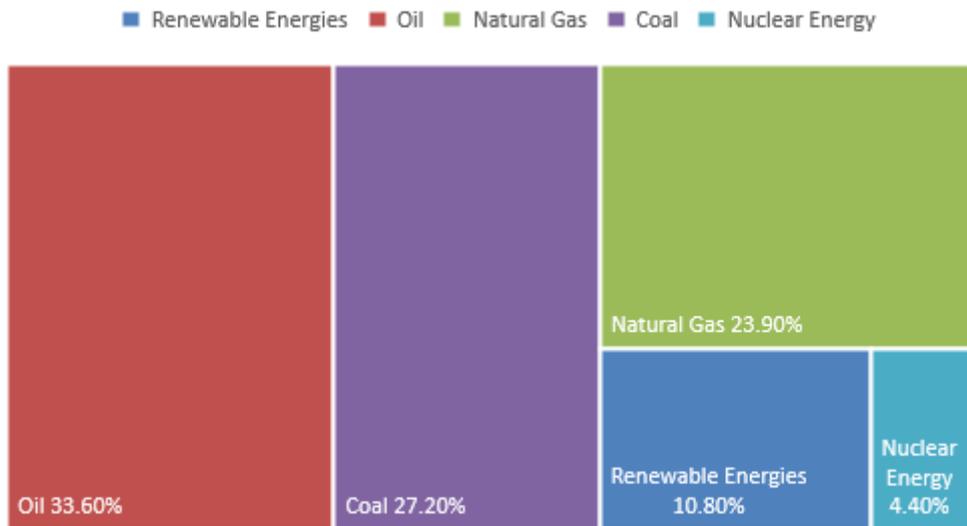


Figure 1. Distribution of consumption of primary energy worldwide in 2018

Figure 2 shows the primary energy consumption data in Europe. Something that is necessary to value if we compare them with the data at the world level is the importance of RE that reach the third place, ahead the coal as a primary source, however, the dependence on fossil energies and nuclear, as a whole it is very high.

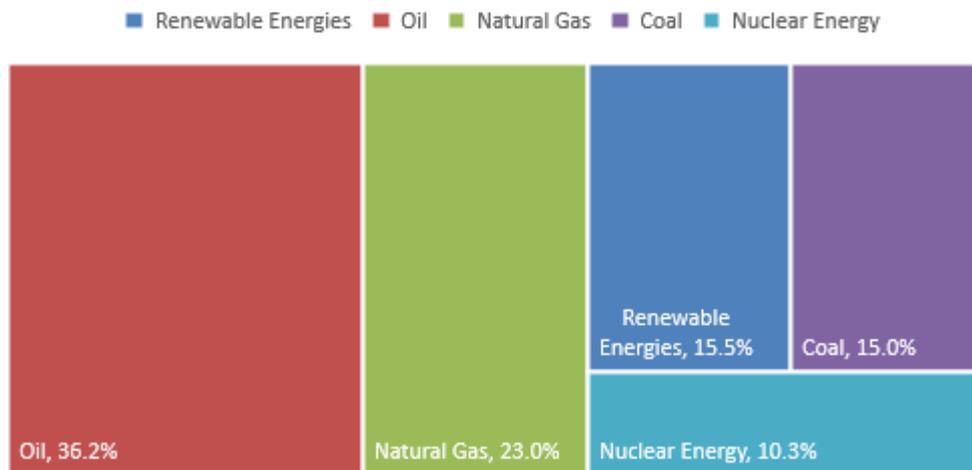


Figure 2. Distribution of consumption of primary energy in Europe in 2018

Be able to estimate the trend of the evolution in the behavior of the different RE energy sources in Europe is helpful and very interesting to be able to forecast the future of RE sources and determine their capacity to become substitutes for conventional energy sources.

Electric power generation is a value priority and strategic for any country, and therefore one of the bases of the world economy is its generation and distribution^{2,3,4}. Taking into account that conventional energy sources have a large number of harmful effects on our planet, their reduction and replacement by alternative energy sources is a goal to be achieved by all countries, so that, in recent years, research on the production of RE in all aspects indicates the interest that arouses the substitution, as far as possible, of conventional sources. The progressive implementation of RE in all areas of production and consumption makes the importance of these sources reaches greater relevance and is postulated as a substitute for conventional energy in more and more applications^{5,6,7}. The objective of this article is the analysis and comparison between the different countries of Europe in terms of consumption of RE as primary energy in order to determine the evolution of each of them over this 21st century. This study will allow us to have an idea of the prioritization or not, throughout this period

of RE sources and thus be able to estimate and reduce dependence on conventional energy sources in the near future.

This article is divided into five sections. Section 2 introduces the different types of energy sources to be analyzed. Section 3 shows the current situation in Europe regarding renewable energy. Section 4 analyzes the evolution of the different RE sources in the most important European countries in terms of the installed capacity of these energies. Finally, the discussion and conclusions are included in section 5.

II. Types of renewable energy to analyze

RE are clean and almost inexhaustible resources that nature provides, and that due to their typology contribute to reducing a territory's dependence on external energy sources, thus favoring its growth and development based on environmental ethical principles⁸. The use of these RE dates back to ancient times, taking into account the use of the sun and the wind by civilizations such as the Roman or Egyptian⁹.

This section briefly describes the energies that will be analyzed in each of the countries of the Europe and thus be able to verify their evolution throughout this century.

Biofuels

Biofuels are the main source of RE used in transport, and the one that generates the greatest savings in greenhouse gas (GHG) emissions, thus contributing to the fight against climate change¹⁰. All biofuels consumed in the European Union meet the strict sustainability criteria provided for in the Renewable Energy Directive (DER): GHG emissions savings of at least 50% and the use of raw materials that do not come from lands with high biodiversity or high carbon stocks, including forests, wetlands and peatlands. Compliance with these requirements is currently independently certified by systems authorized and supervised by the European Commission¹¹.

The increasing use of biofuels also reduces the energy dependence on fossil fuels in the transport sector, without the need for the introduction of new technologies in vehicles, since biofuels can be used mixed with fossil fuels in the same engines. internal combustion that run on diesel and gasoline.

Biomass

Biomass is renewable organic material that comes from plants¹². Biomass, has multiple uses: electricity generation, heating, sanitary hot water ... Electricity generation with biomass allows very high uses, contributing with firm and manageable power to the community renewable mix. With high decarbonization scenarios for 2030 and 2050, biomass will be essential to have a balanced mix¹³. At a thermal level, biomass allows us to have heating and sanitary hot water with a competitive and carbon-neutral fuel.

Wind energy

Wind energy is a well-known type of energy that is giving very good results. With a gradual implementation, this technology has generated an important industry worldwide at the same time that it has significantly reduced its generation costs due to its improvements in terms of construction and efficiency¹⁴.

In addition to the industry generated and the electricity produced, wind power has achieved one of the great achievements of renewables worldwide: with a very high-cost reduction in the last years, it is now competitive against polluting forms of generation¹⁵.

Hydropower

Hydraulic energy is the use of the kinetic energy of a mass of water. The water moves a turbine whose rotation movement is transferred to an electricity generator through a shaft. Until the middle of the 20th century, hydropower was the main source for large-scale electricity production. Mini-hydraulic plants are those whose installed power is less than 10 MW. This renewable technology is the most environmentally friendly way that is known to produce electricity as corroborated by Life Cycle Analysis (LCA) studies carried out for different technologies¹⁶.

