

## PUBLIC POLICIES FOR ENERGY

# ELECTRIFYING THE ENERGY SUPPLY



**José P. Sucena Paiva**

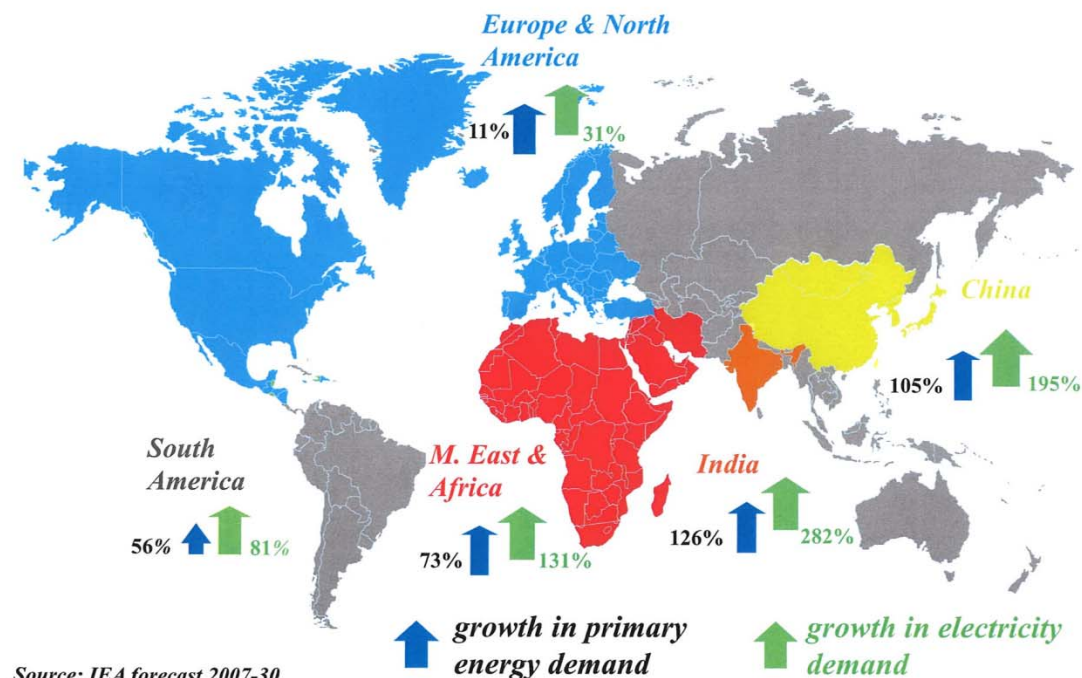
*Prof. Emeritus do IST*



# GROWTH IN PRIMARY ENERGY AND ELECTRICITY DEMAND, 2007-30

[Source: IEA, World Energy Outlook 2011]

## TODAY'S ENERGY CHALLENGE: GROWING DEMAND



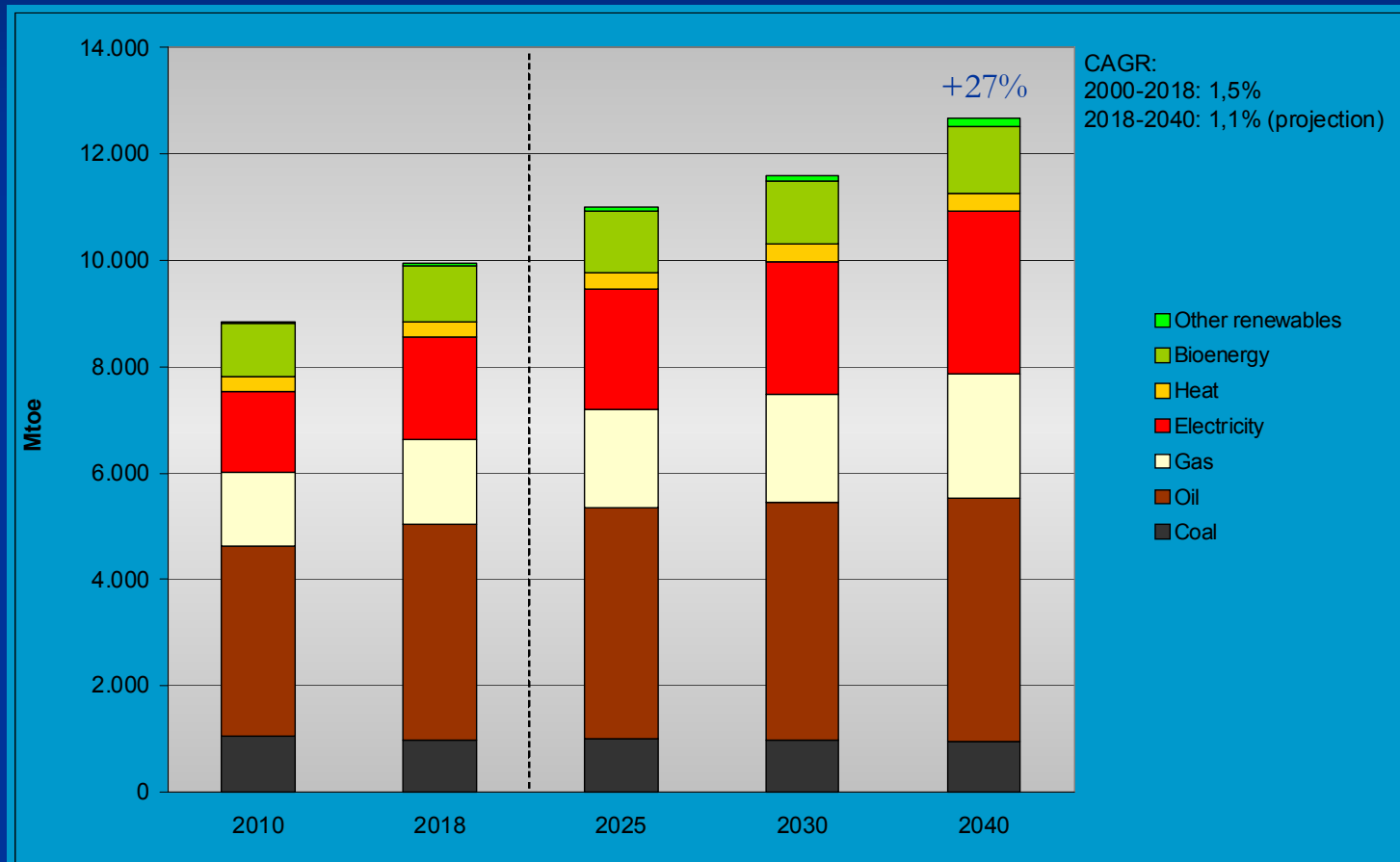
Source: IEA forecast 2007-30

# ELECTRIC ENERGY

- 20-25% of final energy demand
- 40% of primary energy demand
- 40% of total CO<sub>2</sub> emissions

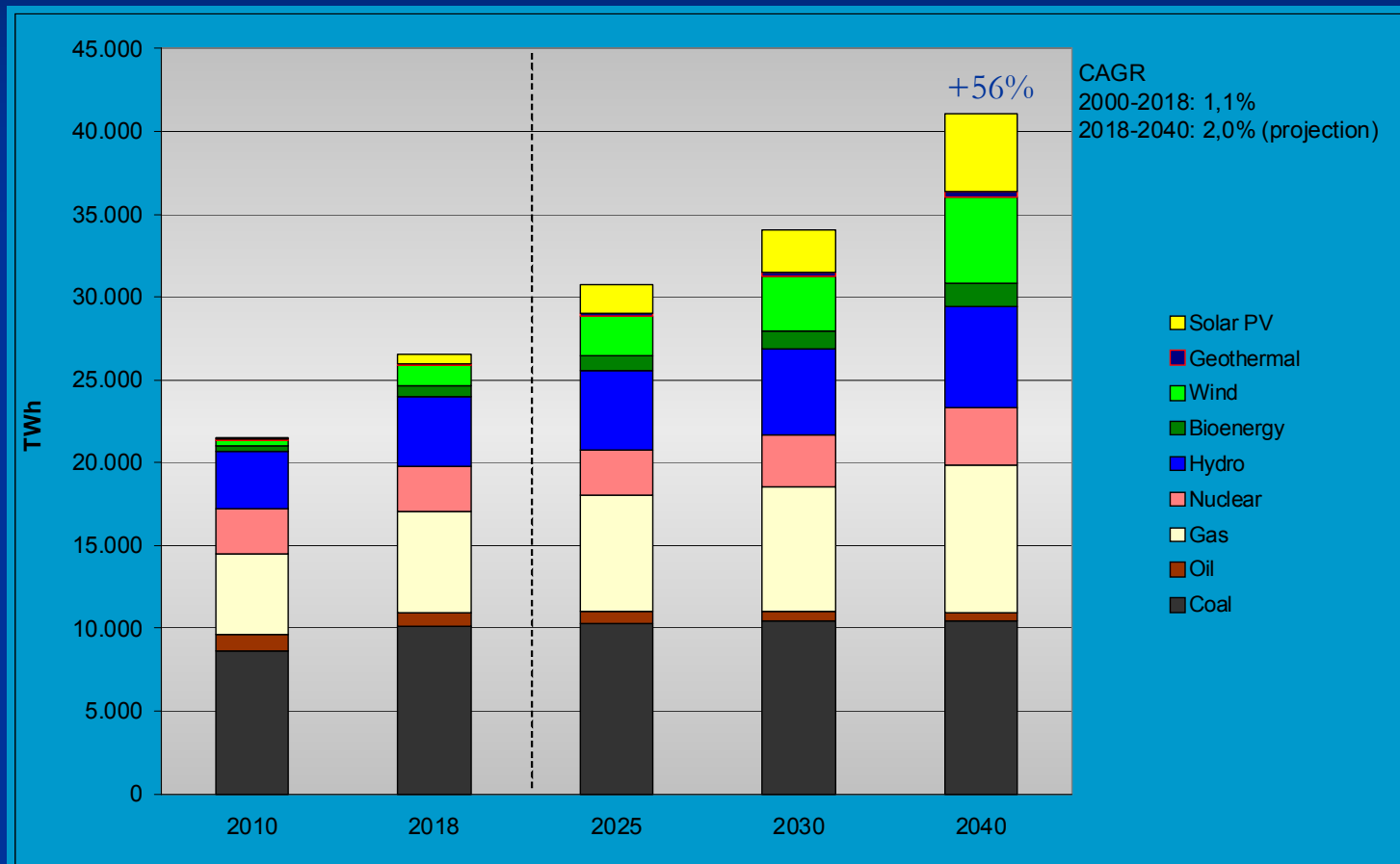
# TOTAL FINAL CONSUMPTION, WORLD, 2010-2040 (Mtep)

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]



