EUROPEAN
COMMISSION

Brussels, 9.1.2023
SWD(2023) 1 final

PART 1/6

COMMISSION STAFF WORKING DOCUMENT

Accompanying the document

REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

JRC technical report on "Assessment of the potential for energy efficiency in electricity generation, transmission and storage"

{COM(2023) 1 final}

Assessment of the potential for energy efficiency in electricity generation, transmission and storage.

Berizzi, A.
Benato, R.
Bosisio, A.
Petrelli, M.
Vicario, A.
Serrenho, T.
Bertoldi, P.

2021

EU Science Hub
https://ec.europa.eu/jrc

JRC125030

Luxembourg: Publications Office of the European Union, 2021

How to cite this report: Berizzi, A., Benato, R., Bosisio, A., Petrelli, M., Vicario, A., Serrenho, T., Bertoldi, P., *Assessment of the potential for energy efficiency in electricity generation, transmission and storage*, Publications Office of the European Union, Luxembourg, 2021, JRC125030.

Contents

Abstract

The revised Energy Efficiency Directive (2018/2002) in Article 23 15 (b) 13 states that "the Commission shall carry out an assessment of the potential for energy efficiency in conversion, transformation, transmission, transportation and storage of energy, and shall submit a report to the European Parliament and to the Council." This Report presents the results of the assessment of the potential for energy efficiency in conversion, transformation, transmission and storage of electric energy. The report is focused on three main pillars of possible energy efficiency imporvements, namely conventional fuels power generation, energy storage and High Voltage Direct Current (HVDC) transmission. In this report, those three main technological solutions have been taken into account in the light of the energy efficiency, to identify possible energy savings potential. For each topic considered, a review of current efficiency levels has been carried out, margins for improvements have been identified, and simple quantitative assessments have been made in order to estimate possible primary energy savings at European level. The document is organized as follows: first the single technological solutions have been investigated separately; then, conclusions and ranking are presented in the last Chapter.

1 Introduction

In this Report, the results of an assessment carried out to perform research for the identification and preparation of a study evaluating the potential for energy efficiency in conversion, transformation, transmission and storage of electric energy is presented.

The guideline is outlined in Article 23 (b) 13. of the revised Energy Efficiency Directive; the report is focused on three main pillars of possible energy efficiency development, namely conventional fuels, storage and High Voltage Direct Current (HVDC) transmission. Therefore, in this document, those three main technological solutions have been taken into account in the light of the energy efficiency, to identify possible savings potentially obtainable. For each topic considered, a review of current efficiency levels has been carried out, margins for improvements have been identified, and rough quantitative assessments have been made in order to estimate possible primary energy savings at European level. The document is organized as follows: first the single technological solutions have been investigated separately; then, conclusions and ranking are presented in the last Chapter.

Chapter 2 presents the results on the technology adopted and efficiency assessment in thermal power plants, with particular reference to conventional fossil fuels (coal, gas, oil) power stations. Some statistical data about efficiencies, consumptions, capacities, etc. are also shown. Current and perspective efficiency levels are described and estimates of potential primary energy savings have been determined under some assumptions related to the decarbonisation policy currently adopted.

Regarding storage, in Chapter 3, different types of storage useful for electric systems are considered and described with reference to the maturity of technology. Details are provided for those technologies that show current and future better perspectives (hydro pumped power stations, batteries, compressed air, flywheel). It is worth noticing that it is difficult to compare directly, in terms of efficiency, storage alternatives that might be addressed to the solution of very different technical issues (in other words, one cannot use supercapacitors to deal with large amount of energy issues): each technical problem should be addressed by the proper class of storage systems; within that class, of course, the most efficient technology should be adopted. In general, storage technologies are interesting not because they allow a direct saving of primary energy, but because they make it possible to integrate energy coming from Renewable Energy Sources (RES) into power systems, thus saving primary energy indirectly.

The same concept is true also for HVDC systems, dealt with in Chapter 4. HVDC transmission is not suitable to improve the efficiency of transmission systems, which is already very high (about 98%) and could be hardly increased. HVDC transmission is interesting because it makes it possible to transfer energy in conditions where HVAC systems would neither be technically nor economically affordable, and this is true in particular for subsea cables that allow the integration of wind power from large off-shore wind farms, thus resulting in an indirect saving of primary energy. In Chapter 4, the main characteristics of HVDC systems are hence described; for such systems, the operating conditions leading to best efficiency are derived and present and possible future uses in the European context are highlighted.

Chapter 5 reports the conclusions of the assessment carried out on the potentials of each technology for what the energy efficiency is concerned. Wherever possible, a quantification of realistic saving has been performed, under simplifying assumption, showing the potential for improvements in terms of primary energy saving.

