

Renewable and Alternative Energies

Topic 0. Introduction to renewable energies



Pablo Castro Alonso

Department of Electrical and Energy Engineering

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Contents:

- **Topic 0.** Introduction to Renewable Energies.
- **Topic 1.** Wind energy.
- **Topic 2.** Solar energy.
- **Topic 3.** Ocean energy.
- **Topic 4.** Hydropower.
- **Topic 5.** Geothermal energy.
- **Topic 6.** Biomass and biofuels.
- **Topic VII.** Hydrogen energy.



Required prior knowledge:

Thermodynamics and Fluid Mechanics.

Objectives of the course:

- To obtain a quantitative view of the use of different energy sources at a national and international level.
- To learn about the different sources of renewable and alternative energy used today and others that can be used in the near future.
- To become familiar with national and international regulations governing the use of renewable energy.
- To design facilities to obtain work and energy using renewable sources.

Structure:

Class hours

Theory	30
Exercises	20
Laboratory	10
Subtotal of class hours	<u>60</u>

Follow-up activities

Tutorials	5
Assessment	10
Subtotal of follow-up activities	<u>15</u>

Out-of-class activities

Group work	15
Individual work	60
Subtotal of out-of-class activities	<u>75</u>

TOTAL HOURS	<u>150</u>
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Assessment:

Laboratory report

Percentage: 20%.

Date: during the semester.

Comments: to pass the subject, students must attend laboratory practical classes and submit the laboratory report before the last day of class for the subject.

Classwork

Percentage: 20%.

Date: during the semester.

Comments: several exercises and tasks in the classroom as well as oral presentations.

Assessment:

1st Midterm exam

Percentage: 30 %

Minimum mark: 3

Date: halfway through the semester.

Retake conditions: to take an exam covering the same contents in the February or September sitting.

2nd Midterm exam

Percentage: 30 %

Minimum mark: 3

Date: February sitting, see official calendar.

Retake conditions: to take an exam covering the same contents in the September sitting.

Assessment:

General comments

To pass the subject through continuous assessment, it is necessary to:

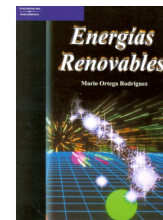
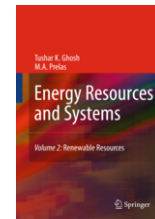
- Submit the laboratory report.
- Attend 80% of class activities.
- Obtain higher than 30% of the maximum mark in the midterm exams.
- Obtain a final average mark which is at least 50% of the maximum mark.

Comments for part-time students

Part-time students must take an exam covering all the subject's contents in the February or September sitting.

Readings:

- Twidell, John & Weir, Tony (2006): «*Renewable energy resources*». Taylor & Francis.
- Tushar K. Ghosh & Mark A. Prelas (2011): «*Energy resources and systems. Volume 2: Renewable resources*». Springer.
- Ortega Rodríguez, Mario (2007): «*Energías renovables*». Thomson Paraninfo.



Software:

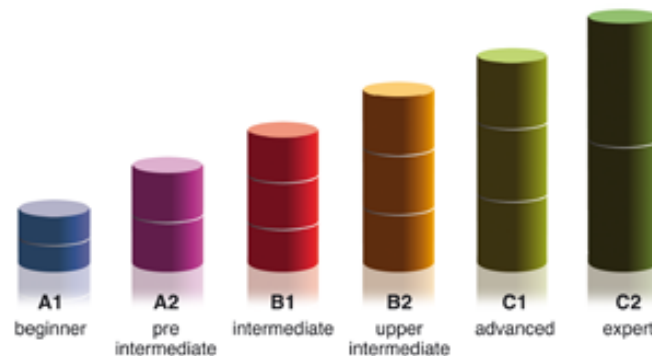
- System Advisor Model (SAM): <https://sam.nrel.gov/>
- ANSYS Academic Teaching CFD: www.ansys.com



Online contents:

- Moodle course: G605. Renewable and Alternative Energies:
<https://aulavirtual.unican.es/>.
- OpenCourseWare (OCW):
<http://ocw.unican.es/>.

Linguistic competence:



Why English?

UC requisite:

European English Level **B2** to obtain the degree for all students.

UC actions to achieve this:

Every degree will include a 6 Cr. English course in the first half of the degree.

Every student should attend **one subject of their degree taught in English** in the second half of it.

Complementary plans to reinforce English learning:

<http://web.unican.es/consejo-direccion/vcinternacionalizacion/area-de-capacitacion-linguistica>.

Reading check:

(From «*Sustainable energy - without the hot air*», David J.C. MacKay)

Why are we discussing energy policy?

Three different motivations drive today's energy discussions:

- First, fossil fuels are a finite resource. It seems possible that cheap oil (on which our cars and lorries run) and cheap gas (with which we heat many of our buildings) will run out in our lifetime. So we seek alternative energy sources. Indeed given that fossil fuels are a valuable resource, useful for manufacture of plastics and all sorts of other creative stuff, perhaps we should save them for better uses than simply setting fire to them.
- Second, we're interested in security of energy supply. Even if fossil fuels are still available somewhere in the world, perhaps we don't want to depend on them if that would make our economy vulnerable to the whims of untrustworthy foreigners.
- Third, it's very probable that using fossil fuels changes the climate. Climate change is blamed on several human activities, but the biggest contributor to climate change is the increase in greenhouse effect produced by carbon dioxide (CO₂). Most of the carbon dioxide emissions come from fossil-fuel burning. And the main reason we burn fossil fuels is for energy. So to fix climate change, we need to sort out a new way of getting energy. The climate problem is mostly an energy problem.
- Whichever of these three concerns motivates you, we need energy numbers, and policies that add up. The first two concerns are straightforward selfish motivations for drastically reducing fossil fuel use. The third concern, climate change, is a more altruistic motivation – the brunt of climate change will be borne not by us but by future generations over many hundreds of years.

Reading check:

(From «*Sustainable energy - without the hot air*», David J.C. MacKay)

- What are the three main motivations for energy discussions?
- Does the author say that oil and gas will run out soon?
- Does he suggest that we stop using fossil fuels?
- Why are we interested in security of energy supply? Why can it be vulnerable?
- Does the use of fossil fuels change the climate? How?
- Why is the climate problem an energy problem?
- How does the author divide these three concerns?
- What is the author's conclusion?