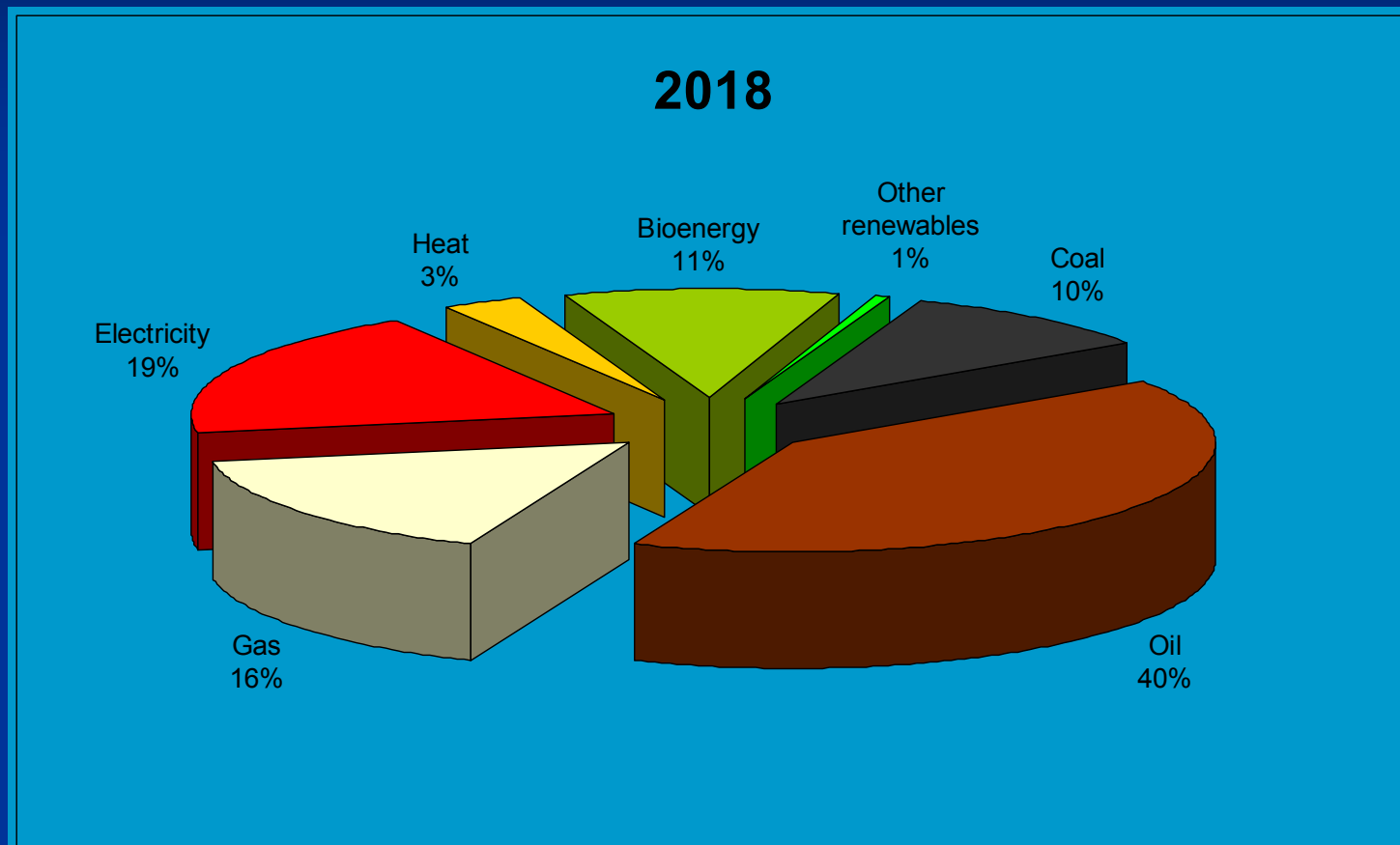
# ELECTRIC ENERGY GENERATION WORLD, 2010-2040 (TWh)

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]



# WORLD TOTAL FINAL CONSUMPTION, 2018

[Source: IEA World Energy Outlook 2019, Stated Policies Scenario]

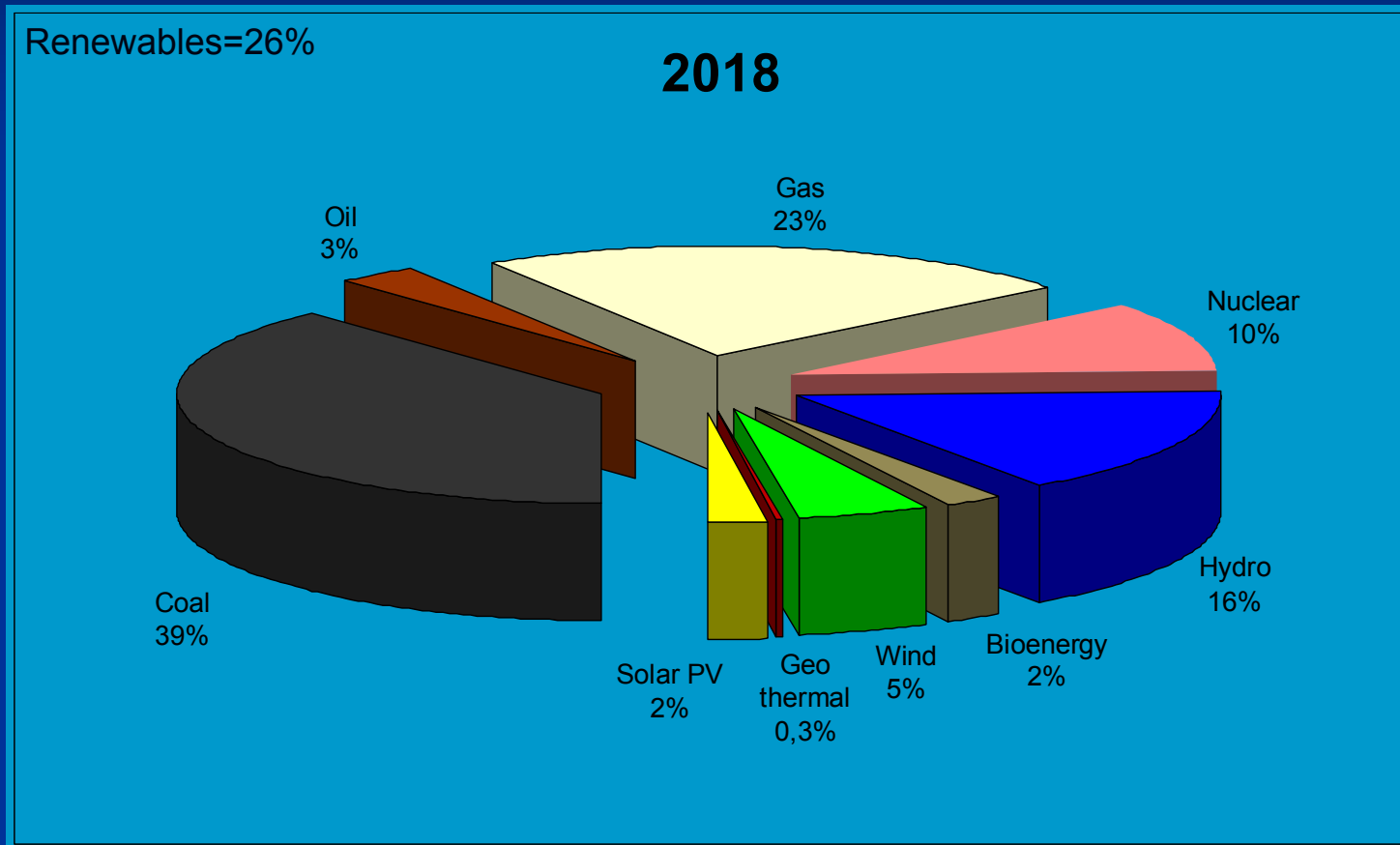


Average power: 13 TW

Average power per capita: 1,9 kW

# ELECTRIC ENERGY GENERATION WORLD, 2018

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]

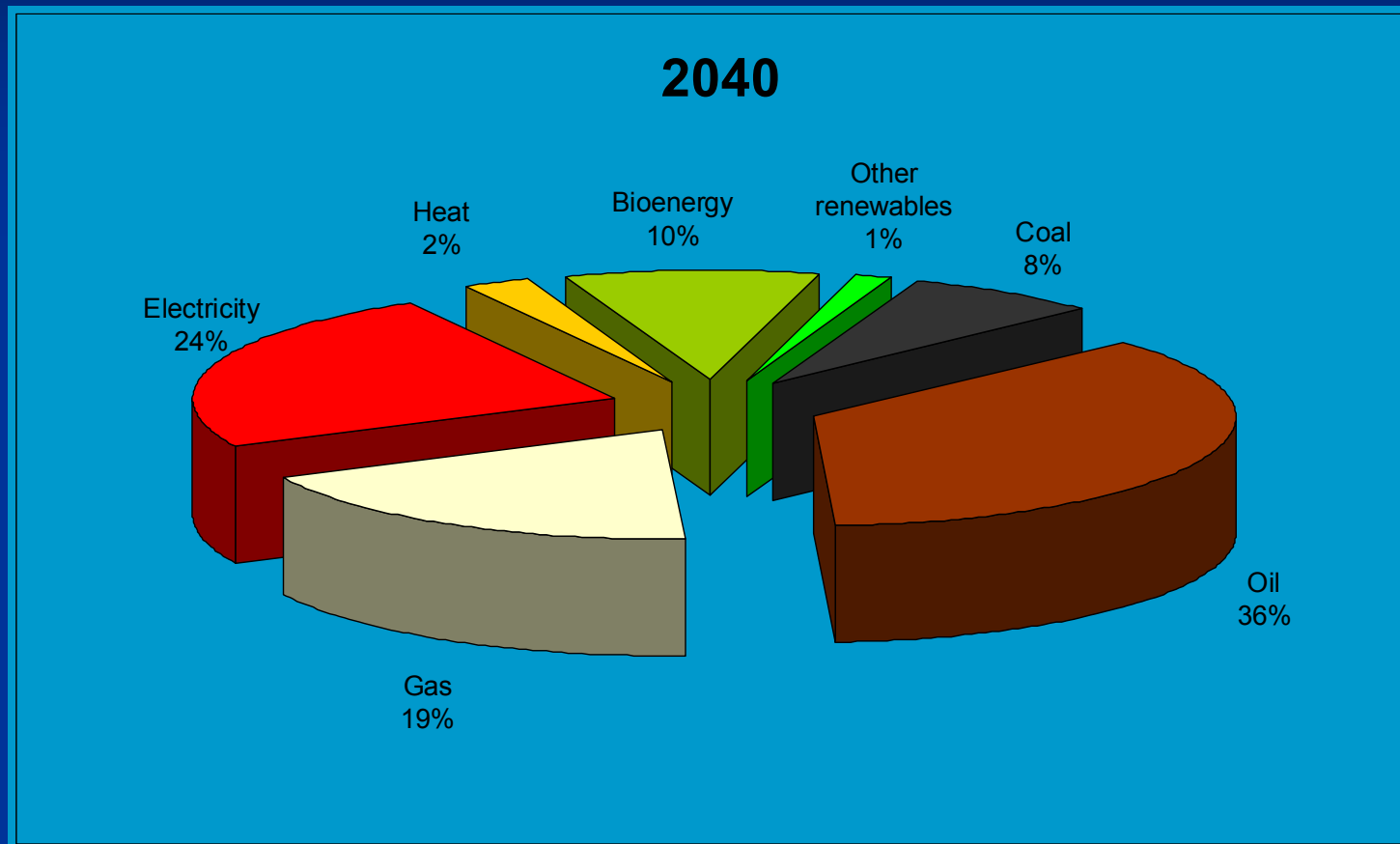


Average power:3,0 TW

Average power per capita: 0,40 kW

# WORLD TOTAL FINAL CONSUMPTION, 2040

[Source: IEA World Energy Outlook 2019, Stated Policies Scenario]



