The Role of Natural Gas in the Energy Transition Phase

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1 Introduction

The rapid growth of the world population driven by the development of the industrial sector, have led to an increase of the anthropogenic greenhouse gas emissions. It has been detected an unprecedented, in at least the last 800,000 years, concentration of carbon dioxide (Figure 1-1) in the atmosphere. Such event, together with other anthropogenic drivers, have been related as the main cause of the phenomena of the "global warming" observed since the mid-20th century.

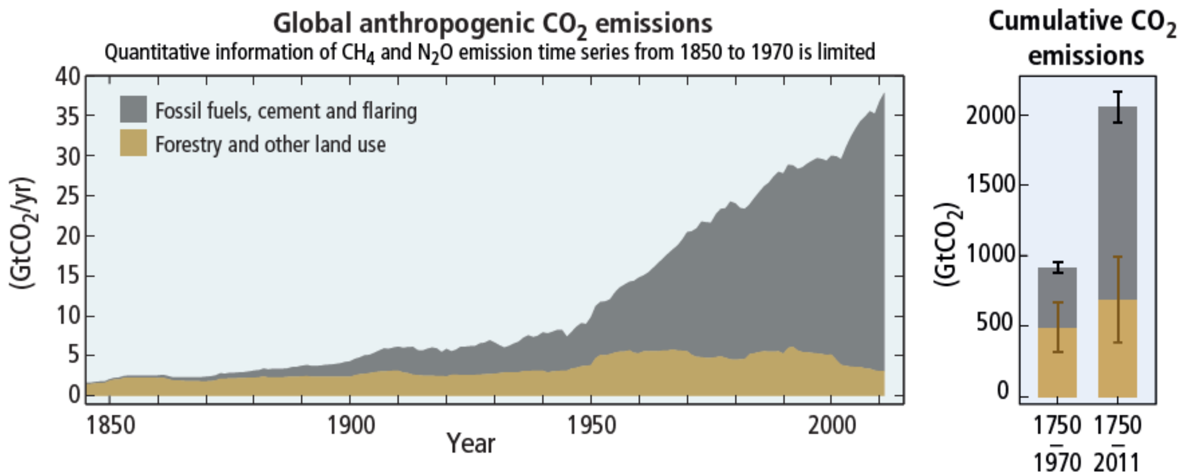

Figure 1-1 Global anthropogenic CO2 emissions[1].

In order to face the issue raised from the considerations about CO_2 concentration, the first worldwide agreement on greenhouse gas emissions was signed in April 2016. The 196 countries responsible for 55% of total CO_2 emissions agreed, at the Conference of the Parties in November 2015, to commit to cap global warming at a maximum 1.5°C (referred to the global land-ocean mean surface temperature, GMST), a more challenging target than the 2°C cap originally proposed in the Paris World Climate Conference. Given this commitment, signatory countries need to review their energy strategies in order to reduce emissions by actively promoting low carbon economy policies[2].

[1] "Climate Change 2014 Synthesis Report Summary Chapter for Policymakers," 2014.
[2] https://safeonline.it/wp-content/uploads/2016/09/Articolo-Accenture-2016.pdf

Natural gas is a fossil gas mixture consisting mainly of methane (C1). The remainder is heavier hydrocarbons: ethane (C2), propane (C3), isobutane (iC4), n-butane (nC4), and small amounts of heavier components down to C7s. The typical values of the percentage of methane mole fraction in natural gas may vary from 87% up to 97%[3].

Among all the fossil primary energy sources, natural gas presents the highest hydrogen to carbon ration. This characteristic is of extreme importance since leads the following two main properties:

- The highest lower heating value expressed in MJ/kg respect to all the others fossil fuels. (As described in the picture below[4])
- The lowest mass of CO_2 produced per mass of combustible.

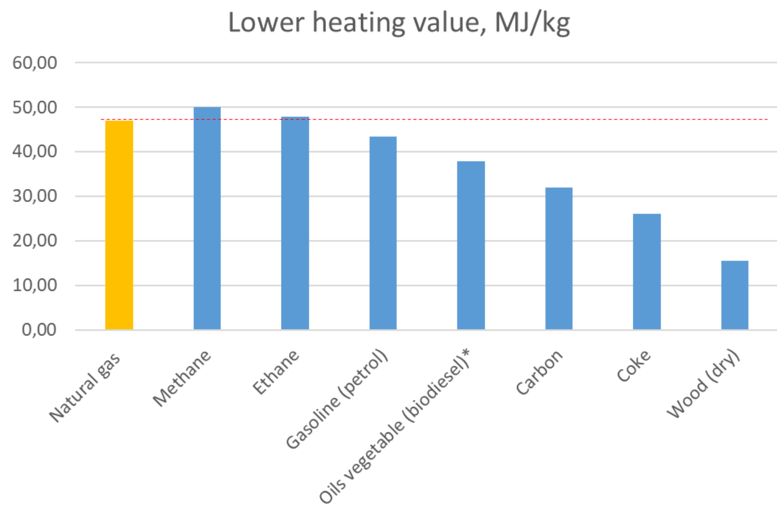

Figure 1-2 Lower heating value [MJ/kg] for different types of hydrocarbons[5].