2 Fossil fuels power plants

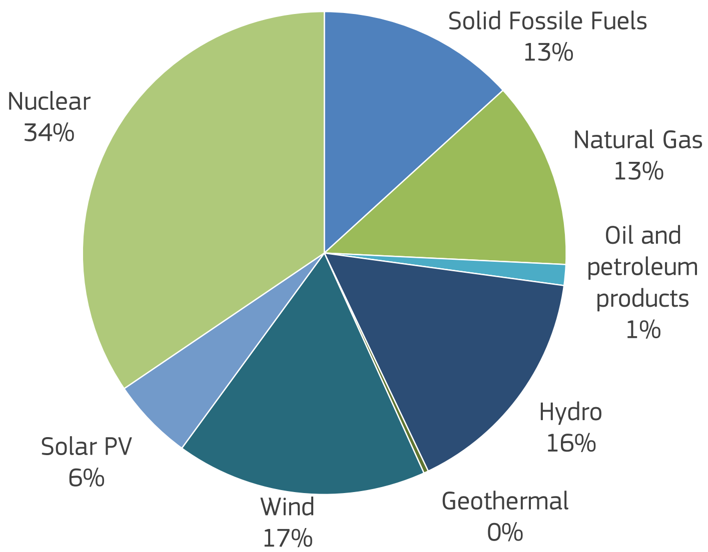
2.1.1 Introduction

In this chapter, the main characteristics of European thermal power stations fed by fossil fuel are described and their actual efficiency levels are analysed based on public data available from the Eurostat database [1] and by the most recent analysis reported in [2], with particular reference to coal, oil and gas thermal plants only.

A wider review of European energy sector is presented in the annual statistical book [3]. In [4], critical factors that influence the development of the fossil-fuel fired power generation are investigated; moreover, an updated analysis can be found in [5], where the results of a baseline scenario of the total European energy system up to 2050 are also shown. Finally, the perspective of the International Energy Agency is presented in the well-known 2020 World Energy Outlook [6].

According to the Eurostat database, the European Union still highly relies on conventional thermal generation for the electricity production. As shown in the following chart1 (Figure 1), in 2019 about 61 % of the electricity production has been generated by conventional thermal and nuclear power plants; hence, renewables were responsible for the 39 % of the total generation. As a comparison, in 2010, the renewable share was around 25 %, mainly hydropower [1].

Figure 1. Gross electricity production in 2019 in percentage. Elaboration of data from [1].



The chart[2] in Figure 2 shows the installed capacity in Europe in 2019. Out of a total capacity of 868,7 GW, conventional fossil fuels plants represent 40 %.

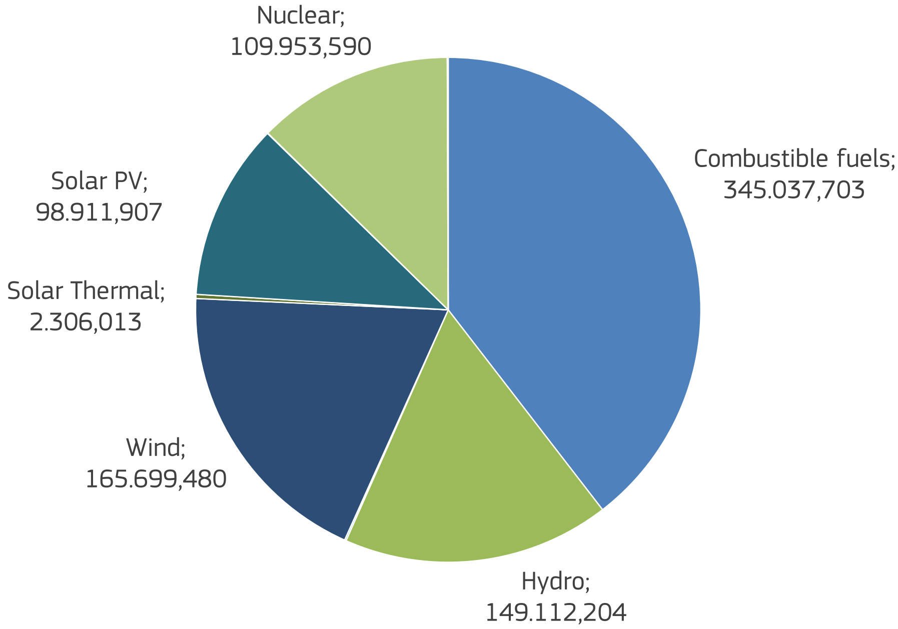
Focusing on the 27 European countries in EU27, their thermal power plants can be categorized according to the type of fuel and technology. Considering fuel, the main categories identified are [4]:

- Coal plants: including plants that use hard coal, lignite or peat;
- Oil plants: plants fed by petroleum-derived fuel;
- Gas plants: including natural gas and derived gas.