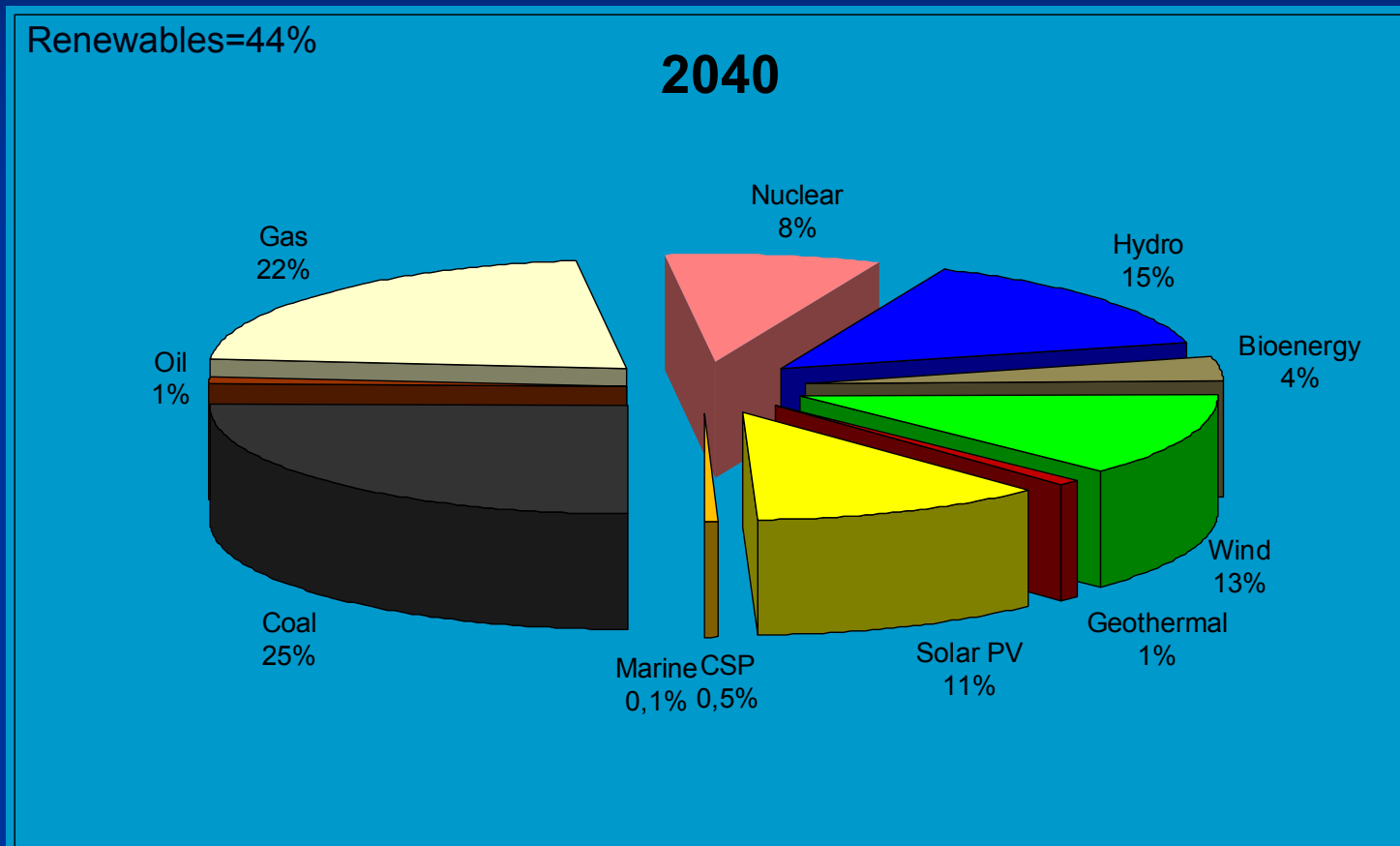
Average power: 17 TW

Average power per capita: 2,4 kW



# ELECTRIC ENERGY GENERATION WORLD, 2040

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]