Photovoltaic solar energy

Photovoltaic energy has long since stopped talking about the space race to talk about self-consumption or debate, you to you, with traditional technologies. After a cost reduction of 85% in 7 years, the energy that produces 3% of our electricity is now competitive against polluting forms of generation¹⁷.

At a scientific level, photovoltaic solar energy is the direct transformation of solar radiation into electricity. This transformation occurs in devices called photovoltaic panels. In photovoltaic panels, solar radiation excites electrons in a semiconductor device, generating a small potential difference. The series connection of these devices allows to obtain greater potential differences¹⁸.

Although the photovoltaic effect has been known since the 19th century, photovoltaic panels did not begin to undergo significant development until the 1950s, in the middle of the space race. Initially they were used to supply electricity to geostationary communications satellites, but today they constitute a renewable electricity generation technology.

Thermal solar energy

The use of solar thermal energy to supply the different thermal demands existing in the building, industrial and agricultural sectors, is one of the most efficient and economical ways to take advantage of an abundant and indigenous resource, which is also free and available at the same point of consumption¹⁹.

Its use supposes the reduction of the consumption of primary energy and of CO2 emissions corresponding to the energy source that it replaces and that supplies these demands. Therefore, it implies the improvement of the energy efficiency of buildings, industries, etc. where solar thermal energy is incorporated.

Solar thermal technology is a mature technology that has been widely used in the building sector in recent years. The current technological development and the high reliability of solar installations allow them to be easily integrated into buildings and industries²⁰.

Current technology allows solar thermal installations to require minimal maintenance and have control systems for remote monitoring, thus offering all the guarantees regarding safety and comfort of use.

III. Renewable Energy situation in Europe

Currently, the use of RE in Europe is constantly growing due to the European Union (EU) commitment to the different treaties for the conservation of the environment and reduction of the generation of greenhouse gases^{21, 22, 23}. The data published by the International Renewable Energy Agency (IRENA)²³ allow an analysis of the current situation in Europe at the level of installed renewable capacity, as well as its typology. Electricity generation capacity is the maximum electric output an electricity generator can produce under specific conditions and this is the principal measure we that is take in account to do the analysis.

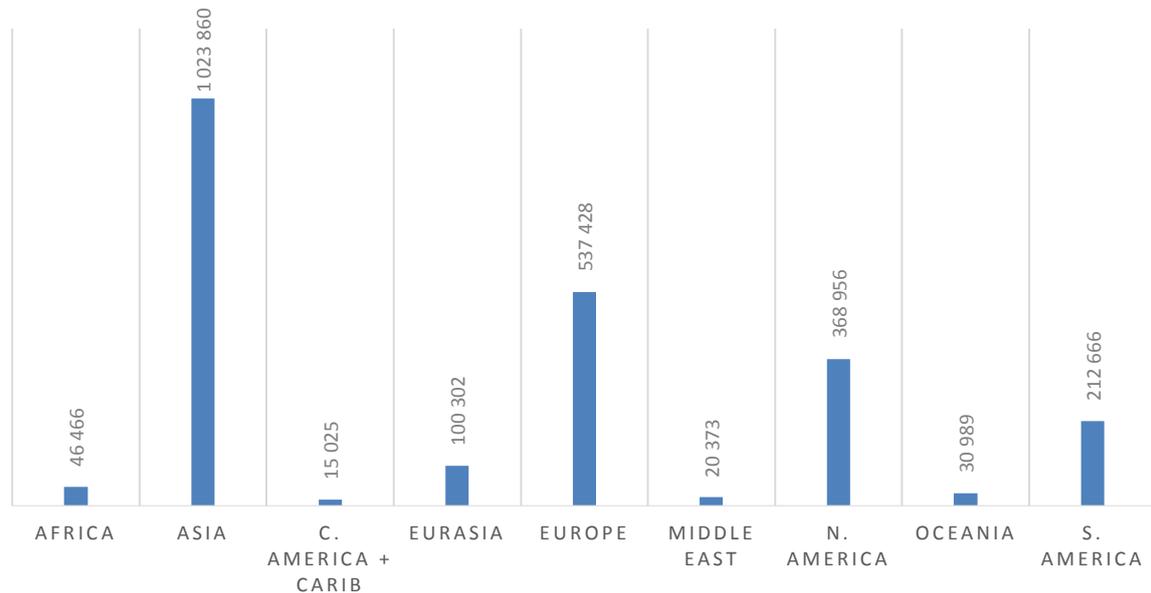


Figure 3. Electricity Capacity of RE in the world in 2018 (MW)

Figure 3 shows the electrical capacity of renewable energies in the world in 2018. For the American continent, four areas are represented independently: North America, South America, the Middle East, Central America and the Caribbean. It can be observed that the RE capacity installed in Europe is 537428 MW, which makes it the second region with the most installed capacity. Asia is the region with the largest capacity, which is almost double that of Europe. Certainly, China has an installed capacity of 695488 MW, which makes it the country with the largest installed RE capacity in the world, and also surpasses any continental area.

In this sense, Europe can also be considered as a global power in terms of installed capacity, since if it is considered as an economic and territorial nucleus, its capacity is very close to that of China, and far exceeds that of North America, despite the fact that this region includes two world economic powers (United States and Canada).

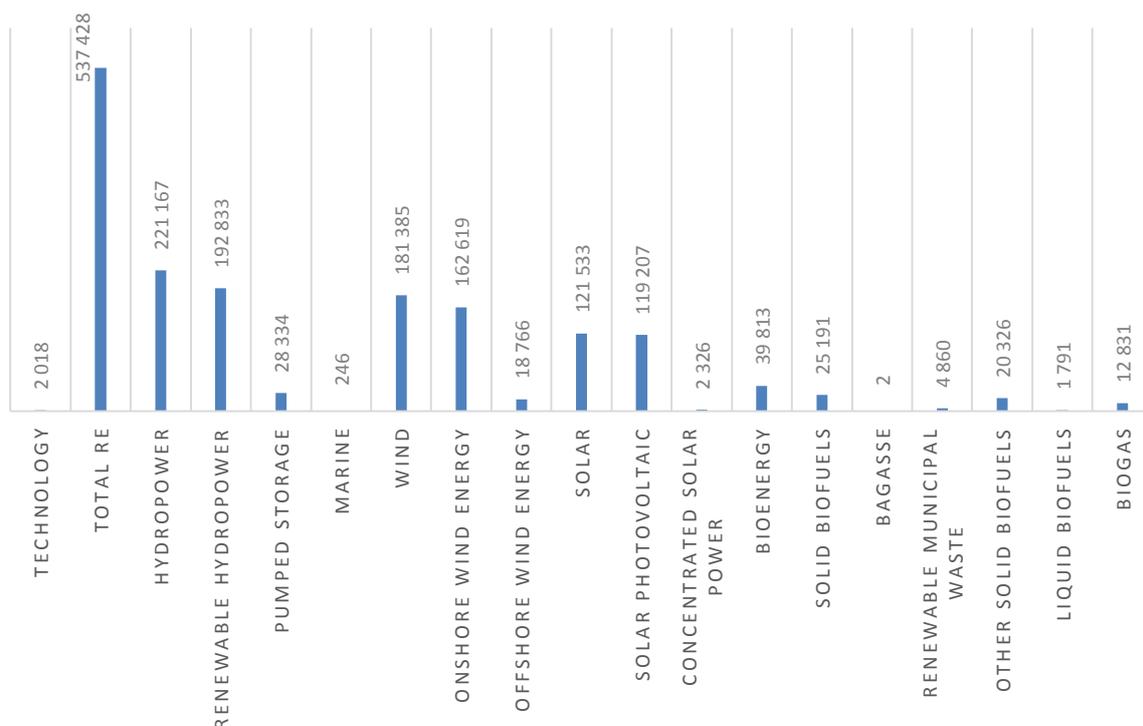


Figure 4. Electricity Capacity of Renewable Energies in Europe in 2018 (MW)