Basic definitions:

(Macmillan Encyclopedia of Energy)

- **Renewable energy:** energy that can be replenished on a time scale appropriate to human use.
- **Sustainable development:** development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland, 1987).
- **Resources:** a concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust in such form that economic extraction of a commodity is currently or potentially feasible.
- **Reserves:** that portion of the identified resource from which a usable mineral and energy commodity can be economically and legally extracted at the time of determination.

Basic definitions:

- **Primary energy:** energy form found in nature that has not been subjected to any conversion or transformation process. It is energy contained in raw fuels, and other forms of energy received as input to a system. Primary energy can be non-renewable or renewable.
- **Final energy:** form of energy available to the user following the conversion from primary energy.

Some numbers:

Earth's energy:

There are five ultimate primary sources of useful energy:

1. The Sun. **173,000,000,000,000,000 W = 173,000 TW**
2. The motion and gravitational potential of the Sun, Moon and Earth. **3 TW**
3. Geothermal energy from cooling, chemical reactions and radioactive decay in the Earth. **32.3 TW**
4. Human-induced nuclear reactions.
5. Chemical reactions from mineral sources.



In English:
1 billion = 1000 million

Solar radiation 173,000 TW	Direct reflection	52,000 TW (30%)	Short-wave radiation
	Direct conversion to heat	78,000 TW (45%)	
	Evaporation of water	39,000 TW (22%)	
	Wind & waves	3,600 TW (2%)	
	Photosynthesis	40 TW	Long-wave radiation
	Tides	3 TW	
	Geothermal	Volcanos & hot springs	
		0.3 TW	
		Rock conduction	32 TW

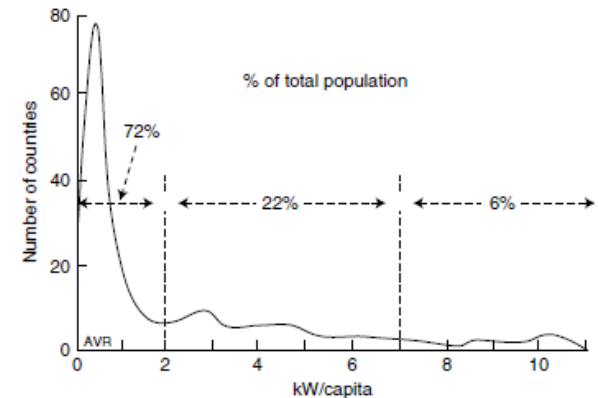
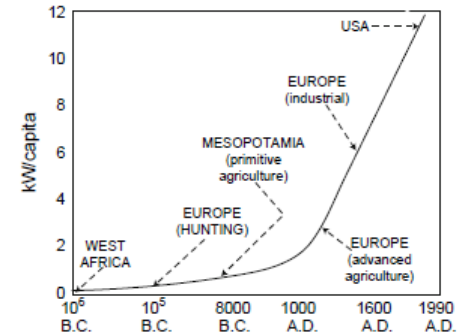
Renewable energy is continuously derived from sources **1, 2 and 3**.

Some numbers:

Energy utilization rate:

There are five ultimate primary sources of useful energy:

- **Early times:** human force 100 W.
- **4.000 B.C.:** animal power 800 W.
- **1.000 A.D.:** wind and water use 2.000 W.
- **XIX Century:** industrial revolution 10.000 W.
- **Today:**
 - Irregular distribution of energy utilization rate throughout the world.
 - 72% of the world population uses less than 2 kW/ capita.
 - 6% of the population uses more than 7 kW/ capita.



Why use renewable energy?:

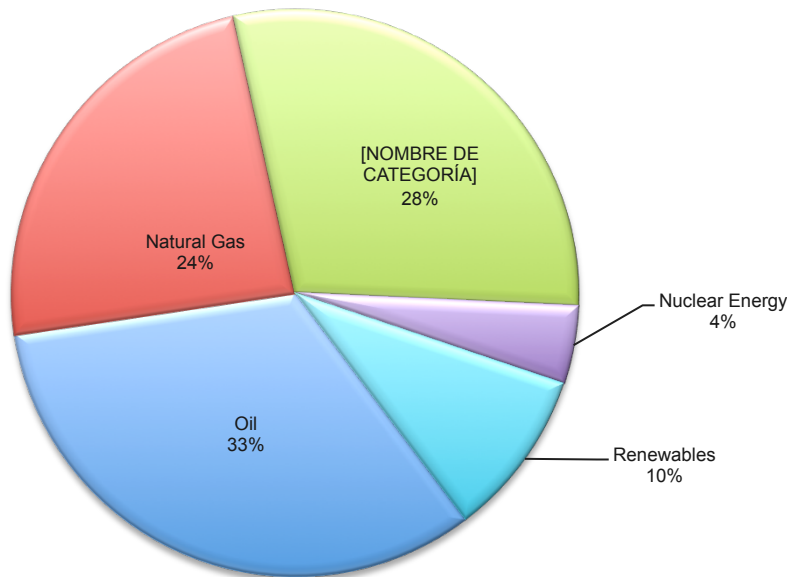
1. **Finite fossil fuel resources.** Cheap oil and gas will probably run out in our lifetime. Alternative energy sources must be found.
2. **Energy supply security.** To avoid dependence on energy sources from other countries.
3. **Climate change.** The biggest contributor to climate change is the increase in greenhouse effect produced by carbon dioxide (CO_2) which mainly comes from fossil-fuel burning for energy. The climate problem is mostly an energy problem.