According to the proprieties described above, natural gas plays a fundamental role in the fight against climate change. The substitution of high carbon content fossil fuels, such as coal, with natural gas, may represent the first step forward the decrease of CO_2 emissions.

The main sectors that will immediately benefit of replacing low hydrogen to carbon fuel with methane in terms of CO_2 emissions are:

- **Energy production**. All the thermo-electric energy plants belong to this sector. They may easily introduce methane as fuel in the burner for the production of high pressure steam. This strategy, adopted already by many companies, reduces CO_2 emissions saving operative costs on the post-combustion carbon capture unit.
- **Transportation**. On road transportation is already affected by the presence of vehicles fed by methane. In this case engines are designed to host such type of fuel and this constitutes a positive direction for the reduction of CO_2 emissions.

It is clear that the substitution of "conventional" fuel with methane is just a temporary solution, a clever way to "take time" establishing a ***transition phase***, until the worldwide development of the zero-emission (renewable) energy sources will take place.

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[3] https://www.uniongas.com/about-us/about-natural-gas/Chemical-Composition-of-Natural-Gas
[4] https://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html
[5] https://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html

2 Economic strategies and environmental impact

2.1 Natural gas distribution

Transportation is an essential aspect of the gas business, since gas reserves are often quite distant from the utilization points. For almost a century, natural gas has been transported safely, reliably, and economically via pipelines which are used to bring the gas supply in various production wells to the metropolis. Pipeline system has been providing the stability and long-term security by balancing the supply and demand markets. Now, in the twenty-first century, the vast majority of the large, easy to produce, and pipeline gas reserves plays have been already tapped, and attention is shifting to stranded reservoirs that were previously thought too small, too remote, or technically too difficult to develop. The liquefied natural gas (LNG) industry has commercialized many large remote gas fields over the past three decades and developed gas markets commercially unreachable by pipeline.

Both pipelines and LNG marine transportation, reported in Figure 2-1, are two possible solutions for Natural gas transportation. The evaluation of all the issues related to the particular case under analysis, will determinate the choice to adopt one instead of the other. What has to be taken into account for both the technologies is to avoid emissions of natural gas for obvious economic reasons, but also for environmental issues: it is better to never forget that methane (natural gas) is a greenhouse gas with a GWP (gas warming potential) around 25 times the one of CO_2 over a period of time of 100 years.

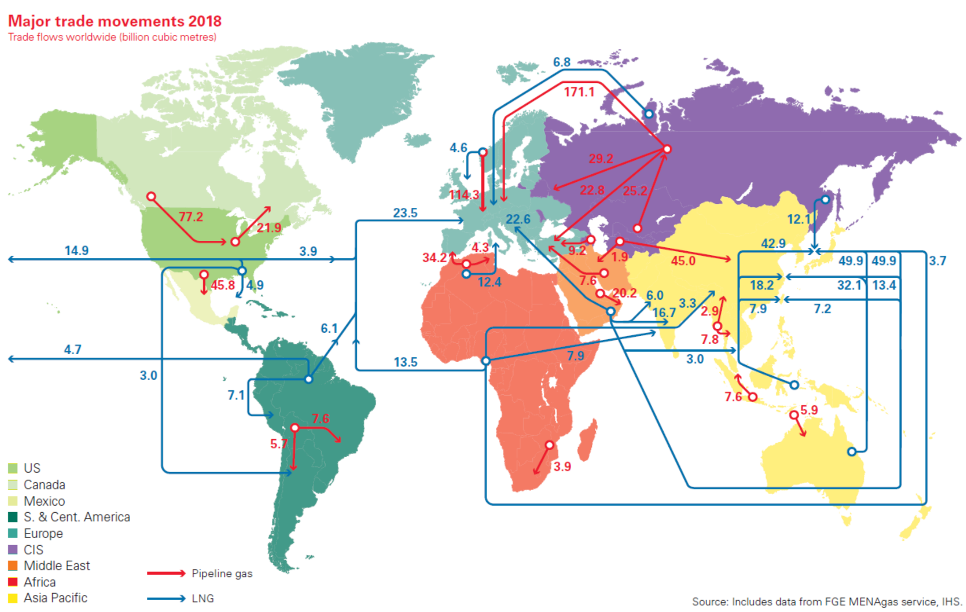

Figure 2-1Major trade movements of Natural gas via pipelines or LNG transportation.