Once Europe is positioned as one of the main territorial cores in terms of installed RE capacity, we have to focus on the typology of this energy so that an analysis of its performance and its evolution can be carried out according to the same. As shown in figure 4, hydropower, solar and wind energy are the three that accumulate the greatest development and installation in Europe, with hydroelectric energy being the one with the highest installed capacity. The great knowledge of these three technologies and their constant development mean that the performance of these energies is increasing and therefore that they can compete with conventional energies²⁴. Thus, analyzing the data in table 1 we have that among the three types of energy mentioned they make a total of 97.52% of the renewable capacity of Europe, therefore converting the rest into residual energy with 2.48% of the total.

Table 1. Capacity Renewable Energy by country and Technology in 2018. (*The total installed energy is not equal to the sum of the different types of energy due to the existence of residual geothermal capacity not considered in this analysis.)

Country	Hydropower	Marine	Wind	Solar	Bioenergy	Total RE
Albania	2105	0	0	1	1	2107
Andorra	46	0	0	1	5	52
Austria*	14516	0	3133	1438	1271	20358
Belarus	95	0	101	157	48	401
Belgium	108	0	3261	3987	887	8242
Bosnia Herzg	1816	0	51	18	9	1894
Bulgaria	2515	0	699	1033	195	4441
Croatia*	2200	0	586	68	115	2979
Cyprus	0	0	158	118	13	289
Czechia	1093	0	316	2075	782	4265
Denmark	9	0	6121	998	1797	8925
Estonia	7	0	310	32	259	609
Faroe Islands	40	0	16	1438	0	56
Finland	3287	0	2041	140	2230	7698

France*	24065	218	14900	9617	1711	50527
Germany*	5585	0	58843	45181	9651	119296
Gibraltar	0	0	0	0	0	0
Greece	3409	0	2877	2652	82	9020
Holy See	0	0	0	0	0	0
Hungary*	57	0	329	726	484	1599
Iceland*	2099	0	2	0	0	2857
Ireland	237	0	3676	24	101	4038
Italy*	18558	0	10230	20114	3491	53161
Kosovo	96	0	37	7	0	140
Latvia	1565	0	78	2	134	1779
Liechtenstein	0	0	0	0	0	0
Lithuania	117	0	533	82	83	815
Luxembourg	34	0	123	131	36	324
Malta	0	0	0	131	5	136
Moldova Rep	64	0	33	3	6	106
Monaco	0	0	0	0	0	0
Montenegro	653	0	118	3	0	775
Netherlands	37	2	4393	4522	849	9803
North Macedonia	674	0	37	21	8	740
Norway	32530	0	1207	68	87	33893
Poland	968	0	5766	562	1004	8300
Portugal*	7236	0	5172	681	648	13767
Romania	6609	0	3032	1386	141	11169
San Marino	0	0	0	0	0	0
Serbia	2489	0	25	10	15	2539
Slovakia	1612	0	3	472	243	2330
Slovenia	1163	0	5	221	60	1450
Spain	16743	5	23405	7068	1037	48257
Sweden	16431	0	7300	492	5021	29244
Switzerland	14979	0	75	2171	243	17468
UK	2178	20	21770	13118	6963	44051
Ukraine	4809	0	621	2003	98	7530

The data shown in table 1 show the electrical capacity of RE that is installed in each European country. The country with the highest capacity is Germany, which has 22.20% of the EU total. Italy, France and Spain are the following countries which each represent approximately half the capacity of Germany. In addition, observing the data, it can be obtained that among the five countries that have the most installed capacity, there is a total of 58.67% of the total of the countries present in table 1. Analyzing each of these five countries and referring to each type of energy it can be seen that hydropower is more widespread in southern European countries, that is, Spain, France and Italy with capacities twice that of Germany. Regarding maritime RE, only France and the UK (United Kingdom) are the only two countries that of these five have installed capacity greater than or equal to 20 MW, with France being the one with the greatest capacity with a huge difference compared to the rest of the EU countries, as can be measured from the data available to us, represents 88.98% of the installed maritime RE capacity in Europe. Regarding wind energy, it is Germany that has a capacity that doubles to the second largest producer, which is Spain. This type of energy is undergoing a significant evolution in terms of the efficiency achieved, which implies a constant growth in the near future^{25,26}. For its part, installed solar capacity is also in Germany where it has the greatest response, with Italy being the second country with the

highest capacity. It is striking that Spain, taking into account the characteristics of southern Europe in terms of climatology, is the one with the least installed capacity among these five countries, which will be analyzed in its progression over time in the next point. Finally, the installed capacity of bioenergy, Germany is again followed by the UK the countries with the greatest resources.

Throughout this point, the importance of renewable energies in Europe has been highlighted and how they are the ones that have been in use for the longest time and have the greatest impact in terms of installed capacity due to their development.

IV. Evolution of Renewables in Europe

As indicated above, five European countries have the highest percentage of installed renewable energy capacity in Europe (Germany, Italy, France, Spain and United Kingdom) with a total of 58.67%. However, this percentage can not be significant for an analysis of Europe as a whole, for this reason, to analyze the evolution of the different types of energy in Europe, the ten countries with the highest installed capacity will be taken, which have 80% of the European total as showed in Figure 5, so that the percentage is more significant and allows a more detailed analysis of their evolution.

Table 2. Renewable Energy Capacity Evolution in Europe (MW). TRE (Total Renewable); HP (Hydropower); ME (Marine Energy); WE (Wind Energy); SE (Solar Energy); BE (Bioenergy).