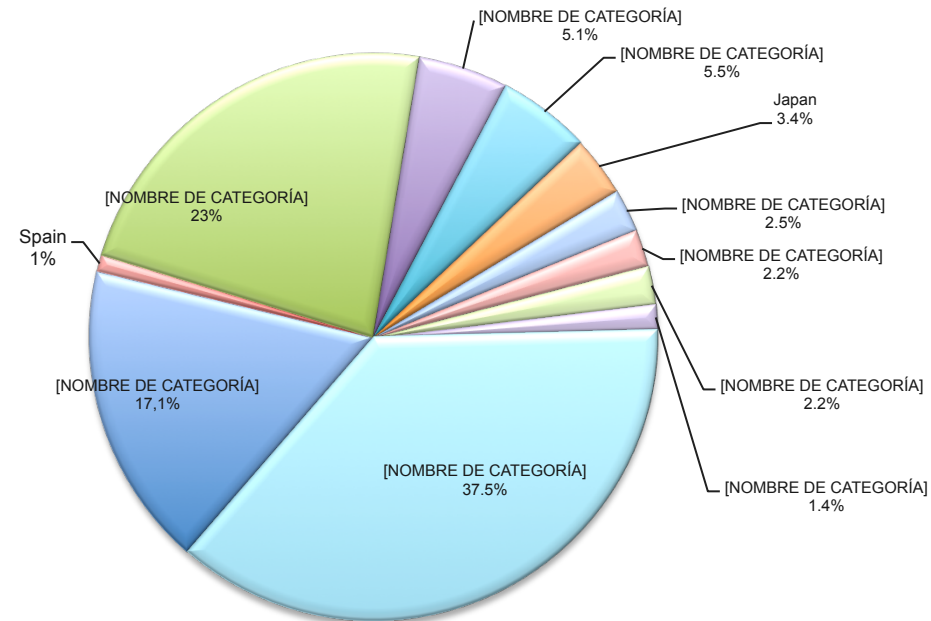
Current use of energy in the world (2016):

(BP Statistical Review of World Energy, June 2017)

2016 World Primary Energy* Consumption by fuel



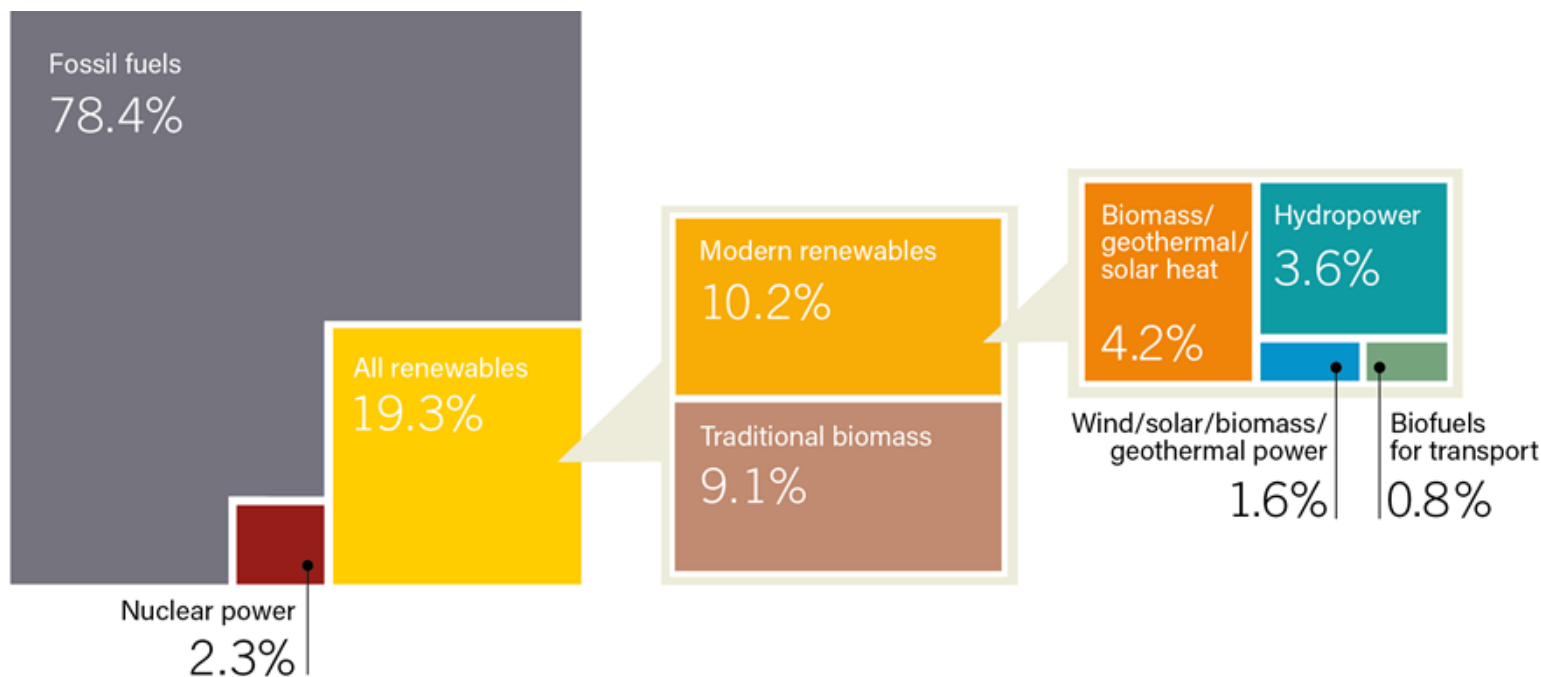
2016 World Primary Energy* Consumption by country



* Primary energy comprises commercially-traded fuels, including modern renewables used to generate electricity.