2.2 Production methods

Gas is contained in porous rocks at different depths in different locations. The extraction techniques vary, depending on whether the natural gas is “conventional” or “unconventional”.

In general, the mechanics of drilling are complex, and are significantly more so for an offshore well than for one on land. The well depth can vary from 1000 to 20,000 ft. The well may encounter several layers of gas-, oil-, or water-bearing rocks, but usually, there is one particular layer that is the primary target of interest. While drilling, the wellbore is filled with drilling mud. The hydrostatic pressure of the mud counterbalances the reservoir’s pressure, and avoids blowouts during drilling.

If one or more productive layers are found, a steel pipe (casing) is placed in the wellbore and cemented.

The differences in conventional and unconventional gas consist on the type of reservoir rock and the consequent easiness of gas extraction:

- *Conventional gas*: high permeability of the reservoir rocks, and easiness of extraction utilizing the natural pressure from the well[6].
- *Unconventional or “shale” and “tight” gas:* extremely small permeability of the reservoir rocks. In order to increase the productivity of such type of gas, two strategies are adopted:
  1. The productivity of the vertical well is too low which is improved by using a horizontal well (single or multilateral).
  2. The area of the reservoir that is drained by a vertical well is so small that it would require a large number of wells to effectively drain the whole reservoir. This could be very intrusive on the surface land activity and is solved by drilling multiple directional wells from a single pad, which significantly minimizes the surface footprint.

The technique described in point 2 is realized by means of pressurized water and, for this reason, is called hydraulic fracking. A visual overview of the different extraction techniques is given in the picture (Figure 2-2) below.

The hydraulic fracking is indeed a profitable instrument to enhance the production of Natural gas but its invasive nature makes it subjected to various complains:

- Contamination of drinking water wells[7].
- Induced seismicity from the injection of waste fluids into deep disposal wells[8].

[6] https://www.gryphonoilfield.com/conventional-vs-unconventional-oil-gas-wells-in-u-s/
[7] https://www.greenpeace.org/usa/global-warming/issues/fracking/environmental-impacts-water/
[8] https://www.usgs.gov/faqs/what-environmental-issues-are-associated-hydraulic-fracturing?qt news_science_products=0#qt-news_science_products

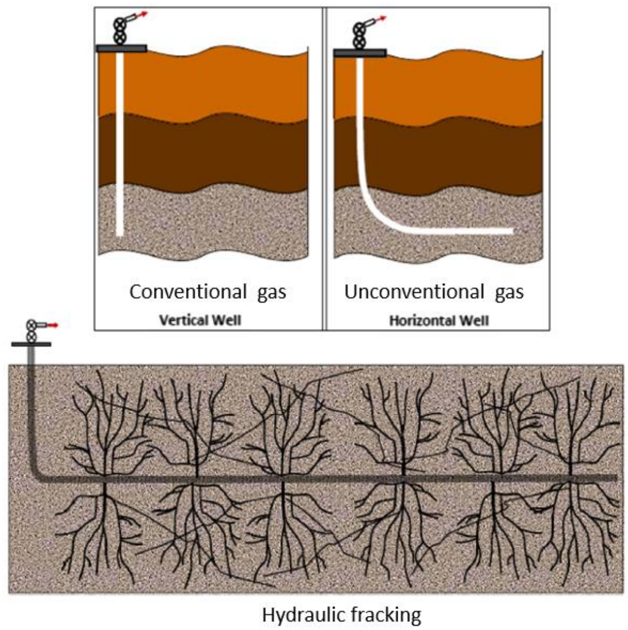

Figure 2-2 Differences in conventional and unconventional gas extraction techniques (above). Hydraulic fracking extraction method (below) [9].

It is true that the production of Natural gas represents a first move toward the reduction of CO_2 emissions, but, on the other hand, in order to follow the definition of sustainable development, long term environmental effects should be taken into account. According to this, the debate along the environmental impact of the hydraulic fracking is still under investigation.