Country		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Europe	TRE	190756	196418	203602	211245	221092	233816	244682	256915	273127	295544	322106	360876	395220	419969	440785	465037	488496	513025	537428
	HP	168665	168639	169194	169942	171412	173476	173924	175602	177062	177987	179489	181243	182508	184411	184668	186205	189399	191200	192833
	ME	214	216	219	220	219	217	216	216	219	218	222	221	228	228	231	231	241	245	246
	WE	12731	17393	23288	28153	34320	40684	47919	56341	64055	75808	84920	94714	107191	118263	130204	143033	155756	170633	181385
	SE	199	299	385	624	1335	2315	3277	5050	10518	17118	30856	54719	73801	84261	91125	99592	106103	112538	121533
Austria	BE	8171	9082	9632	11382	12946	16206	18228	18522	19999	23111	25282	28539	30043	31344	33053	34471	35491	36850	39813
	TRE	12478	12513	12416	12879	13182	14243	14643	15085	15570	15860	16177	16708	16656	17192	17839	18473	19336	19596	20358
	HP	11613	11640	11504	11545	11578	11799	11825	11988	12441	12630	12895	13177	13309	13383	13532	13650	14116	14150	14516
	ME	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WE	50	67	109	322	581	825	968	991	992	1001	1016	1106	1337	1675	2110	2489	2730	2887	3133
France	SE	5	7	9	23	27	21	22	24	30	49	89	174	337	626	785	937	1096	1269	1438
	BE	810	799	792	987	994	1596	1827	2081	2106	2179	2176	2249	1672	1507	1411	1396	1393	1290	1271
	TRE	23987	24069	24314	24427	24509	24881	25651	26542	27801	29293	31717	34788	37085	38657	40543	42792	44840	47814	50527
	HP	23297	23322	23421	23429	23316	23329	23341	23354	23312	23400	23617	23835	23849	23838	23849	23824	23893	23979	24065
	ME	213	215	218	219	218	216	215	215	218	216	216	215	216	218	220	218	220	219	218
Germany	WE	38	66	138	218	358	690	1412	2223	3403	4582	5912	6758	7607	8156	9201	10298	11567	13499	14900
	SE	7	7	8	9	11	13	15	26	80	277	1044	3004	4359	5277	6034	7138	7702	8610	9617
	BE	432	459	529	552	606	633	668	724	788	818	928	960	1038	1151	1221	1298	1442	1490	1711
	TRE	11807	14828	18362	21658	24876	28475	32219	35427	38448	47234	56545	67421	78150	83766	90325	97851	104436	112514	119296
	HP	4831	4831	4937	4953	5186	5210	5193	5137	5164	51340	51407	51625	51607	51589	51580	51589	51629	51627	51585
Spain	ME	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WE	6095	8754	12001	14381	16419	18248	20474	22116	22794	25732	26903	28712	30979	33477	38614	44580	49435	55580	58843
	S	114	195	260	435	1105	2056	2899	4170	6120	1056	1800	2591	3407	3671	3790	3922	4067	4229	4518

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	E									6	6	6	7	0	0	4	9	3	1	
	BE	767	1048	1164	1889	2166	2961	3653	4001	4367	5590	6222	7162	7471	7964	8202	8429	8660	8982	9651
Italy	TRE	17904	18293	18729	19173	19465	20251	20634	21600	23155	25772	29507	40824	46721	48857	49526	50417	51195	52128	53161
	HP	16390	16457	16558	16704	16787	17036	17115	17160	17319	17414	17563	17780	17923	18052	18116	18238	18316	18486	18558
	ME	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WE	363	664	780	874	1127	1635	1902	2702	3525	4879	5794	6918	8102	8542	8683	9137	9384	9737	10230
	SE	19	20	22	26	31	34	45	110	483	1264	3597	13136	16790	18190	18600	18907	19289	19688	20114
	BE	542	579	703	862	878	875	901	957	1157	1520	1826	2262	3178	3344	3359	3367	3439	3450	3491
Norway	TRE	28193	27746	28125	28213	28297	28913	29109	29420	29926	30082	30250	30632	31365	32002	32252	32394	32814	33251	33893
	HP	28126	27679	27913	27989	28030	280549	280725	280957	290413	290539	290693	290969	300509	310033	310240	310372	310817	310912	320530
	ME	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	0	0	0	0
	WE	13	13	97	97	152	265	284	348	395	423	425	512	705	818	859	867	883	1207	1207
	SE	6	6	6	7	7	7	8	8	8	9	9	10	10	11	13	15	27	45	68
	BE	48	48	109	120	108	92	92	107	110	112	122	140	140	140	140	140	87	87	87
Portug.	TRE	4885	4947	5058	5128	5666	6417	7088	7653	8344	8958	9607	10548	10955	11143	11573	12153	13217	13555	13767
	HP	4535	4560	4583	4583	4831	5017	5053	5061	5058	5091	5106	51535	51712	51661	51715	51668	516960	516226	517236
	ME	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	WE	83	125	190	268	553	1064	1681	2201	2857	3326	3796	4256	4412	4610	4857	4937	5124	5124	5172
	SE	1	1	1	2	2	2	3	24	59	115	134	172	238	296	415	447	522	593	681
	BE	252	247	270	261	266	320	326	342	345	401	546	560	568	551	561	577	587	582	648
Spain	TRE	18005	19289	20963	22087	24673	26367	28400	31929	36645	39711	42246	43920	46413	47676	47711	47742	47773	47921	48257
	HP	15542	15614	15650	15619	15743	15796	15894	15948	16027	16056	16086	16075	16085	160730	160768	160773	160743	160742	160743
	ME	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5
	WE	2206	3397	4891	5945	8317	9918	11722	14820	16555	19176	20693	21529	22789	22958	22925	22943	22990	23124	23405
	SE	10	13	17	22	33	52	141	505	3445	3705	4605	5432	6569	6994	7001	7008	7017	7027	7068
	BE	247	265	405	501	580	601	643	656	618	774	862	884	970	994	1017	1018	1018	1023	1037
Sweden	TRE	18263	18703	18322	18294	19131	20070	20907	20750	20974	22042	22707	23469	24293	24645	25528	26869	27805	28337	29244
	HP	16506	16523	16187	16098	16302	16302	16234	16592	16352	16544	16624	16478	16315	16395	15897	16230	16367	16502	16431
	ME	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WE	209	295	357	417	475	522	585	823	1089	1475	2017	2764	3606	4194	5088	5819	6435	6611	7300
	SE	3	3	3	4	4	4	5	6	8	9	11	12	24	43	60	104	153	402	492
	BE	1545	1882	1775	1775	2350	3242	4083	3329	3525	4014	4055	4215	4348	4013	4483	4716	4850	4822	5021
Switz.	TRE	13112	13163	13178	13200	13219	13267	13282	13396	13420	13504	13645	13789	14064	14409	14637	15040	16259	17049	17468
	H	12	12	12	12	13	13	13	13	13	13	13	13	13	13	13	13	14	14	14

	P	923	966	978	993	001	039	040	147	159	205	267	313	346	361	287	346	279	826	979
	M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	W	3	5	5	5	9	12	12	12	14	18	42	46	49	60	60	60	75	75	75
	S	16	18	20	22	24	28	30	37	49	79	125	223	437	756	1061	1394	1664	1906	2171
	B	170	174	175	180	185	188	200	200	198	202	211	207	232	232	229	240	241	242	243
UK	T	2893	3201	3260	3650	4009	4922	5412	6011	7055	8237	9627	1278	1590	2002	2489	3080	3545	4003	4405
	R												3	2	7	5	0	1	4	1
	E																			
	H	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
	P	785	929	883	785	799	801	815	822	928	940	947	979	993	009	030	077	136	173	178
	M	1	1	1	1	1	1	1	1	1	2	4	4	9	8	9	9	13	18	20
	E																			
	W	412	493	534	742	933	1565	1955	2477	3446	4422	5421	6596	9030	1128	1307	1430	1612	1958	2177
	E														2	4	6	6	5	0
	S	2	3	4	6	8	11	14	18	23	27	95	1000	1753	2937	5528	9601	1193	1278	1311
	E																	0	2	8
	B	693	775	839	1116	1268	1544	1627	1693	1657	1846	2160	3204	3117	3791	4254	4808	5245	5476	6963
	E																			

Table 2 shows data obtained from¹⁸ to analyze the behavior of the growth of RE capacity installed in the ten European countries above.