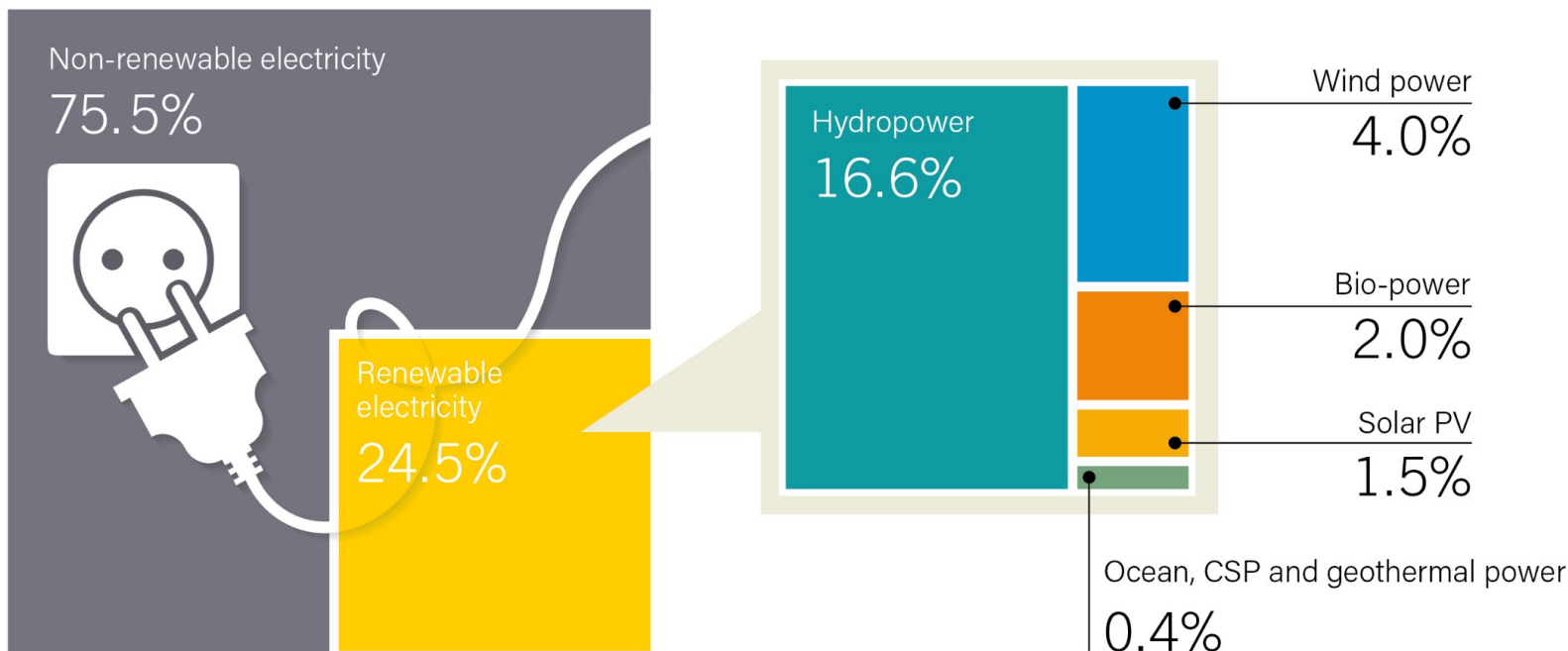
Estimated renewable energy share of global final energy consumption in the world (2015):

(Renewables 2017 Global Status Report;
Renewable Energy Policy Network REN21)













Estimated renewable energy share of global electricity production in the world (2016):

(Renewables 2017 Global Status Report;
Renewable Energy Policy Network REN21)



Renewable energy in the world*:

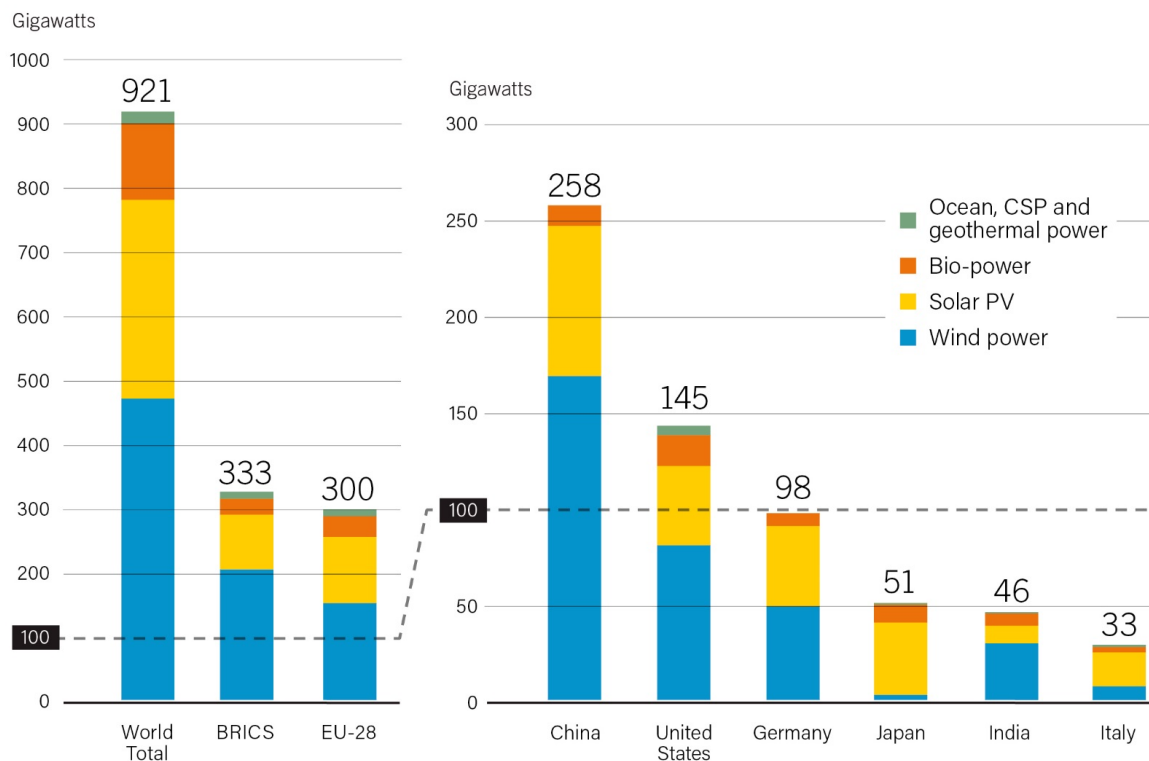
* Renewables 2017 Global Status Report.
Renewable Energy Policy Network REN21