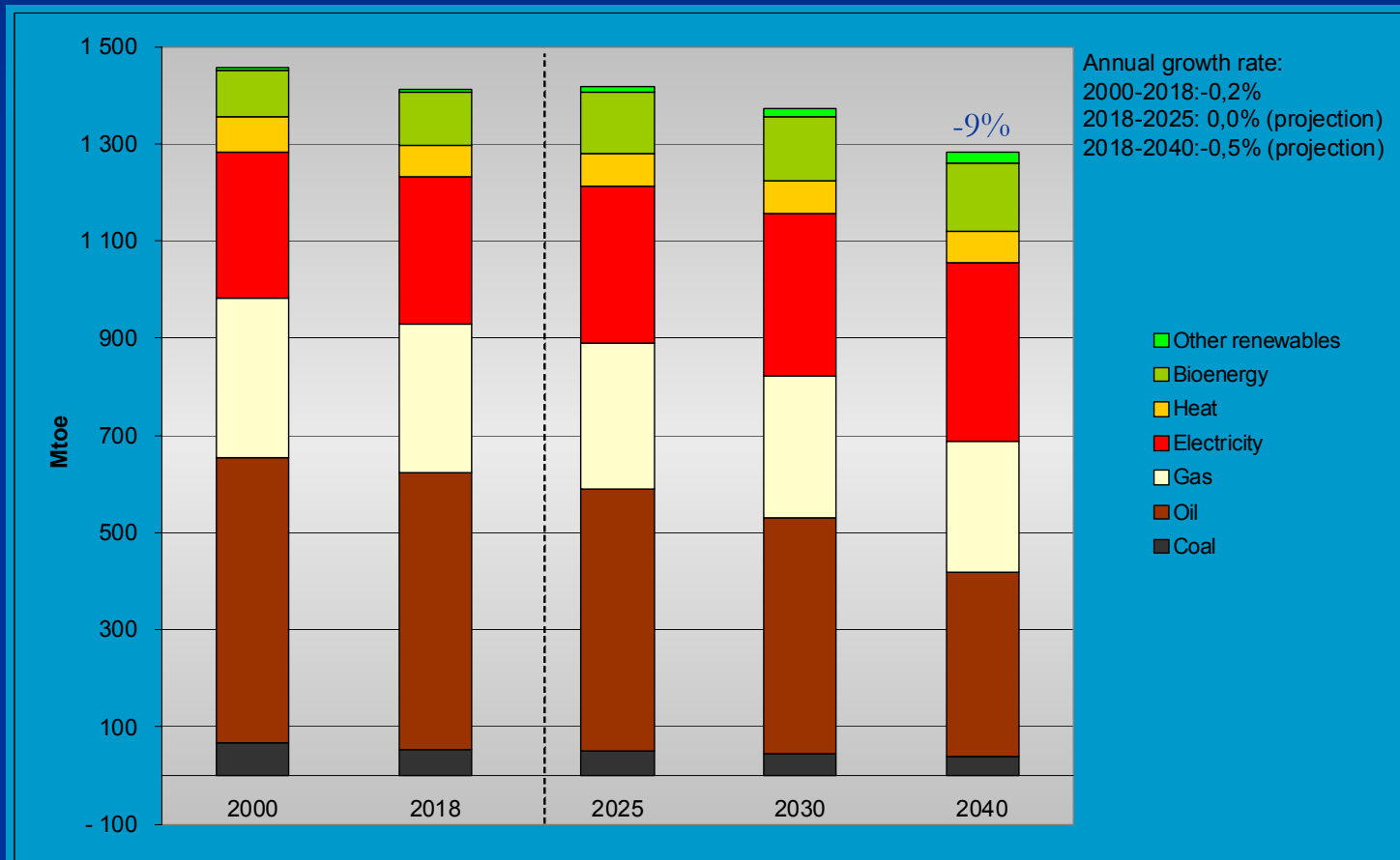


Average power: 4,7 TW

Average power per capita: 0,56 kW

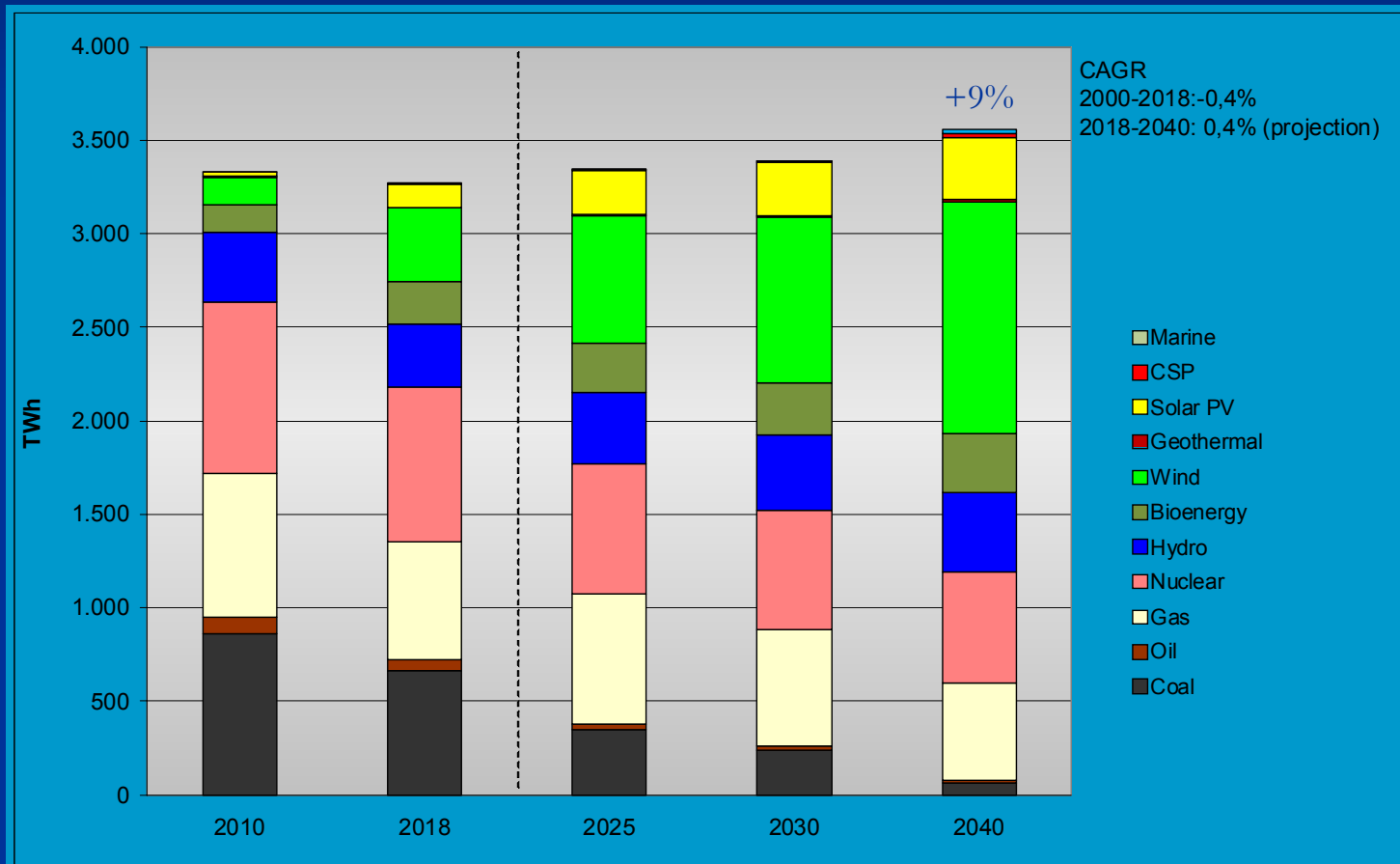
# EU TOTAL FINAL CONSUMPTION, 2000-2040

[Source: IEA World Energy Outlook 2019, Stated Policies Scenario]



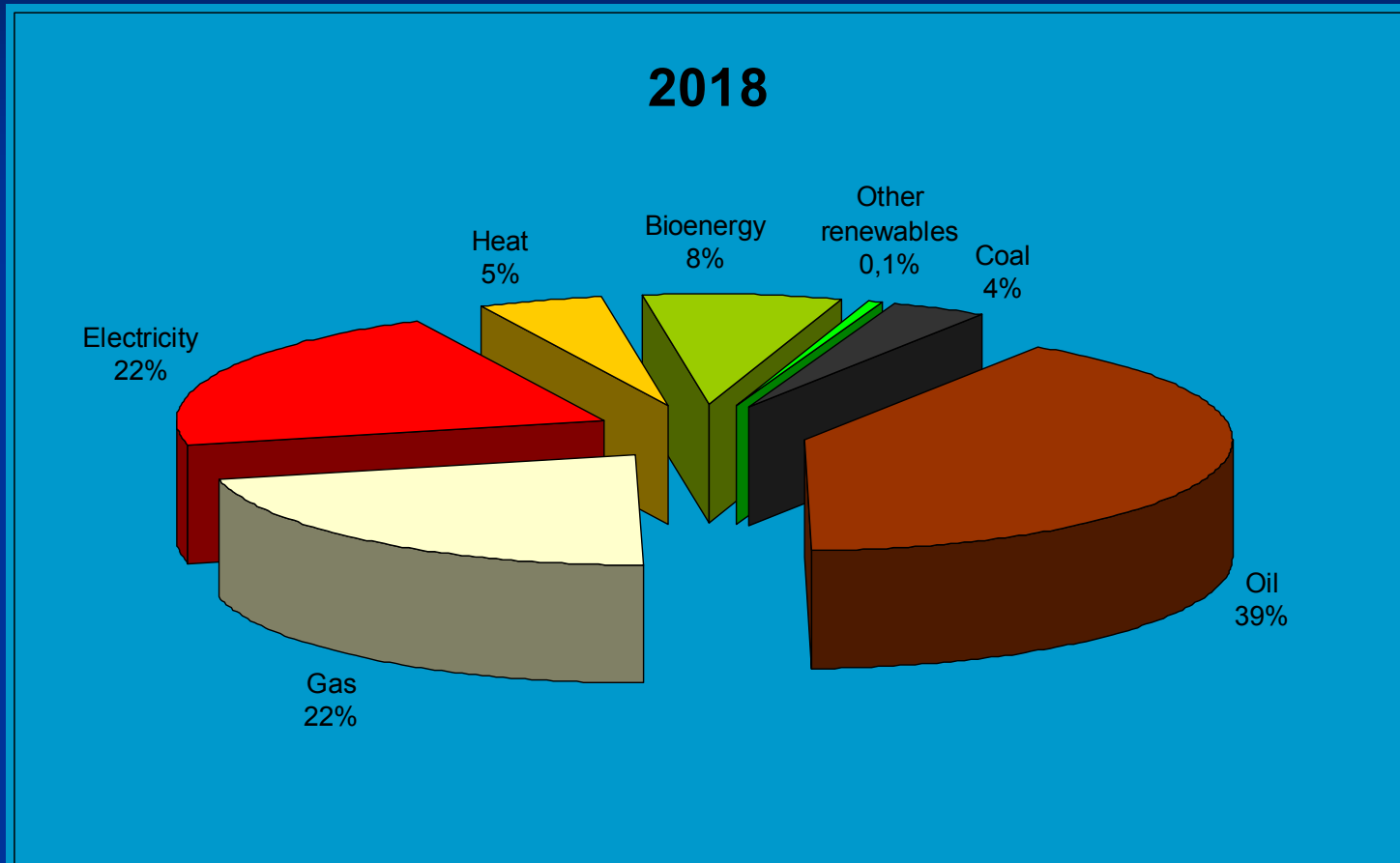
# EU ELECTRIC ENERGY GENERATION 2010-2040

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]



# EU FINAL ENERGY CONSUMPTION, 2018

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]