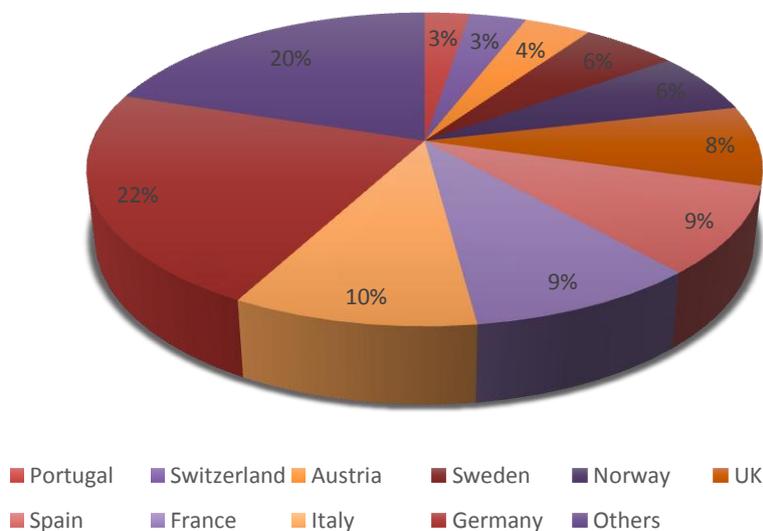


Figure 5. Distribution of the Renewable Energy Capacity in Europe in 2018

Europe

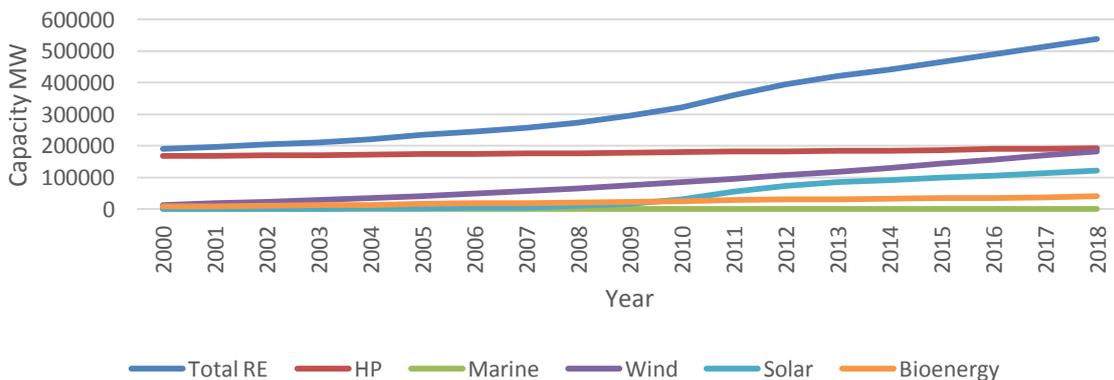


Figure 6. Renewable Energy Capacity Evolution in Europe (2000-2018)

Figure 6 shows the evolution of installed RE capacity in Europe between 2000 and 2018. As it can be seen, growth begins to be remarkable as over 2008-2009, which will occur in the countries that will be analyzed as a whole, as a uniform trend within the set of energies analyzed. The wind and the solar energies are that they have had the highest growth throughout the period analyzed.

It should be noted that the trend of hydropower energy is flat. This indicates that there has been no evolution in the performance of the plants already in operation, nor has any new plant been built that could contribute to increasing installed capacity.

Germany

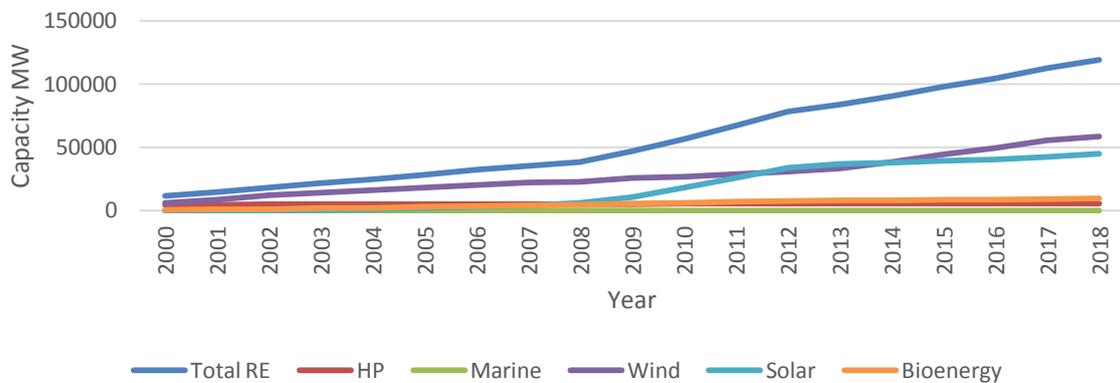


Figure 7. Renewable Energy Capacity Evolution in Germany (2000-2018)

Germany is the country with the largest installed RE capacity. At the beginning of the period analyzed, the main source of RE in Germany was wind power, and at the end of that period it was wind too. The growth in wind and solar energy from 2008 has been remarkable. In the case of solar energy, the greatest development has occurred in the 4-year period between 2008 and 2012. During the period of time analyzed in this article, this country increased its installed capacity of wind energy by 52748 MW and its solar energy capacity by 45067 MW. The investment made by Germany in this area is very important, which has allowed it to increase its RE capacity by 107490 MW between 2000 and 2018.

Italy

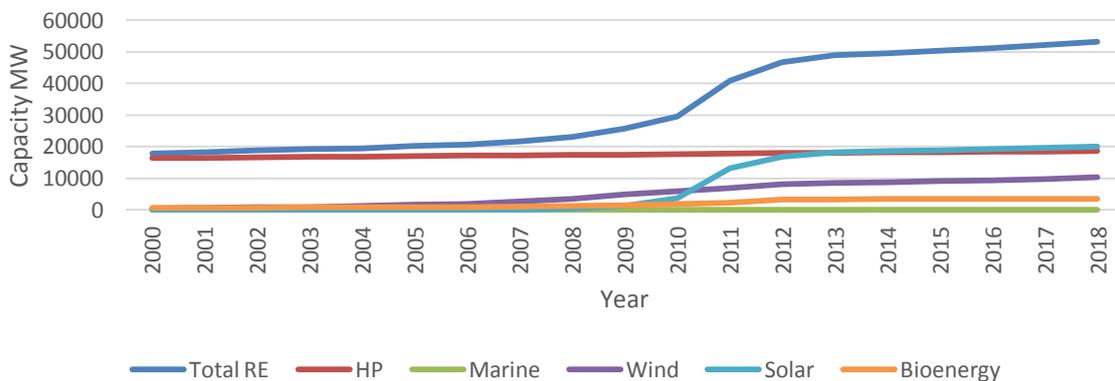


Figure 8. Renewable Energy Capacity Evolution in Italy (2000-2018)

Italy is the second European country with the highest capacity installed. The predominant RE source in this country is hydropower. It ever has occupied the first place during the whole period of time analyzed and has experienced a smooth continuous increase as shows Figure 8. The bigger increase in this country has occurred mainly in the field of solar energy since 2010. Solar energy capacity reached 21114 MW installed in 2018, thanks to an increase of 20095 MW over the time interval studied. It should be noted that more than half of the power was installed in a single year (13136 MW during 2011)

Italian solar energy accounts for 37.84% of the total renewable capacity installed in the country in 2018, and also implies a growth of 105861.36% of this energy from 2000 to 2018 obtained from Table 2 compares values corresponding to 2000 and 2018.