		START 2004 ¹	2013	2014	2015	2016
INVESTMENT						
New investment (annual) in renewable power and fuels ²	billion USD	45	232	270	285.9	241.6
POWER						
Renewable power capacity (total, not including hydro)	GW	85	560	657	785	921
Renewable power capacity (total, including hydro)	GW	800	1,578	1,712	1,849	2,017
 Hydropower capacity (total) ³	GW	715	1,018	1,055	1,064	1,096
 Bio-power capacity	GW	<36	88	93	106	112
 Bio-power generation	TWh	227	396	433	464	504
 Geothermal power capacity	GW	8.9	12.1	12.8	13.2	13.5
 Solar PV capacity (total)	GW	2.6	138	177	227	303
 Concentrating solar thermal power (total)	GW	0.4	3.4	4.4	4.8	4.8
 Wind power capacity (total)	GW	48	319	370	433	487
HEAT						
 Solar hot water capacity (total) ⁴	GW _{th}	86	373	406	435	456
TRANSPORT						
 Ethanol production (annual)	billion litres	28.5	87.8	94	98.3	98.6
 Biodiesel production (annual)	billion litres	2.4	26.3	29.7	30.1	30.8

Renewable energy in the world*:

* Renewables 2017 Global Status Report.
Renewable Energy Policy Network REN21








Renewable Power Capacities in World, BRICS, EU-28 and Top 6 Countries, 2016



Note: Not including hydropower.

Renewable energy in the world*:

* Renewables 2015 Global Status Report.
Renewable Energy Policy Network REN21

	World	EU-28	BRICS	China	United States	Germany	Italy	Spain	Japan	India
TECHNOLOGY	GW			GW						
 Bio-power	93	36	29	10	16.1	8.8	4	1	4.7	5
 Geothermal power	12.8	1	0.1	~0	3.5	~0	0.9	0	0.5	0
 Hydropower	1,055	124	463	280	79	5.6	18	17.3	22	45
 Ocean power	0.5	0.2	~0	~0	~0	0	0	~0	0	0
 Solar PV	177	87	32	28	18	38	18.5	5.4	23	3.2
 Concentrating solar thermal power (CSP)	4.4	2.3	0.2	~0	1.6	0	~0	2.3	0	0.2
 Wind power	370	129	144	115	66	39	8.7	23	2.8	22
Total renewable power capacity (including hydropower)	1,712	380	668	433	185	92	50	49	54	76
Total renewable power capacity (not including hydropower)	657	255	206	153	105	86	32	32	31	31
Per capita capacity (Watts / inhabitant, not including hydropower)	90	500	70	110	330	1,070	530	680	250	20

* **BRICS:**

- Brazil.
- Russia.
- India.
- China.
- South Africa.

Electric power global capacity of Spain in 2014: 102,26 GW

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Renewable energy in the world*:

* Renewables 2017 Global Status Report.
Renewable Energy Policy Network REN21



Top Five Countries - Total Capacity or Generation as of End-2016

	1	2	3	4	5
POWER					
Renewable power (incl. hydro)	China	United States	Brazil	Germany	Canada
Renewable power (not incl. hydro)	China	United States	Germany	Japan	India
Renewable power capacity <i>per capita</i> (not including hydro)	Iceland	Denmark	Sweden/Germany		Spain/Finland
🔌 Bio-power generation	United States	China	Germany	Brazil	Japan
🔌 Geothermal power capacity	United States	Philippines	Indonesia	New Zealand	Mexico
💧 Hydropower capacity	China	Brazil	United States	Canada	Russian Federat.
💧 Hydropower generation	China	Brazil	Canada	United States	Russian Federat.
☀️ CSP capacity	Spain	United States	India	South Africa	Morocco
☀️ Solar PV capacity	China	Japan	Germany	United States	Italy
☀️ Solar PV capacity <i>per capita</i>	Germany	Japan	Italy	Belgium	Australia/Greece
💨 Wind power capacity	China	United States	Germany	India	Spain
💨 Wind power capacity <i>per capita</i>	Denmark	Sweden	Germany	Ireland	Portugal
HEAT					
☀️ Solar water heating collector capacity	China	United States	Turkey	Germany	Brazil
☀️ Solar water heating collector capacity <i>per capita</i>	Barbados	Austria	Cyprus	Israel	Greece
🔌 Geothermal heat capacity	China	Turkey	Japan	Iceland	India
🔌 Geothermal heat capacity <i>per capita</i>	Iceland	New Zealand	Hungary	Turkey	Japan

Renewable energy in the world*:

* **Renewables 2017 Global Status Report.**
Renewable Energy Policy Network REN21

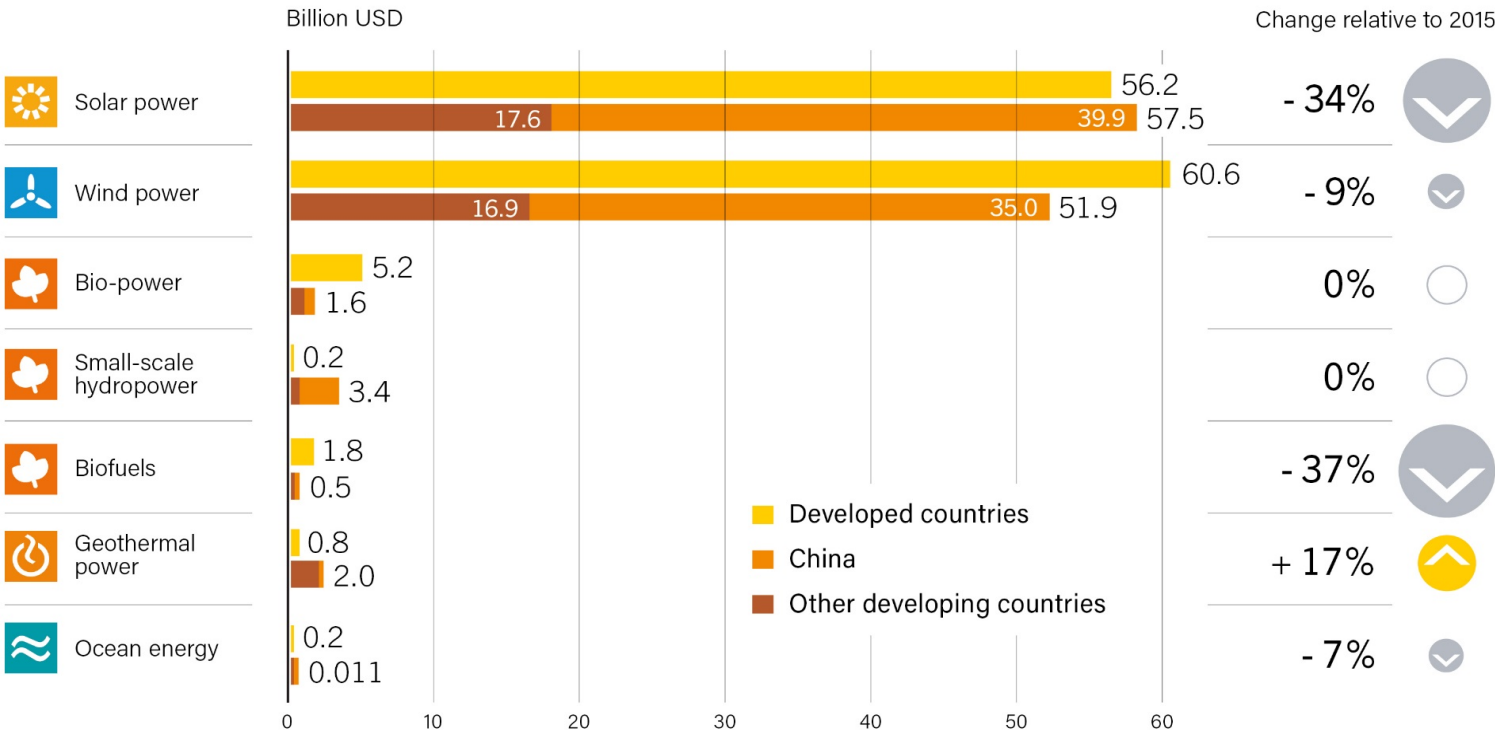
Top Five Countries - Annual Investment/ Net Capacity Additions/Production in 2016