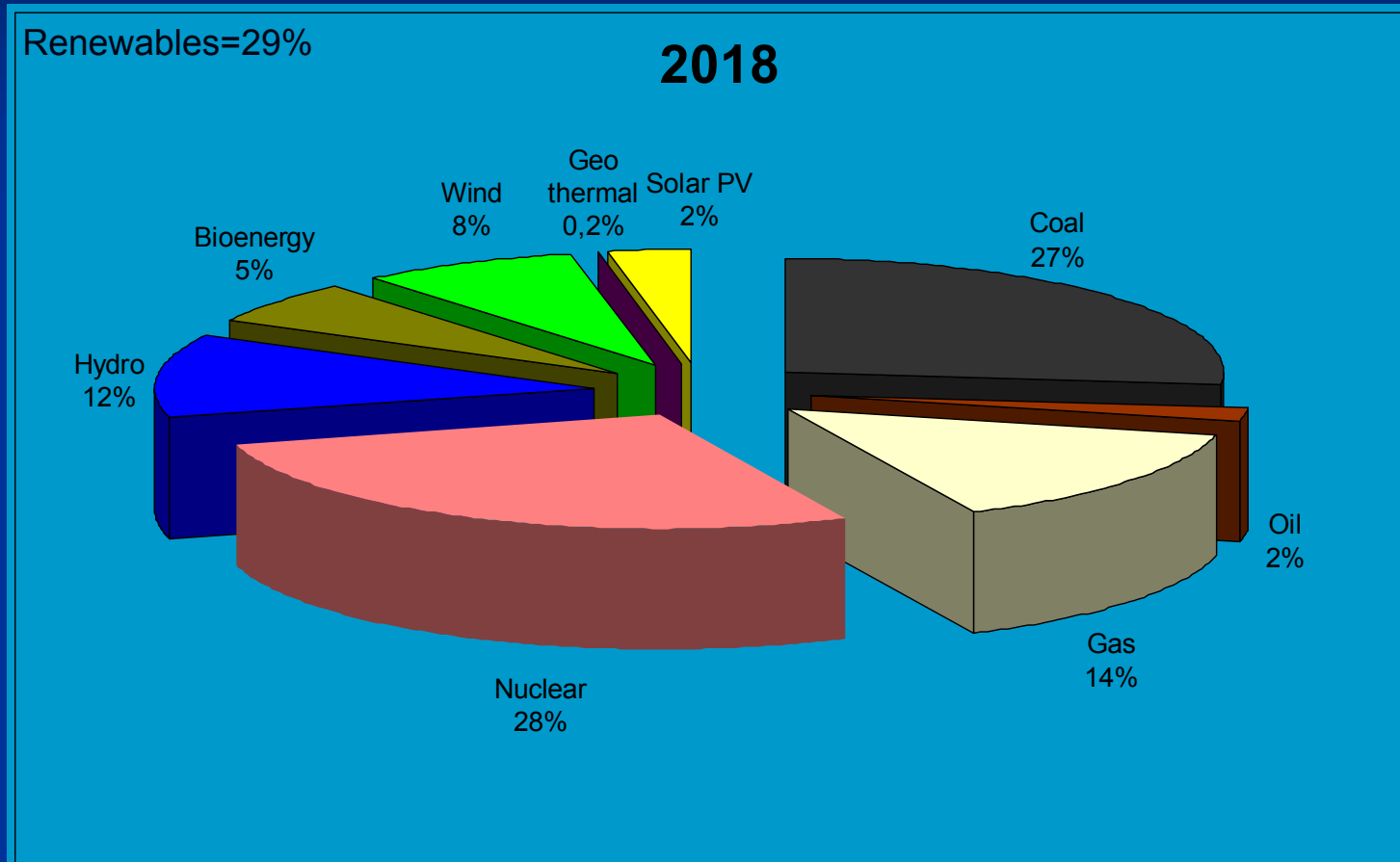


Average power 2018: 1,9 TW

Average power per capita: 3,7 kW

# EU ELECTRIC ENERGY GENERATION, 2018

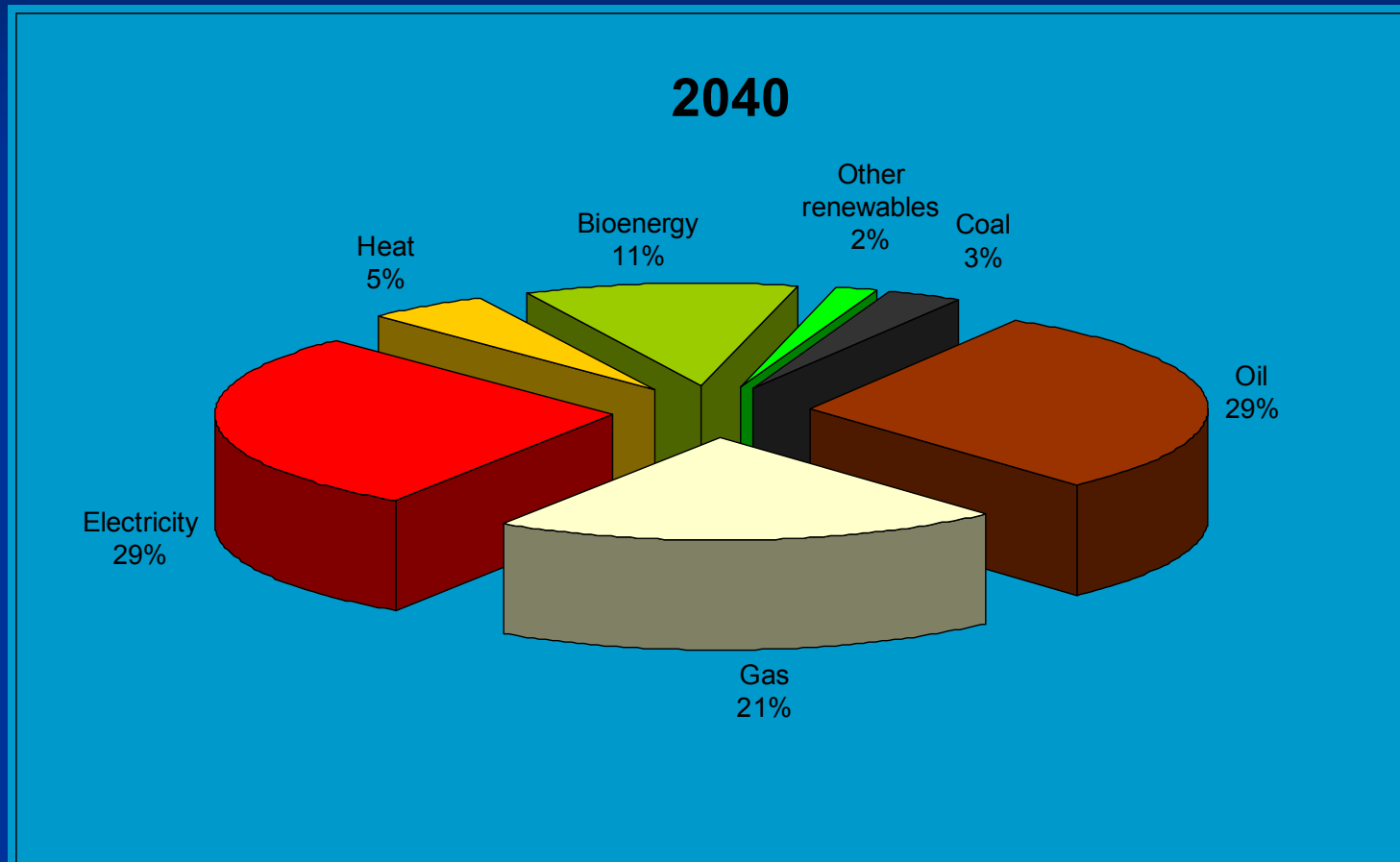
[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]



Average Power: 374 GW  
Average Power per capita: 0,75 kW

# EU FINAL ENERGY CONSUMPTION, 2040

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]

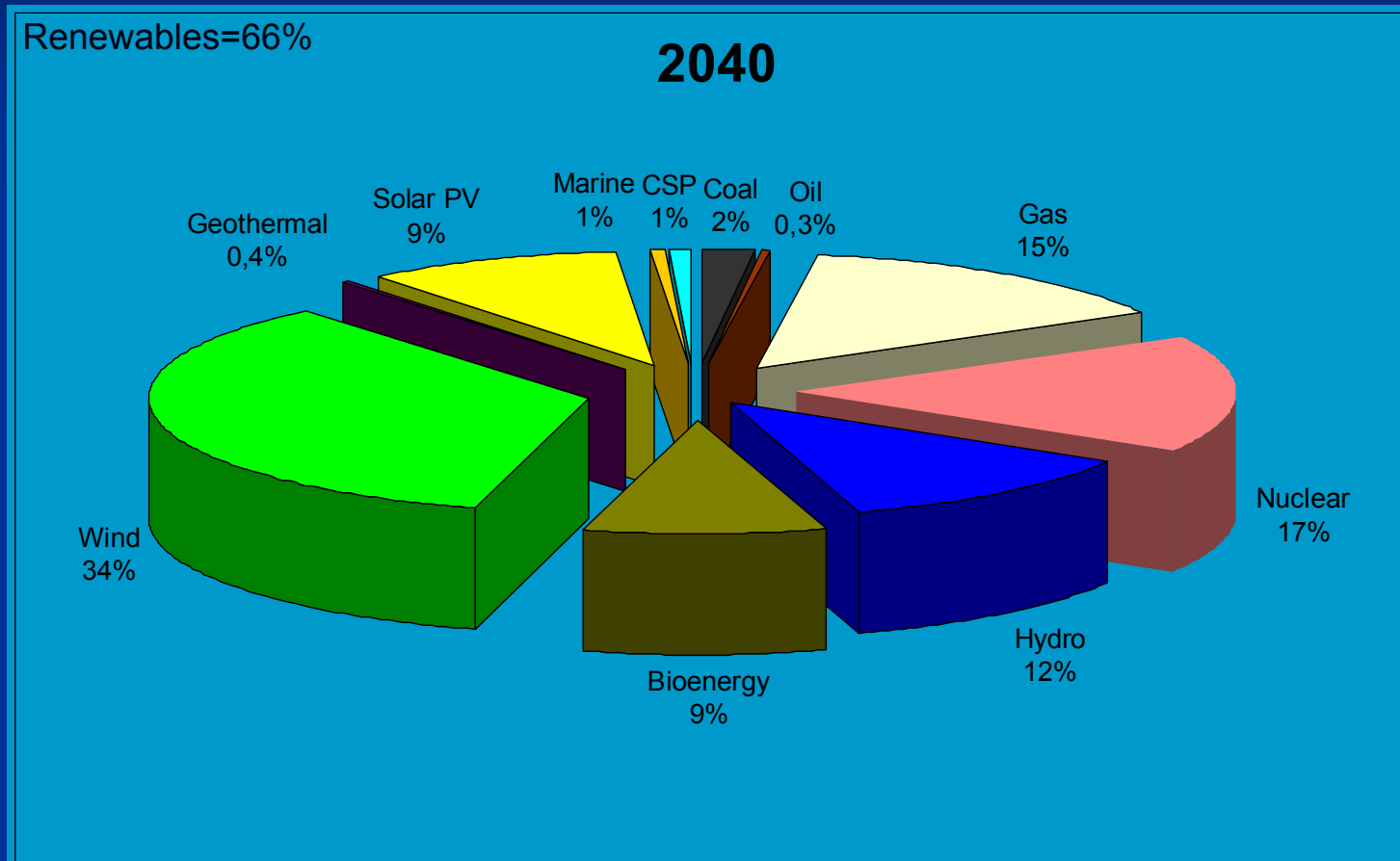


Average power 2040: 1,7 TW

Average power per capita: 3,4 kW

# EU ELECTRIC ENERGY GENERATION, 2040

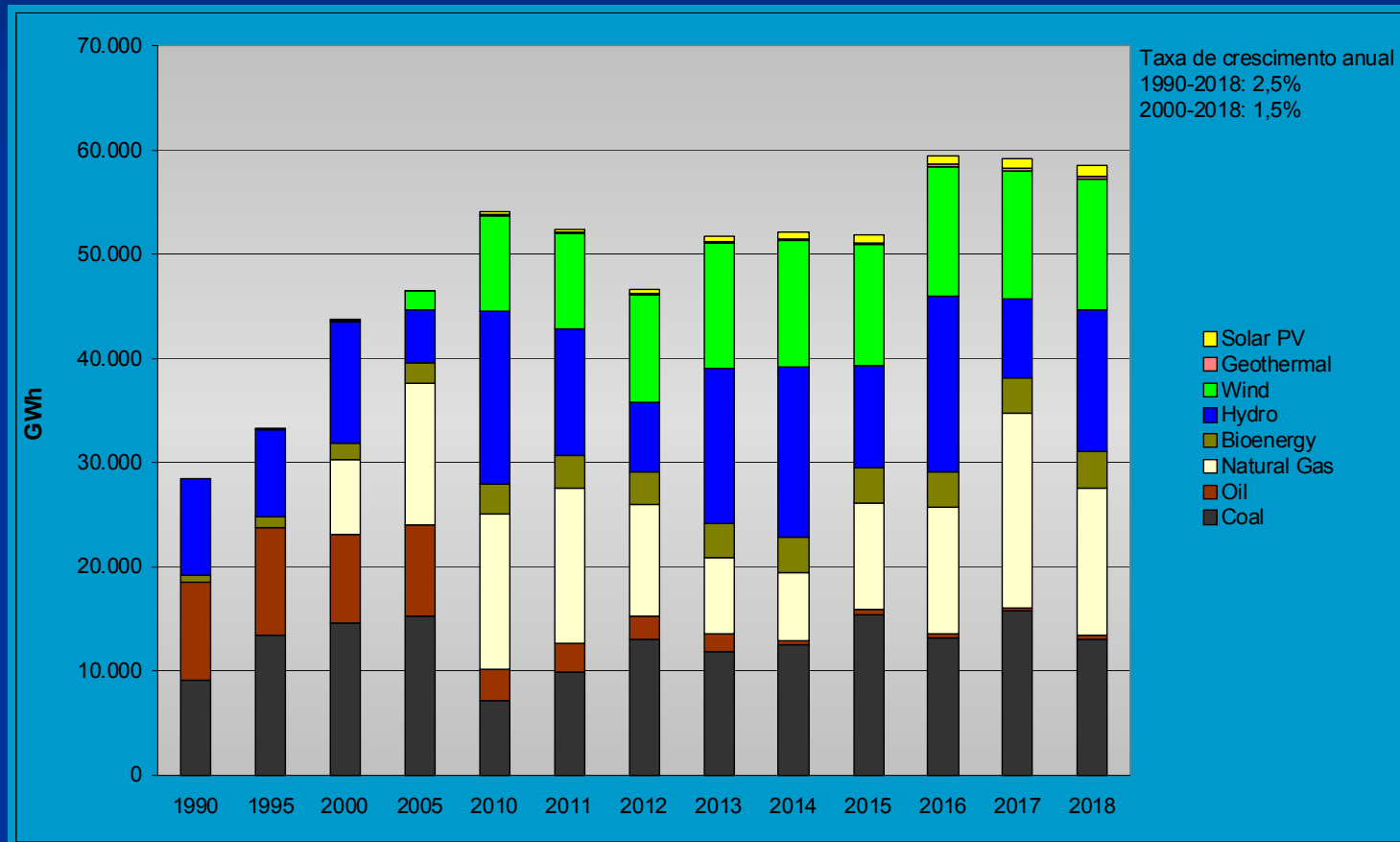
[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]