Wind energy is the second type that has increased the most, especially since 2006, although it has done so more slowly than solar energy and has reached a much lower level of implementation.

France

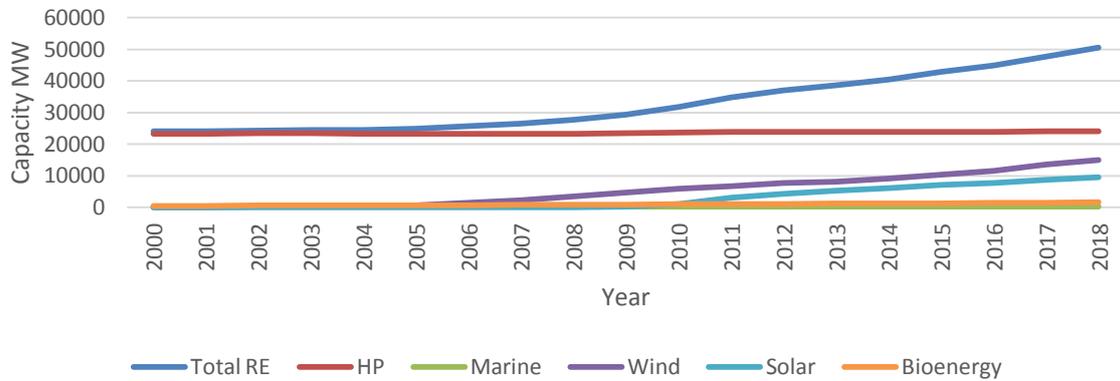


Figure 9. Renewable Energy Capacity Evolution in France (2000-2018)

France is the third European country in terms of installed capacity. The use of solar and wind energy has notably increased in this country as it is shown in Figure 9. Installed wind power was only 38 MW in 2000; after increasing more than 14000MW since 2005, it reached 14900 MW installed in 2018. On the other hand, the installed capacity of solar energy increased from 80 MW in 2005 to 9610 MW in 2018. This increase represents a significant investment and a commitment to RE in a country that has traditionally used non-renewable primary energy. Regarding hydraulic energy, it remains stable throughout the analyzed period, which indicates that no new facilities have been built for these purposes.

Something significant is that France is the most important country in Europe in terms of marine RE. It generates 88.53% of this type of energy produced in Europe.

Therefore, although hydropower energy continues to be the main source of RE in the country, there has been a notable growth in wind and solar energy (Figure 9).

Spain

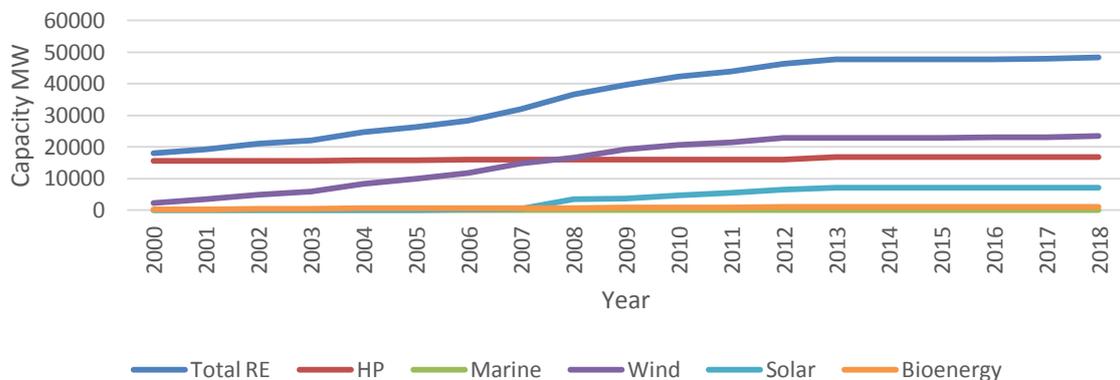


Figure 10. Renewable Energy Capacity Evolution in Spain (2000-2018)

In 2018, Spain had a total installed RE capacity of 48257 MW, with an increase of 30252 MW since 2000. As can be seen in Figure 10, hydropower was practically the only RE available in Spain before 2000. However, wind energy has been increasing in recent years, becoming the most important RE source in this country (Figure 10). Between 2000 and 2012, more than 20000 MW were installed, reaching 23405 Mw of wind energy installed in 2018.

It is observed that solar energy began its growth since 2007, but with a much softer trend than wind energy.

However, as can be observed in Figure 10, renewable capacity in Spain has stagnated between 2013 and 2018, with no significant increase in installed capacity of any type of RE. This stagnation is due to the fact that the government of Spain stopped subsidizing RE, so investment plummeted²⁸. In 2016, a capacity of 5 MW of marine power was installed. This fact is not important in terms of power, however is necessary to comment on it because only four countries in Europe have installed this type of energy as a primary source.

United Kingdom

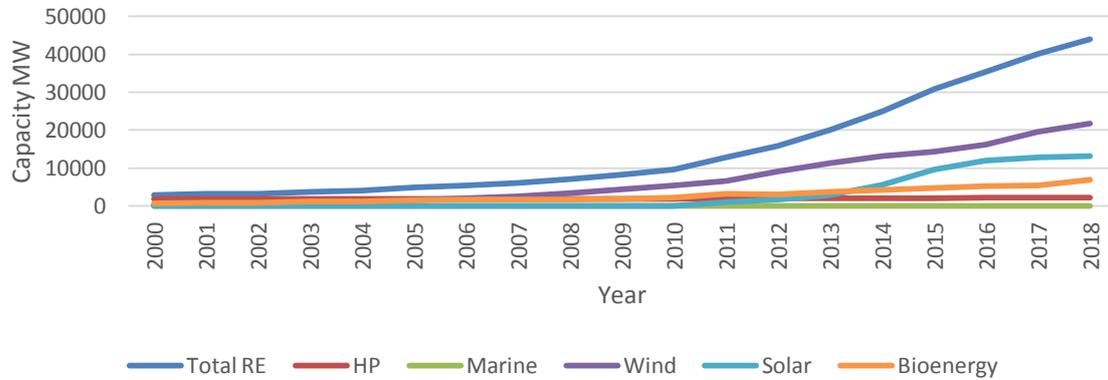


Figure 11. Renewable Energy Capacity Evolution in United Kingdom (2000-2018)

The evolution of the United Kingdom throughout the period analyzed is striking. As shown in Figure 11 the evolution of RE is very significant. Taking the values in Table 2 corresponding to the total capacity in 2000 and 2018, a growth of 1522.67% is obtained that, which is the most significant in Europe, and that is followed by that of Germany, with a total growth of 1010.43%. There is no country of those analyzed with such a high increase and, therefore, with such a high investment in this type of energy. When it is analyzed the type of energy, wind energy is the one that occupies the first place, followed by solar energy. The installed capacity of wind energy has increased by 21358 MW in the analyzed period, while the solar energy capacity has gone from only 2 MW in 2000 to 13116 MW in 2018.