	1	2	3	4	5
Investment in renewable power and fuels (not including hydro > 50 MW)	China	United States	United Kingdom	Japan	Germany
Investment in renewable power and fuels per unit GDP	Bolivia	Senegal	Jordan	Honduras	Iceland
 Geothermal power capacity	Indonesia	Turkey	Kenya	Mexico	Japan
 Hydropower capacity	China	Brazil	Ecuador	Ethiopia	Vietnam
 Solar PV capacity	China	United States	Japan	India	United Kingdom
 Concentrating solar thermal power (CSP) capacity	South Africa	China	—	—	—
 Wind power capacity	China	United States	Germany	India	Brazil
 Solar water heating capacity	China	Turkey	Brazil	India	United States
 Biodiesel production	United States	Brazil	Argentina/Germany/Indonesia		
 Fuel ethanol production	United States	Brazil	China	Canada	Thailand

Renewable energy in the world*:

* Renewables 2017 Global Status Report.
Renewable Energy Policy Network REN21

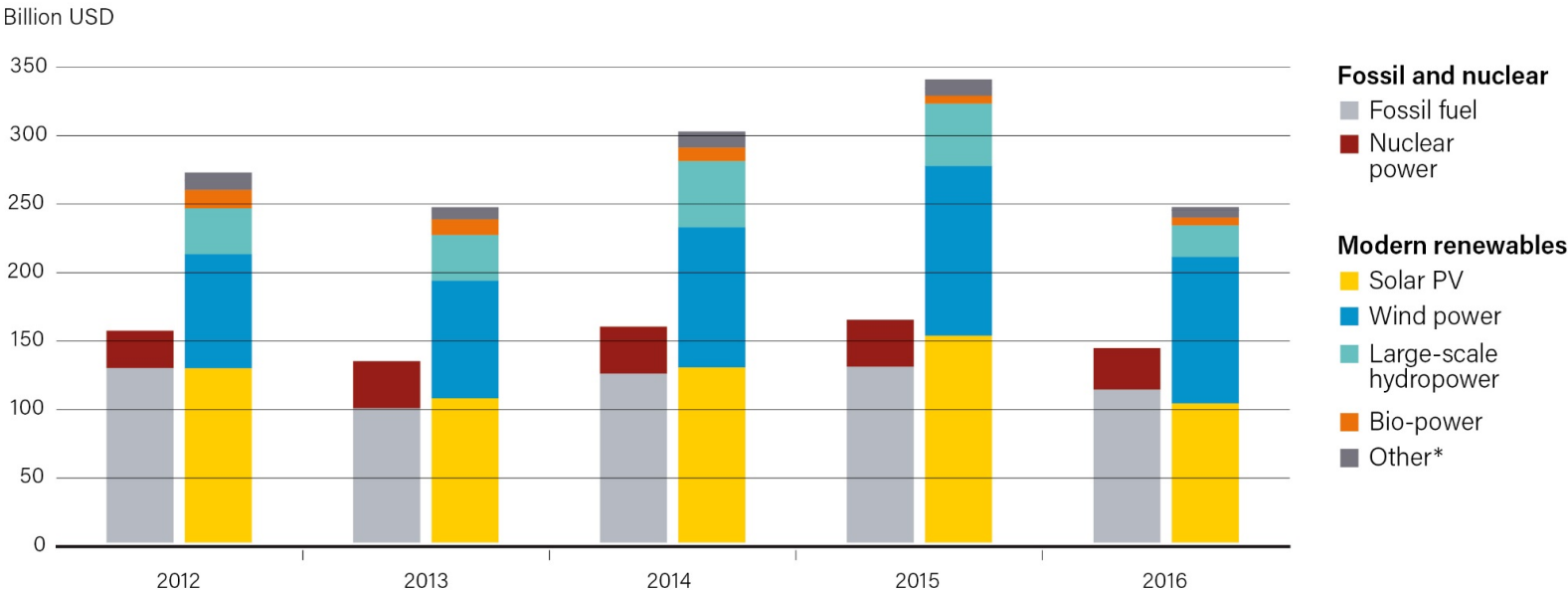
Global New Investment in Renewable Energy by Technology, Developed and Developing Countries, 2016



Renewable energy in the world*:

* Renewables 2017 Global Status Report.
Renewable Energy Policy Network REN21

Global Investment in Power Capacity, by Type (Renewable, Fossil Fuel and Nuclear Power), 2012-2016