Average Power: 407 GW  
Average Power per capita: 0,81 kW

# ELECTRIC ENERGY GENERATION PORTUGAL, 1990-2018

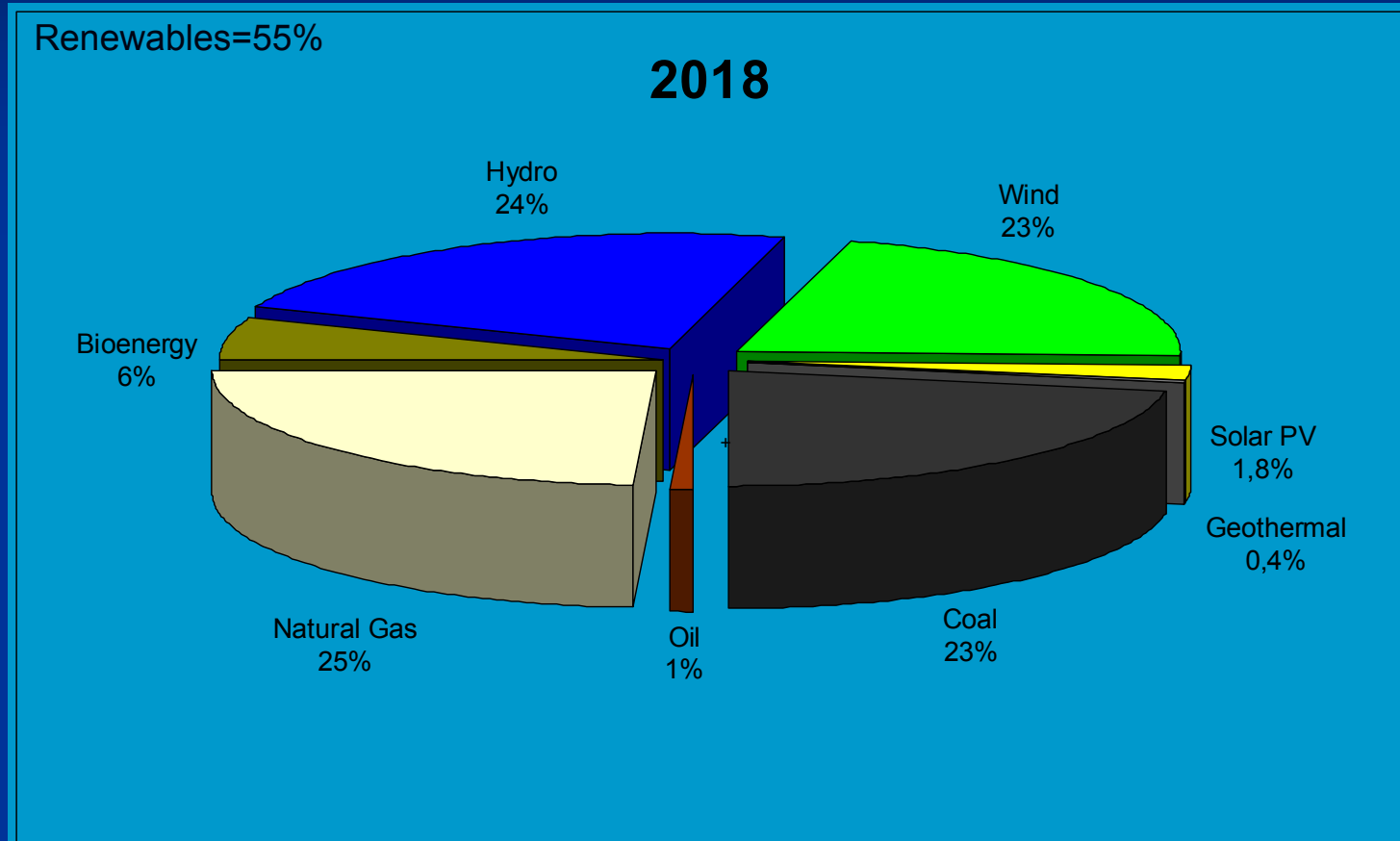
[Source: DGEG, REN]





# ELECTRIC ENERGY GENERATION PORTUGAL, 2018

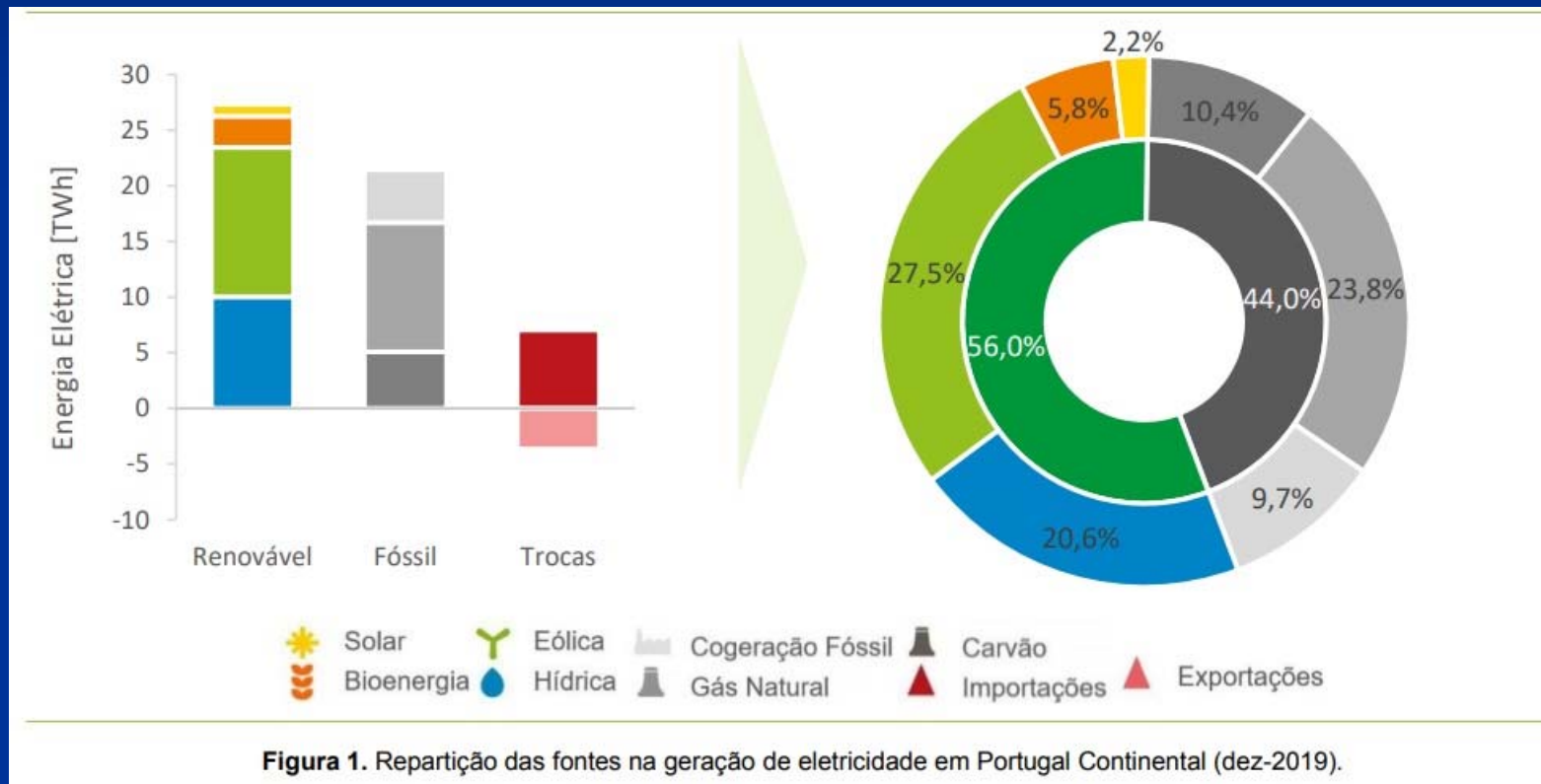
[Source: DGEG, REN]



Average Power 2018: 6,1 GW  
Average Power per capita: 0,58 kW

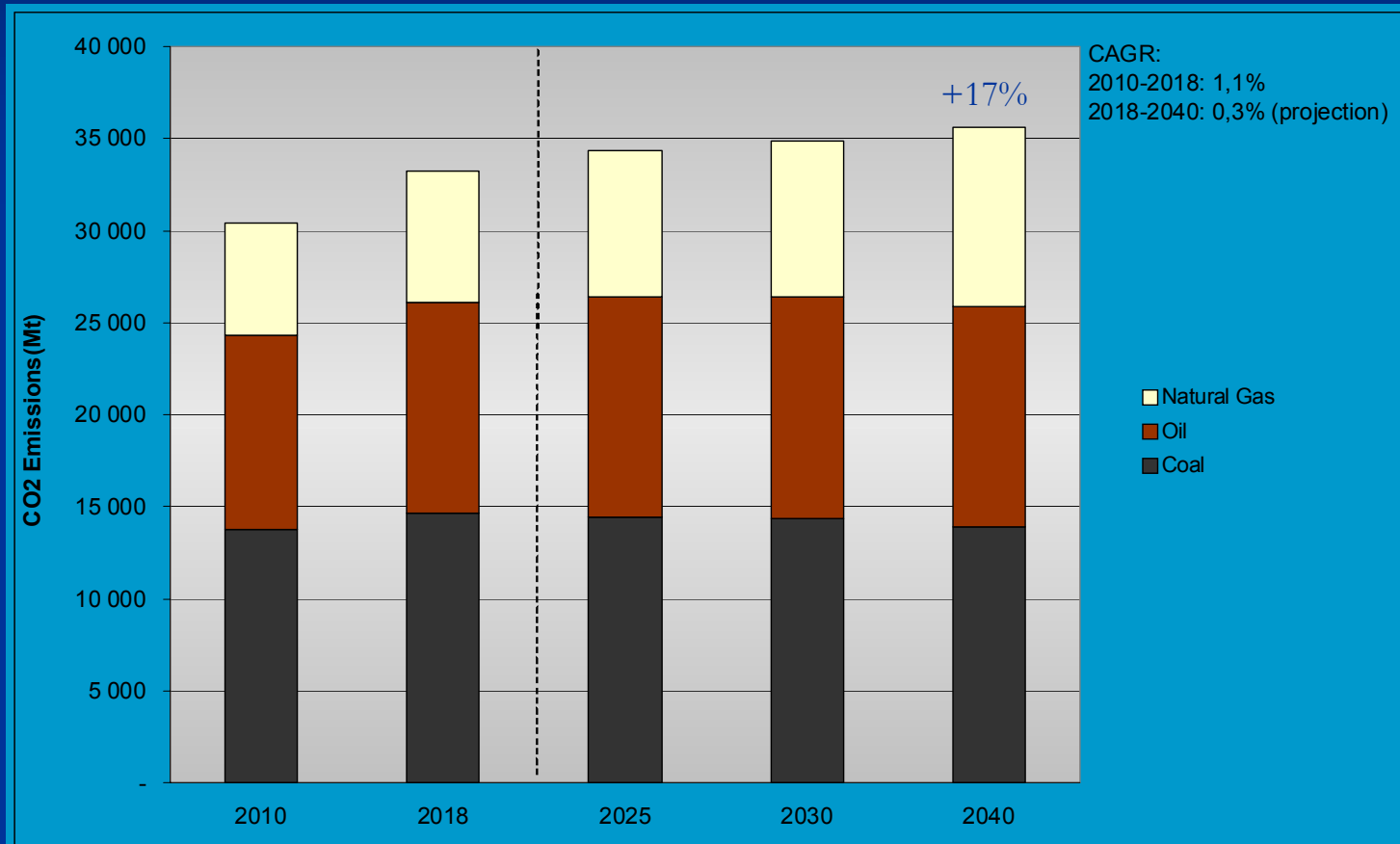
# ELECTRIC ENERGY GENERATION PORTUGAL (CONTINENT), 2019