2.3 Political strategies during the natural gas transition phase

Countries' investments and political strategies regarding Natural gas (NG) are deeply affected by the presence, or absence, of NG reservoirs in their territory. According to this it is possible to establish a net division between:

- **NG exporters** are investing for the creation of new LNG facilities (i.e. Norway which exports the 86% of NG that produces) or the construction of new of pipelines (i.e. Iran which detains the 18%[10] of the world production of NG) in order to increase and enhance the network for NG exportations.
- **NG importers** are interested in the development of renewable energy sources. The UK, for example, which imports more than 50% of the NG that consumes, finds in renewable energy a manner to avoid future competition with potential emerging economy markets such as China and India which are both importers of NG.

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[9] Chapter 1 - Natural gas fundamental, Editor(s): Saeid Mokhatab, William A. Poe, James G. Speight, Handbook of Natural Gas Transmission and Processing, Gulf Professional Publishing, 2006, Pages 1-28, ISBN 9780750677769,

[10] "Natural gas: A transition fuel for sustainable energy system transformation ?," no. November 2018, pp. 1075–1094, 2019.

3 General world overview

According to the BP Statistical Review of World Energy, in 2018, primary energy consumption grew at a rate of 2.9%, almost double its 10-year average of 1.5% per year, and the fastest since 2010[11]. By fuel, energy consumption growth was driven by natural gas, which contributed more than 40% of the increase. This trend is due mainly to the US contribution given by the extraction of shale gas by means of the discussed fracking technique. Moreover, the analysis reveals an increase of carbon emissions by 2.0%, the fastest growth for seven years.

The mitigation of CO_2 emission replacing high carbon fossil fuels with natural gas is still far to be reached. The benefits related to an increase of energy produced via renewables sources is shadowed by the development of coal consumption in developing countries of the Pacific Asia, especially China and India. From the graph below (Figure 3-1) it is easy to notice that China and India are the major contributors, together with US, to the primary energy growth in 2018 which justifies the increasing trend of CO_2 emissions.

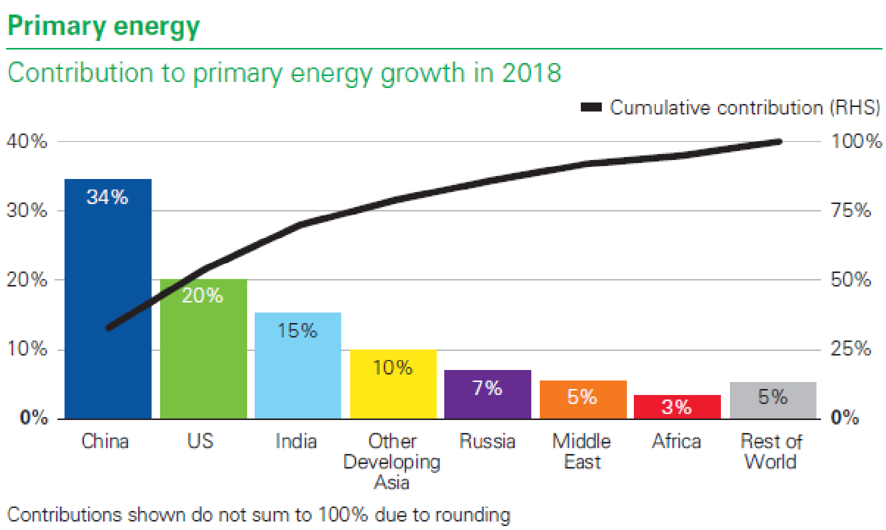

Figure 3-1 Contribution of different countries on the primary energy growth in 2018.

In the following graph (Figure 3-2) the amount of energy sources consumed to supply the global energy demand has been converted in tons of equivalent oil in order to be compared. In such way, a photograph of the actual world situation is given.