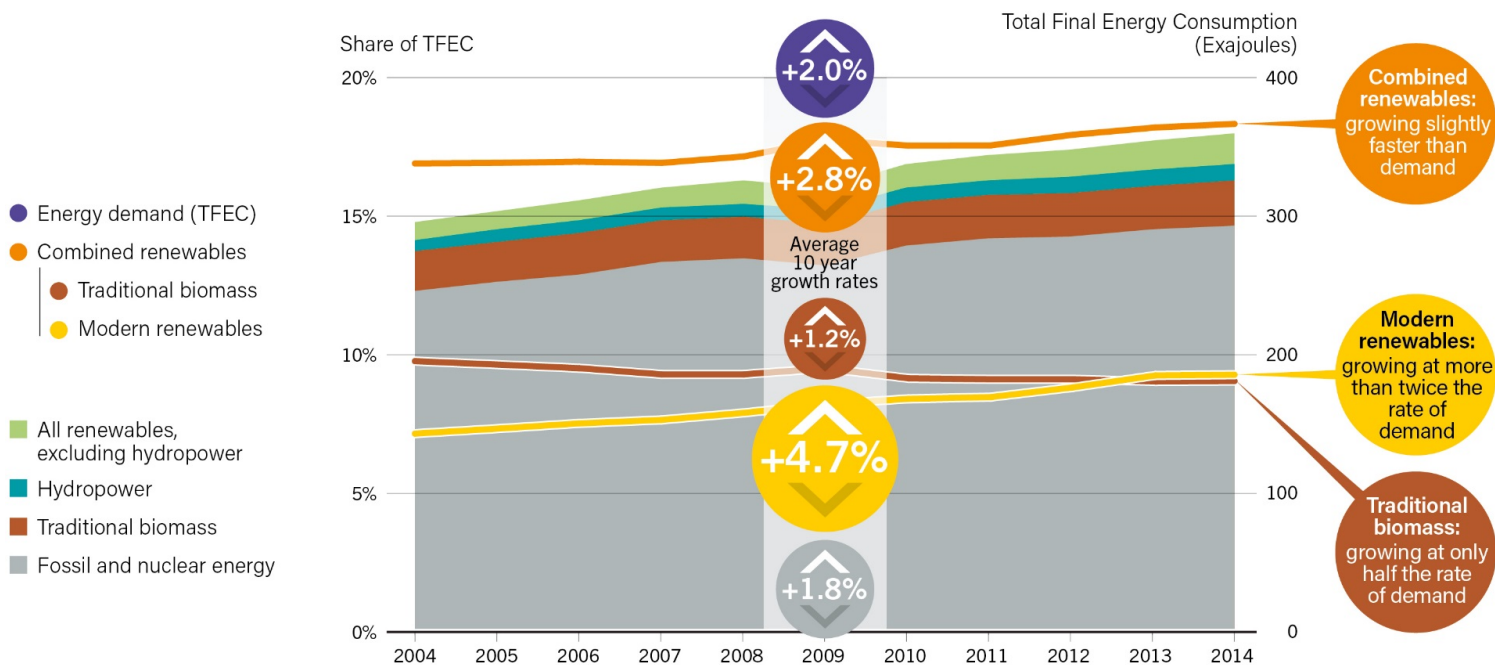


* CSP, geothermal, small-scale hydropower and ocean energy

Renewable energy in the world*:

* Renewables 2017 Global Status Report.
Renewable Energy Policy Network REN21

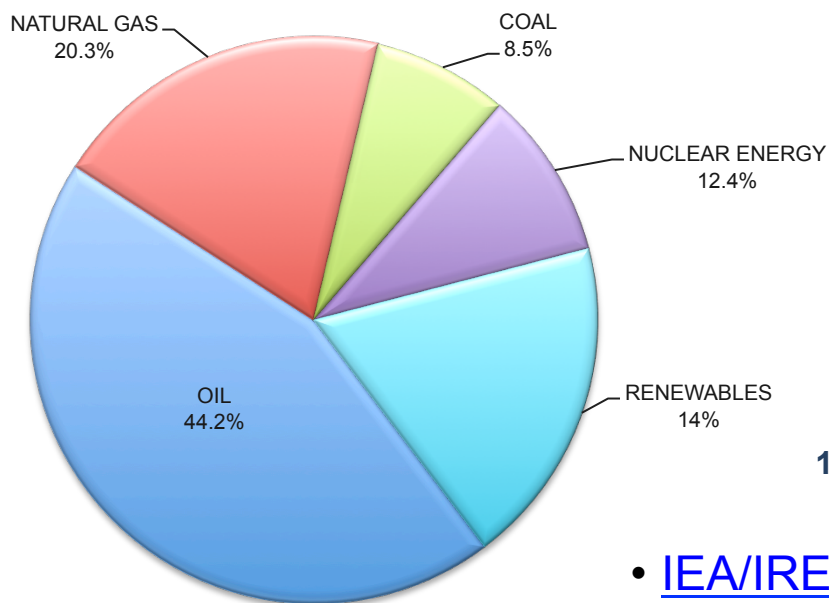
Growth in Global Renewable Energy Compared to Total Final Energy Consumption, 2004-2014



Current renewable energy contribution in Spain (2016):

Instituto para la Diversificación y Ahorro de la Energía (IDAE)
Ministerio de Industria, Energía y Turismo (July 2017)

2015 Spain Primary Energy Consumption



Source	Consumption (Mtoe)	%
Oil	54.63	44.2
Natural Gas	25.03	20.3
Coal	10.44	8.5
Nuclear Energy	15.26	12.4
Renewables	17.21	14
TOTAL	123	100

1 Tonne of Oil Equivalent (toe) = 41,868,000 KJ = 11.630 kWh

- [IEA/IRENA Joint Policies and Measures database](#)
- [Informe Estadístico Energías Renovables IDAE](#)



Current renewable energy contribution in Spain (2016):

Instituto para la Diversificación y Ahorro de la Energía (IDAE)
Ministerio de Industria, Energía y Turismo (July 2017)