[Source: APREN]



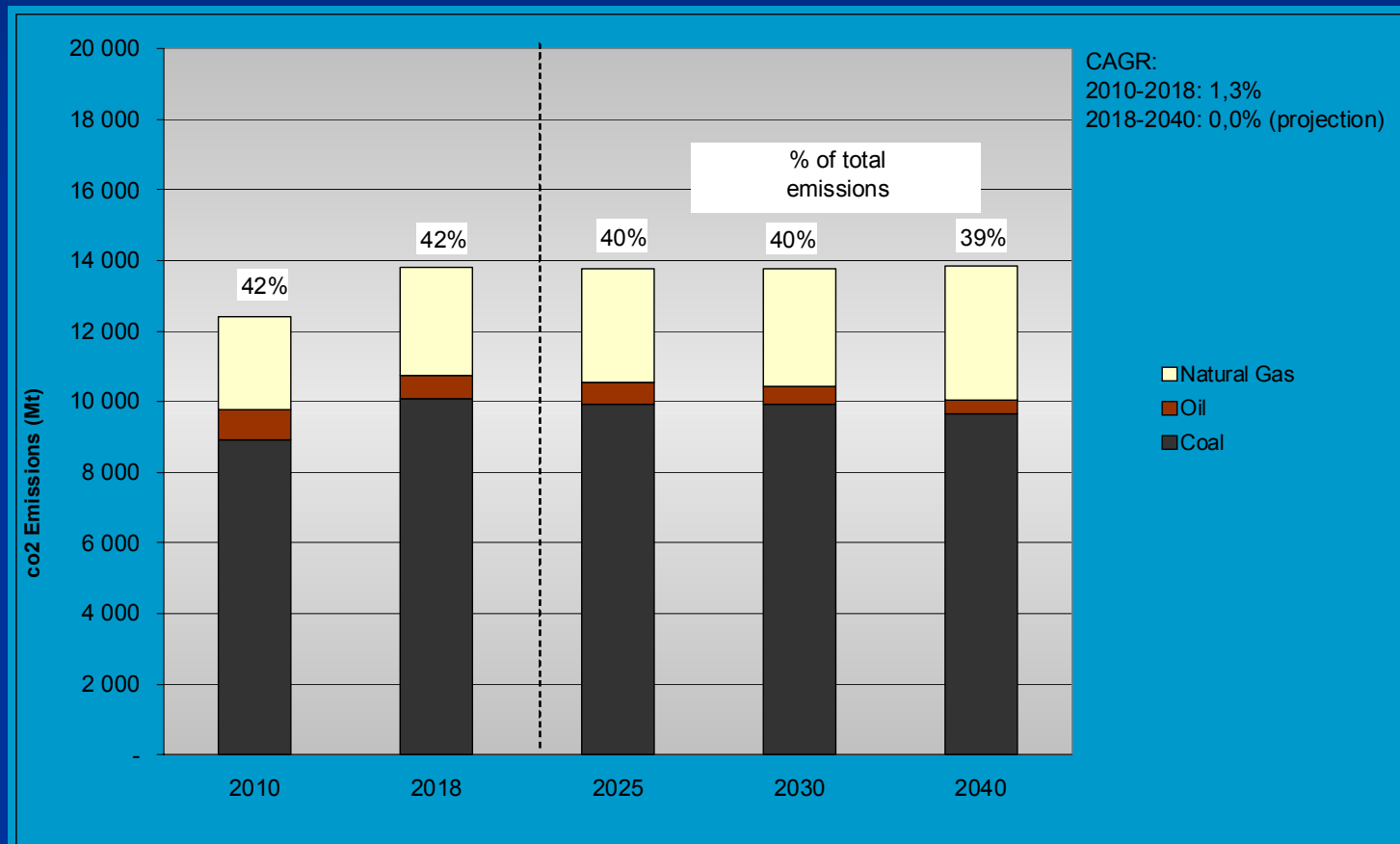
# TOTAL CO<sub>2</sub> EMISSIONS WORLD , 2010-2040

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]



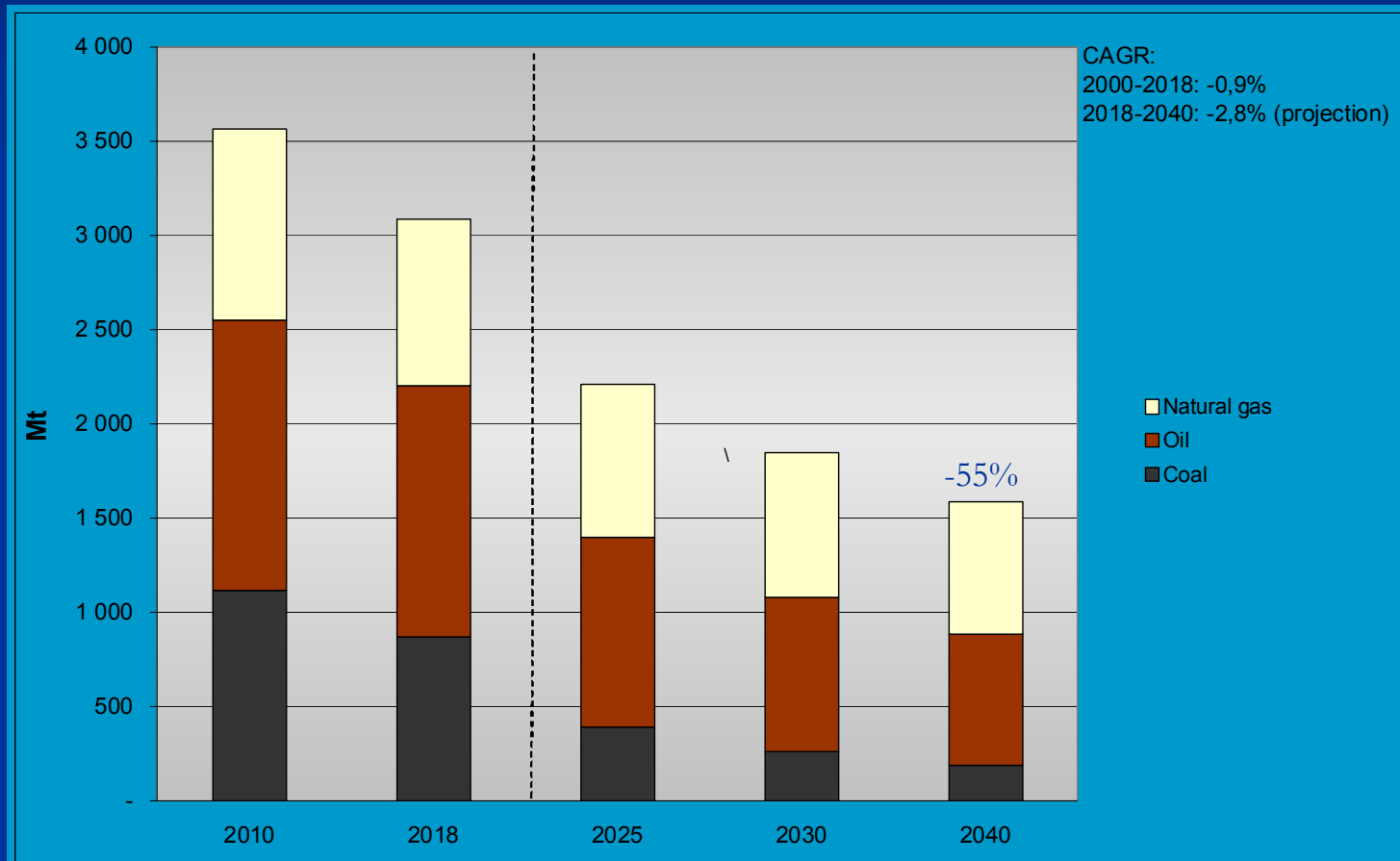
# CO<sub>2</sub> EMISSIONS DUE TO ELECTRICITY GENERATION, WORLD, 2010-2040

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]



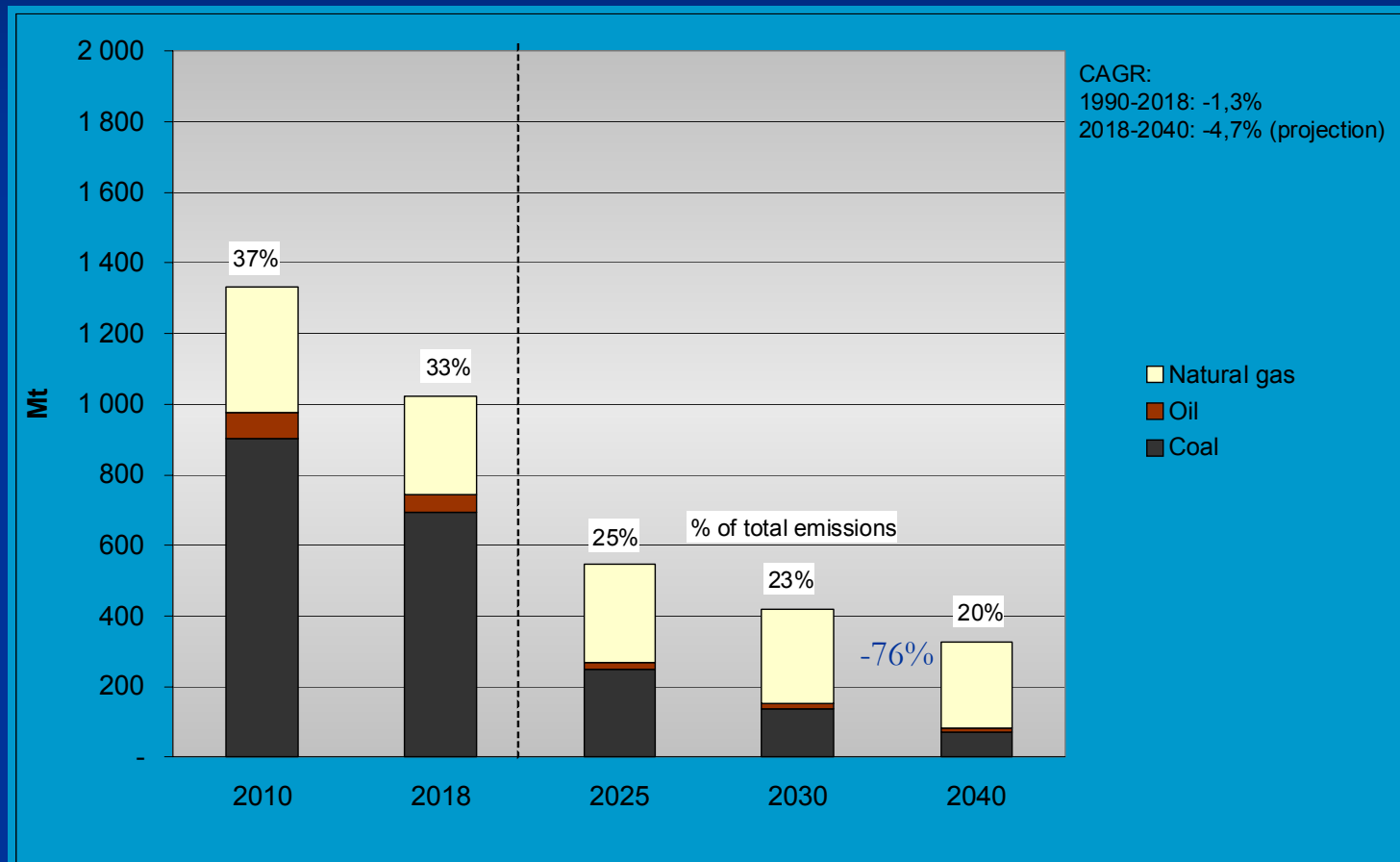
# TOTAL CO<sub>2</sub> EMISSIONS EU, 2010-2040