1 Production of electricity and derived heat by type of fuel [nrg_bal_peh]:
Gross electricity production - main activity producer and autoproducer - electricity only
Solid fossil fuels, Oil and petroleum products, Natural gas, Nuclear, Renewables and biofuels, Non-Renewable – waste.

2 Electricity production capacities by main fuel groups and operator [nrg_inf_epc]: Combustible fuels, Hydro, Wind, Solar PV, Nuclear.

Figure 2. Installed capacity in 2019 in Megawatt. Elaboration of data from [1].

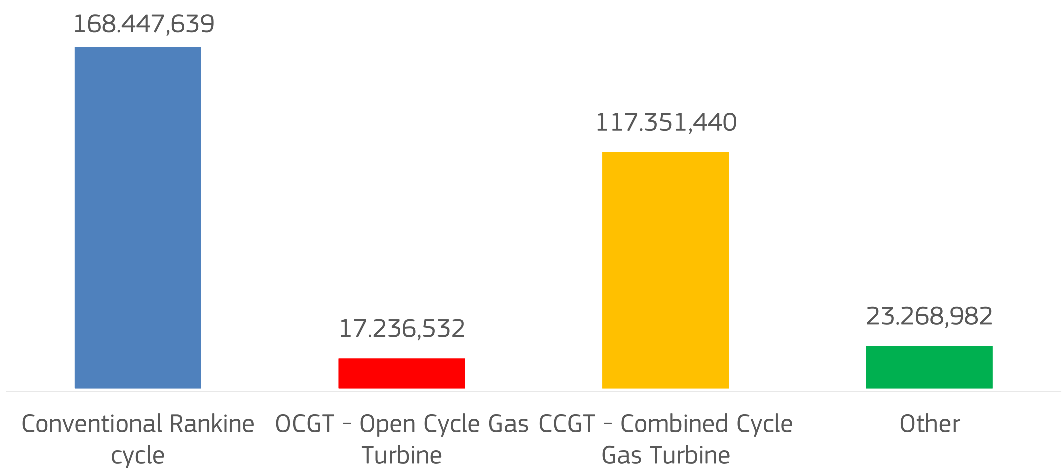


For what technology is concerned, there are:

- Steam plants (based on Rankine cycle), including the vast majority of coal and oil-fired plants, although few gas-fired boilers are still in operation;
- Open Cycle Gas Turbine (OCGT, Brayton cycle);
- Combined Cycle plants (CCGT), typically made by gas turbines, fired by natural gas, combined with downstream steam turbines, i.e., a combination of Brayton and Rankine cycles.

The chart[3] in Figure 3 shows the overall installed capacity in Europe in 2019 for each aforementioned technology [1]: traditional steam plants and combined cycles are widely spread in the European Union.

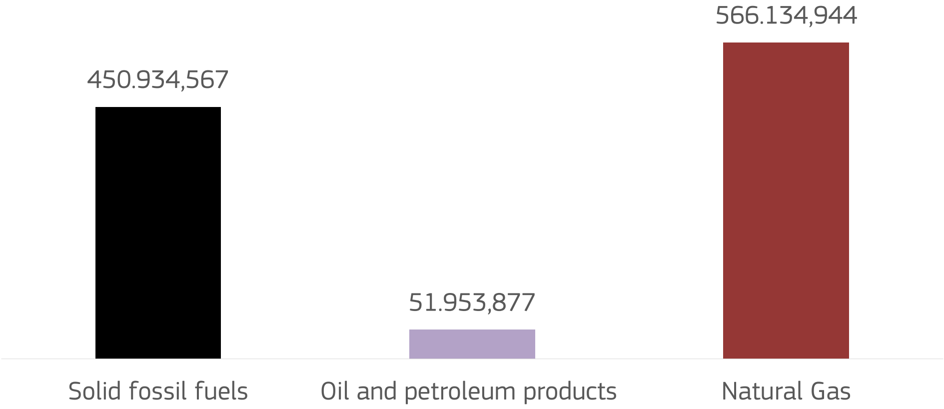
Figure 3. Classification of the installed thermal capacity [MW]. Elaboration of data from [1].



3 Electricity production capacities for combustible fuels by technology and operator [nrg_inf_epct]: Steam, Gas turbine, Combined cycle, Other. Auto-producers not included.

Coming to fuels, solid fuels, i.e., coal, are the main source of electricity production generated by thermal plants[4] (Figure 4) in 2019 [1]:

Figure 4. Gross electricity production of the thermal plants in Europe by type of fuel [GWh]. Elaboration of data from [1].



4 Production of electricity and derived heat by type of fuel [nrg_bal_peh]: Solid fossil fuels, Oil and petroleum products, Natural Gas, main activity producer and autoproducer - electricity only.