69%
Electricity

25%
Heating and cooling

6%
Transport

2016 SPAIN PRIMARY RENEWABLE ENERGY CONSUMPTION	
ELECTRICITY	Consumption (ktoe)
Hydraulic	3,130
Biomass	1,174
Waste	243
Wind	4,205
Solar photovoltaic	693
Biogas	193
Solar thermoelectric	2,190
TOTAL ELECTRIC CONSUMPTION	11,827
HEATING AND COOLING	
Biomass and waste	4,011
Biogas	38
Low temperature solar	293
Geothermal	19
TOTAL HEATING CONSUMPTION	4,362
TRANSPORT	
Biofuels	1,023
TOTAL TRANSPORT CONSUMPTION	1,023
TOTAL PRIMARY RENEWABLE ENERGY CONSUMPTION	17,213
TOTAL PRIMARY ENERGY CONSUMPTION	123,485

Current renewable energy contribution in Spain (2016):

Instituto para la Diversificación y Ahorro de la Energía (IDAE)
Ministerio de Industria, Energía y Turismo (July 2017)

2016 SPAIN ACCUMULATED RENEWABLE ENERGY POWER INSTALLED (kW)

Region	Biogas	Biomass	Ocean energy	Wind	Hydraulic	Waste	S. Photovoltaic	S. Thermo electric	TOTAL
ANDALUCIA	24,005	269,170		3,332,914	1,196,212		922,872	997,330	6,742,769
ARAGON	14,416	23,550		1,893,233	1,562,638	49,900	174,641		3,718,692
CANARIAS	1,272			166,306	12,752		180,392		360,771
CANTABRIA	2,862			35,011	441,477	9,934	2,127		491,435
CASTILLA Y LEON	8,912	37,422		5,571,023	4,481,624		518,700		10,618,113
CASTILLA-LA MANCHA	9,257	50,802		3,785,020	833,324		984,986	349,400	6,012,839
CATALUÑA	50,370	4,490		1,213,986	2,347,656	48,249	275,969	22,500	3,963,310
MADRID	42,545			61	99,369	29,800	68,181		240,112
NAVARRA	10,717	38,484		1,010,522	234,144		164,226		1,458,329
VALENCIA	8,616	7,230		1,260,489	1,272,824		359,116	49,900	2,974,969
EXTREMADURA	800	36,300		15	2,224,102		587,658	849,100	3,697,985
GALICIA	11,664	38,008		3,335,065	3,258,493	50,000	17,355		6,710,745
ISLAS BALEARES	8,690			4,043		67,710	80,339		161,383
LA RIOJA	4,838			448,184	49,857		86,028		588,908
PAIS VASCO	11,888	86,940	296	153,564	169,818	26,000	26,941		475,508
ASTURIAS	9,388	77,977		518,481	742,392		1,020		1,349,291
REGION DE MURCIA	4,181	6,412		261,999	36,096		447,482	31,400	787,690

How to support renewable energy:

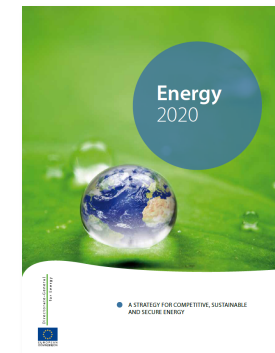
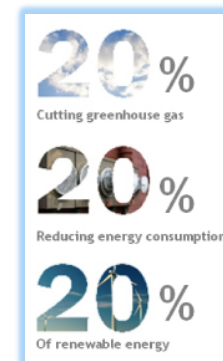
International and national policies:

- **2009/28/EC European Parliament Directive.**

DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 23 April 2009
on the promotion of the use of energy from renewable sources and amending and subsequently
repealing Directives 2001/77/EC and 2003/30/EC

- **Europe 2020 Initiative:**

- 20% greenhouse gases.
- 20% energy consumption.
- + 20% renewable energy.



- **Plan de Energías Renovables PER 2011-20.**



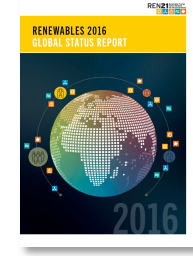
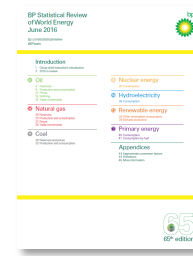
How to support renewable energy:

Research into the main renewable sources:

- International Renewable Energy Agency (IRENA): www.irena.org.
- National Renewable Energy Laboratory, USA (NREL): www.nrel.gov.
- Wind Energy: World Wind Energy Association: www.wwindea.org.
- Solar Energy: International Solar Energy Society (ISES): www.ises.org.
- Ocean Energy: European Ocean Energy Association: www.oceanenergy-europe.eu.
- Hydropower: International Hydropower Association: www.hydropower.org.
- Geothermal energy: International Geothermal Association (IGA): www.geothermal-energy.org.
- Biomass and Biofuels: The World Bioenergy Association (WBA): www.worldbioenergy.org.
European Biomass Association: www.aebiom.org.
- Hydrogen: International Association for Hydrogen Energy: www.iahe.org.

To get the Big Picture:

- BP Statistical Review of World Energy, June 2017.
- Renewables 2017 Global Status Report; Renewable Energy Policy Network REN21.
- Información básica de los sectores de la energía 2014. Comisión Nacional de Energía.
- La energía en España 2015. Ministerio de Industria, Energía y Turismo.
- Informe estadístico de energías renovables en España.
- www.informeestadistico.idae.es.



Current Spanish policies:

- Real Decreto 900/2015, de 9 de octubre, por el que se regulan las condiciones de suministro de energía eléctrica con autoconsumo y de producción con autoconsumo.
- Orden IET/1045/2014, de 16 de junio, por la que se aprueban los parámetros retributivos de las instalaciones tipo aplicables a determinadas instalaciones de producción de energía eléctrica a partir de fuentes de energía renovables, cogeneración y residuos (BOE 20/06/2014).
- Real Decreto 413/2014, de 6 de junio, por el que se regula la actividad de producción de energía eléctrica a partir de fuentes de energía renovables, cogeneración y residuos (BOE 10/06/2014).
- Ley 24/2013, de 26 de diciembre, del Sector Eléctrico (BOE 27/12/2013).