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]



# CO<sub>2</sub> EMISSIONS DUE TO ELECTRICITY GENERATION, EU , 1990-2040

[Source: IEA, World Energy Outlook 2019, Stated Policies Scenario]



# POWER AVAILABLE FROM ALTERNATIVE ENERGY SOURCES

[Source: Science, August 2010]

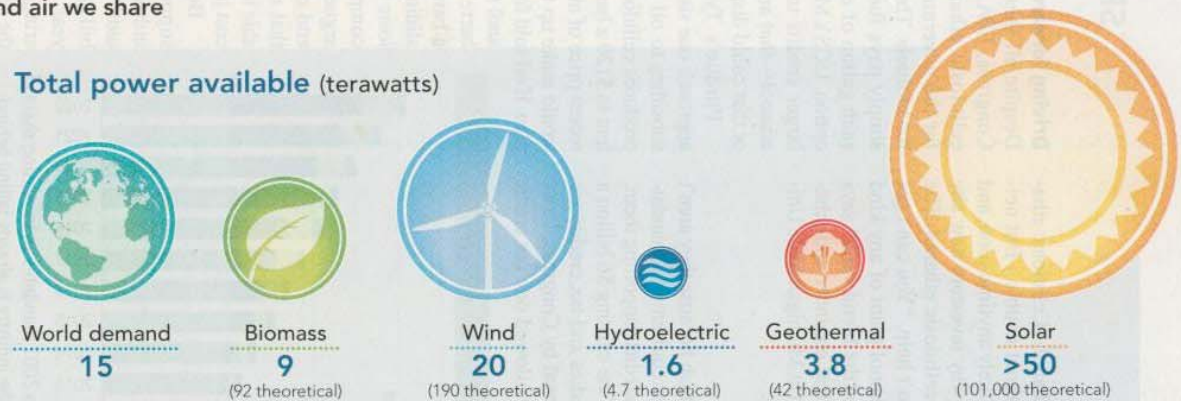
## NEWS

### Energy's Tricky Tradeoffs

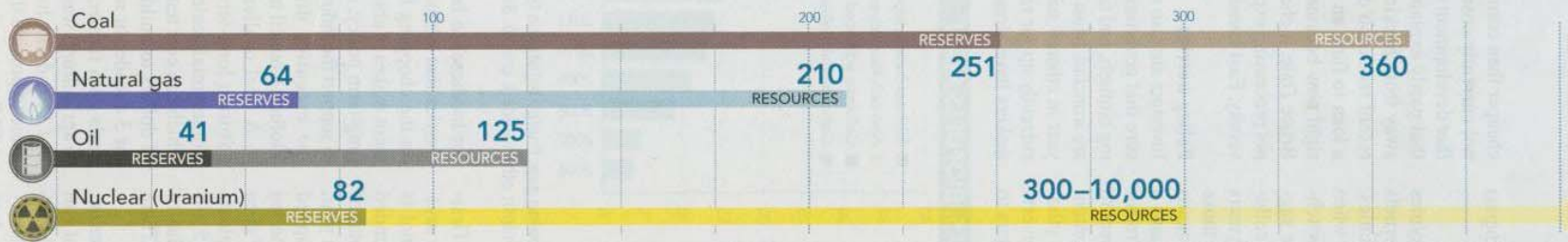
The world's "energy problem" is in fact a slew of technological and sociological challenges involving the use of the land, water, and air we share

**I've got sunshine, plenty of sunshine ...**  
 Sooner or later, humanity must move away from fossil fuels, finite resources that produce planet-warming greenhouse gases. At first blush, Earth appears to have power to spare. The total power from sunlight striking the ground is a whopping 101,000 terawatts, and experts estimate that we could capture enough of that to exceed by a wide margin the 15 terawatts of power that the world's population now consumes.

Total power available (terawatts)



How much is left? (years)



SOURCE: WORLD ENERGY ASSESSMENT 2000/UNDP; WEA 2004/UNDP; REPORT OF THE INTL. GEOTHERMAL ASSOCIATION TO THE U.N. COMMISSION ON SUSTAINABLE DEVELOPMENT 2001; SCLATER ET AL., JOURNAL OF GEOPHYSICAL RESEARCH 86 (1981); NASA

GLOBAL



# CO<sub>2</sub> EMISSIONS AND WATER CONSUMPTION

[Source: Science, August 2010]

engemaq.org SCIENCE VOL. 329 13 AUGUST 2010

## CO<sub>2</sub> output per kilowatt-hour (liters)

SOURCE (TOP): DOE; AWEA; DOE/EPA; ELECTRICITY FROM RENEWABLE RESOURCES, NAS (2010); (BOTTOM): DOE; AWEA



### A river runs through it.

The energy problem is also a water problem. Work on your computer all day, and you'll use about 1 kilowatt-hour of electricity. If that energy comes from coal, you'll have used 1.8 liters of water. If it comes from solar thermal technologies, you'll use 68% more water. Use power from biomass crops and you'll also use hundreds of liters of water to grow the fuel. Of course, fossil fuels produce heat-trapping carbon dioxide gas. If your kilowatt-hour of energy comes from coal, it produces 0.9 kilograms or 530 liters of pure CO<sub>2</sub>—enough to fill 265 large soda bottles.

## Water consumption per kilowatt-hour (liters)



**PERSONAL**

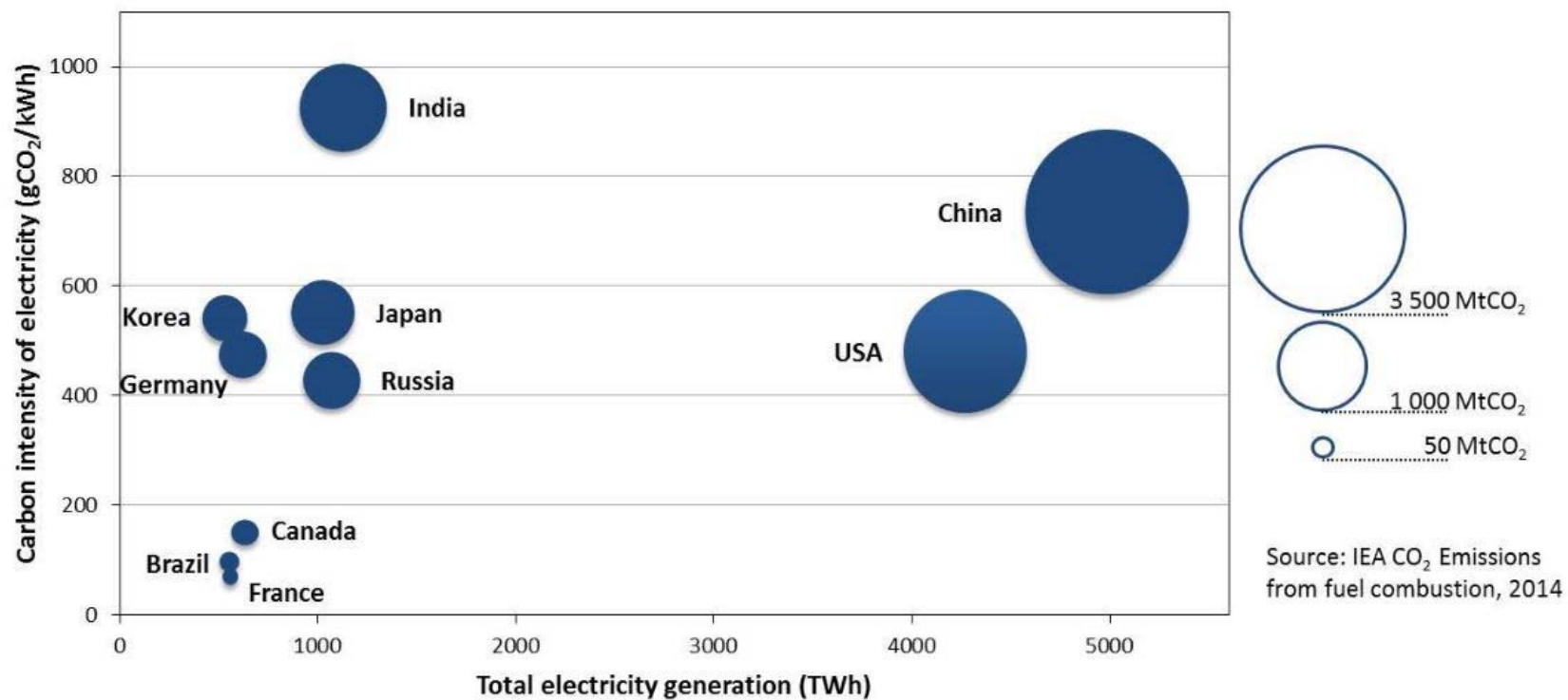
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# CARBON INTENSITY OF ELECTRICITY

[Source: IEA, 2014]

## Energy Snapshot of the Week



# DECARBONIZING ELECTRICITY SUPPLY

- Renewable energy
- Clear price for CO<sub>2</sub> (tax or market price)
- Energy efficiency
- Energy storage
- Electric vehicle
- Natural gas (especially CHP)
- Green hydrogen
- Clean coal (CO<sub>2</sub> capture and storage)