Norway

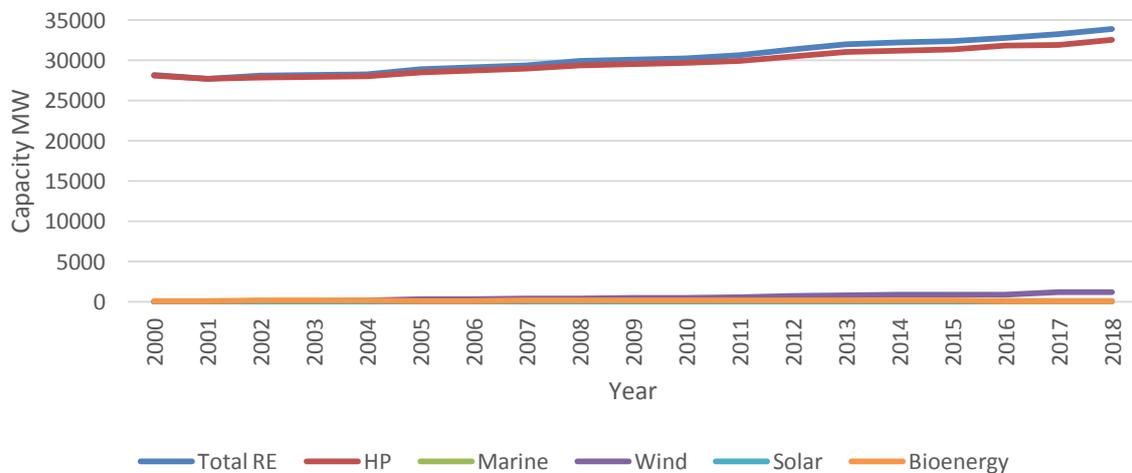


Figure 12. Renewable Energy Capacity Evolution in Norway (2000-2018)

Norway has focused its installed capacity on hydropower. The increase is minimal in this period of time (Figure 12). However, it can be observed that since 2000 the hydropower capacity is very high (28126 MW), which makes Norway the European country with the highest installed hydraulic power capacity. Certainly, in 2018 it maintains the same position with respect to the rest of the countries, with an increase in

installed capacity of 4,404 MW to reach 32530 MW en 2018. Although there has been a small increase in wind energy, it is noted that Norway's efforts are focused on hydropower.

Sweden

The main RE used as a primary source available in Sweden is hydropower. However, as shown in Figure 13, during the time period proposed for this study there is growth in terms of wind energy and bioenergy. It is a discrete growth that occurred between 2000 and 2018 with a global amount of 10981 MW. Wind energy is the most significant, with 7091 MW of installed power between these years. It should be noted that this country is one among a little set of countries in which bioenergy has an important value in terms of its growth and total contribution as RE, with a growth of 3476 MW in this period, which allowed having a total capacity of 5021 MW.

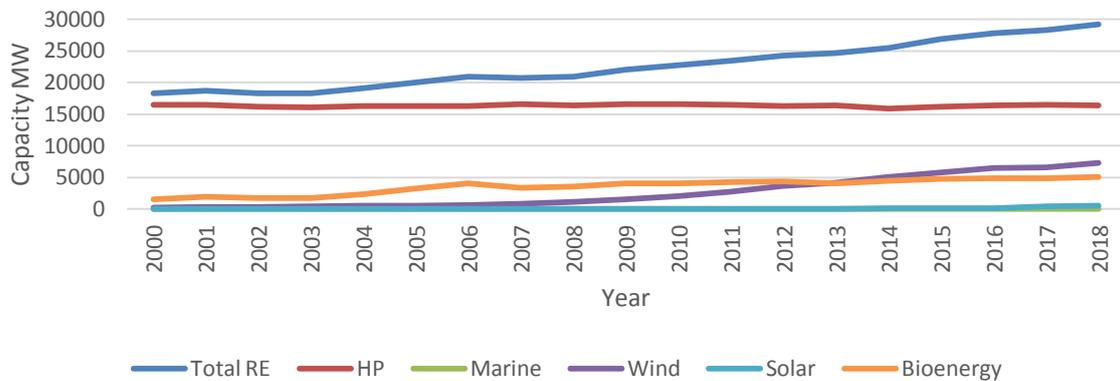


Figure 13. Renewable Energy Capacity Evolution in Sweden (2000-2018)

Austria

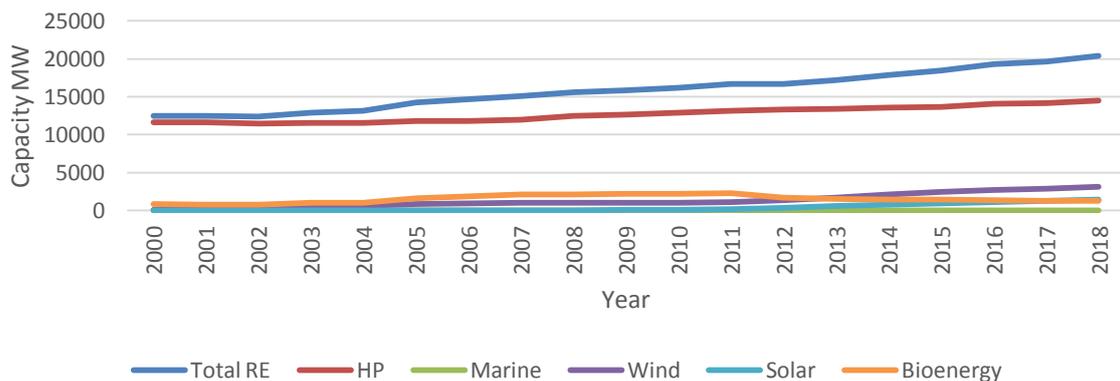


Figure 14. Renewable Energy Capacity Evolution in Austria (2000-2018)

Austria is the eighth European country in installed renewable capacity. As shown in figure 14, there has been practically no evolution in any of its types of RE, except for hydropower, which has experienced a slight increase since approximately 2007.

In addition, bioenergy has regressed since 2010. Although this reduction is not significant, the country's installed capacity has decreased.

Switzerland

Figure 15 shows the RE capacity of Switzerland. It can be observed that almost all the capacity corresponds to hydropower energy, as indicated by the data in Table 2, since this type of energy represents 85.75% of the total in 2018.

The evolution of RE in this country is practically null until 2010. Since that year, solar energy has increased by more than 2000 MW, which represents a notable increase compared to the previously installed capacity. That is the largest increment of RE in this country during the period analyzed (2000-2018) corresponds

to solar energy, with 13568.75% as shows Table 2. About the hydropower energy, the small increase corresponds to the last 4 years of the period analyzed.

Taking into account the data indicated in Table 2, the total increase of installed capacity, regardless of the type of energy, is 4356 MW, which implies 133.22% of the capacity of the year 2000.

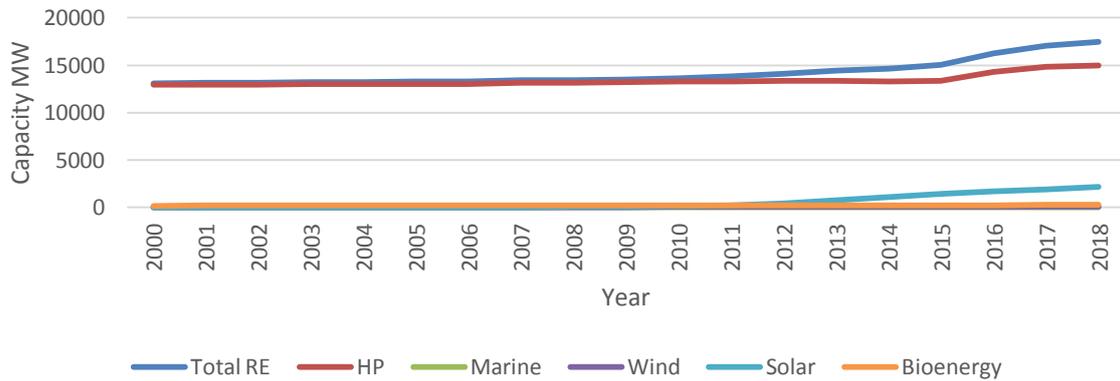


Figure 15. Renewable Energy Capacity Evolution in Switzerland (2000-2018)

Portugal

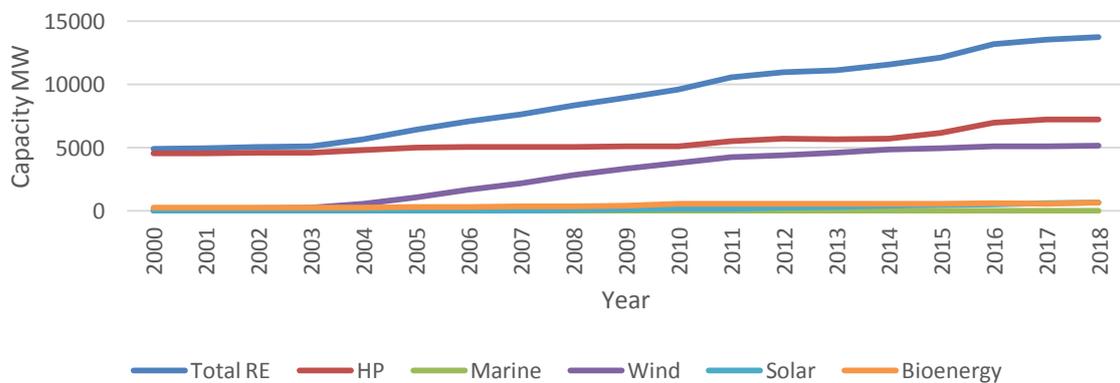


Figure 16. Renewable Energy Capacity Evolution in Portugal (2000-2018)

Portugal is the country with the least capacity of those analyzed. It only has an installed capacity of 13767 MW. However, it can be observed that wind energy began to increase notably as of 2004, becoming the RE with the highest increase in this country during the period analyzed (Figure 16). Despite this, hydropower energy is what we can consider as a benchmark in the country, since it is the one with the highest installed capacity and has experienced a slight continued increase over time. This increase is due to the investment that the Iberdrola company is making in the north of the Iberian Peninsula²⁸, with the aim of being a benchmark in hydropower generation worldwide and, therefore, within European.

V. Discussion and Conclusions

As it is indicated before in the article, the use of traditional sources of energy in 2018 holds the first three positions: oil, coal and natural gas. Due to the growth in the energy demand that occurs each year, it is necessary to look for solutions to the problem of energy supply with the least possible impact on the environment. This competition is not only environmental, it is also economic as it seeks profitability in the types of energy sources proposed to replace traditional sources that harm the environment.

The aim of this article is to analyze the evolution of RE sources in Europe over a period of time between 2000 and 2018, so that it can be shown graphically and visually the data analysis over the involvement of these countries in the energy transition towards a horizon of less polluting energy. For that purpose, data have been collected on the installed capacity in each European country for the generation of electricity, which is the main indicator of the use of RE as primary energy.

Worldwide level, Europe has a growth of 281.74% in this period, materializing in an increase of 346672 MW of installed capacity of RE. Among the different types RE sources, the largest increases are produced in

wind energy and solar energy, with 48.65% of the total corresponding to wind energy and 35% to solar energy. Of the total of European countries, 10 of them concentrate 80% of the installed renewable capacity, and five of these ten, concentrate 73.32%. It is evident that with these data there is significant inequality when analyzing the different territories, which depends on the orographic characteristics, their level of investment in these technologies and the political and economics factors of each country.

In the previous section, we have carried out an analysis of each of the ten countries with the highest RE capacity installed and used as a primary source. Available data show that Germany is the country with the highest capacity, with twice the capacity of the next country. Its growth is mainly due to solar and wind energy, which account for 41.93% and 49.07% respectively of the German total presented.

When the analysis takes into account the technology used, hydropower is the one with the highest installed power in most of these countries, reaching 85.75% in Switzerland and 95.98% in Norway, with Germany and the United Kingdom having the least installed hydraulic capacity (with a 4.68% and 4.94% respectively). Something important about this technology is that its growth in all countries during the period analyzed is minimal compared to other technologies, reaching a maximum of 4404 MW in Norway and a decrease of -75MW in Sweden.

Regarding marine energy, only France, United Kingdom and Spain use this technology during the period analyzed. France, with 218 MW and 89.71%, is the country with the highest capacity for this technology. However, taking into account the data in Table 2, this type of technology can be considered residual compared to the others.

On the other hand, wind energy is the energy that has experienced the highest growth in most of these countries. This source of energy is the second in terms of installed capacity in Europe and the first one in countries such as United Kingdom, Germany, and Spain, with 49.33%, 49.42% respectively and 48.50% respectively. Wind energy is the one with the highest growth in this period, so that in practically all countries the installed capacity of this technology is increasing linearly or exponentially, as shown in Table 2. The countries with the lowest installed wind capacity are Switzerland and Norway, with only 0.43% and 3.56% respectively, of their renewable capacity.

Solar energy consumed as primary energy is a well-known energy that has grown in parallel with wind energy, but with a less installed capacity in most cases. This technology represents 22.61% of the total RE capacity installed in Europe. Among the countries analyzed, those that are benchmarks in terms of their capacity are Germany and Italy, with 37.87% and 37.84% respectively on their total renewable capacity. On the other hand, Sweden and Norway are the countries with the least capacity with 1.68% and 0.20% respectively. However, it is necessary to mention that this technology is the one that has grown the most in percentage from 2000 to 2018, so, if we analyze the data in Table 2, the difference reaches 121,334 MW. If we take into account that the capacity in 2000 was 199 MW, the growth in percentage reaches 61041.09%.

Finally, bioenergy produced from biodiesel and urban solid waste, among others, is an energy source that only represents 7.41% of the renewable capacity in Europe, being a technology with a relevant presence in Sweden and the United Kingdom, with 17.17% and 15.81 % respectively. Regarding its growth, it is Germany and the United Kingdom where it is higher, with an increase in the analyzed period of 8885 MW and 6270 MW respectively, and a more significant value in percentage of 1259.10% and 1004.81% respectively.

Taking this analysis into account, we can conclude that in Europe as a whole investment in RE is an asset that is growing day after day. There are five countries that have the highest installed capacity for use as primary energy, so that they account for 58.67% of the European total. These countries have the necessary infrastructure and the ideal orography for their deployment. We must take into account that for there to be profitability and performance in the deployment of this type of technology, the orography and characteristics of the wind and solar map of a territory must be favorable and a prior analysis is required to support it. Now, based on the analyzed data, we see that Europe is a power in renewable capacity, only surpassed by Asia (China), and that is why it is heading towards the energy transition in a decisive way.

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