[11] BP Statistical Review of World Energy 2019 | 68th edition

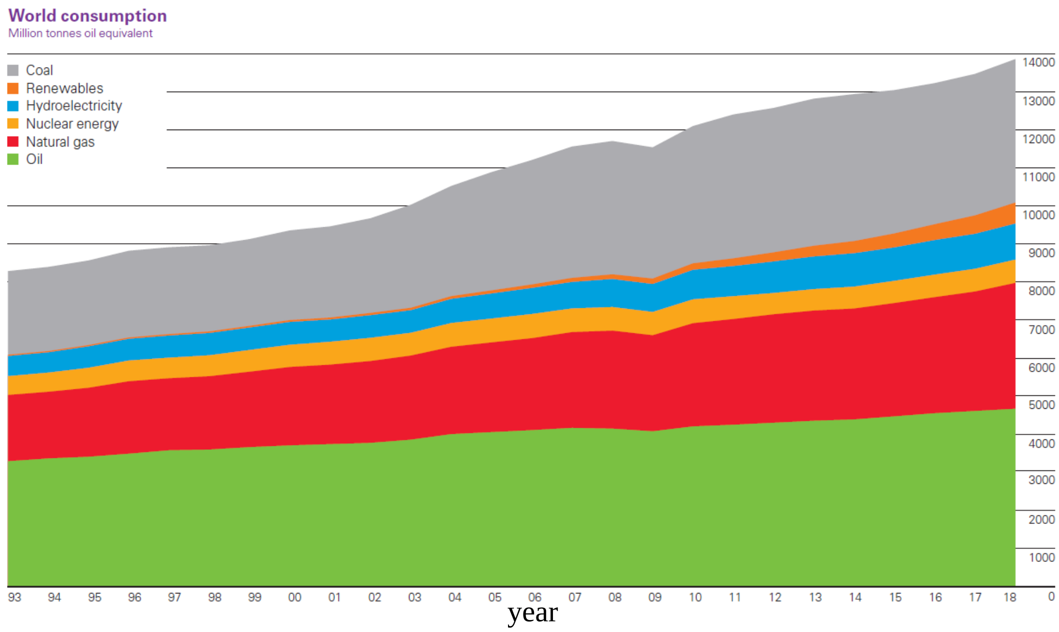

Figure 3-2 Overall world consumption of different energy sources during the years.

The main political strategies to increase the adoption of natural gas are[12]:

- Increase of financial support towards investments in energy innovation and technology. In particular, towards a complementary natural gas and renewable energy systems.
- Implement an effective, transparent and economy wide carbon pricing based on emission regulations.
- Encourage the production of LNG in order to enhance the natural gas exportation and availability.

An example of the both environmental and economic advantages introduced by the production and consumption of Natural gas is given by the US. United States is the major leader in natural gas production and, in fact, is currently experiencing negative growth in CO_2 emissions, while the country's GDP (gross domestic product) per capita has continued to grow since 2007[13] (see Figure 3-3).

[12] https://www.igu.org/sites/default/files/NGV%20Global%20Conference.pdf
[13] Rongrong Li & Min Su, 2017. "The Role of Natural Gas and Renewable Energy in Curbing Carbon Emission: Case Study of the United States," Sustainability, MDPI, Open Access Journal, vol. 9(4), pages 1-18, April.

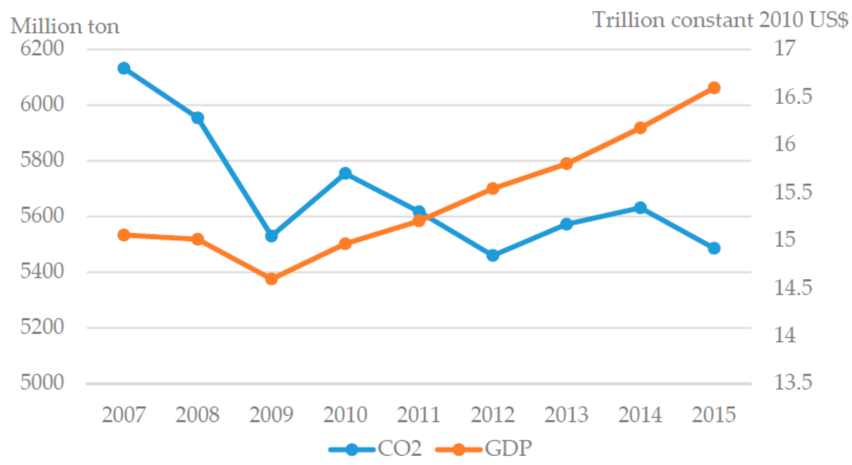

Figure 3-3 US trends of CO_2 emissions and gross domestic product (GDP) [14].

4 Conclusions

It would be extremely difficult to provide sufficient energy for rapid world economic growth while at the same time phasing out fossil energy for environmental reasons. A transition period of time is needed to gently switch the industrial market of energy toward a future with net zero carbon emission. For this purpose, Natural gas will play a main role since it provides the fastest and most economic path to a less carbon intensive and cleaner air world.
For these reasons, in the near future, a strong growth in natural gas demand and consumption is expected. On the other hand, it is important to keep in mind that Natural gas is just a temporary solution for reducing carbon emissions and that the main goal is to produce 100% energy from renewable sources. The methane transition phase will be, in fact, followed by a second "renewable transition phase" in which hybrid systems, feed by methane and renewable sources, will conquer the energy market. Examples of such systems already available may be in the:

- **Energy production sector**: Hybrid Thermal electric power plants (i.e. solar molten slat technology supported by methane burners Figure 4).
- **Automotive sector:** Hybrid electric vehicles (HEV)
- **Energy storage sector:** Recent studies are working on the methanation process for electric energy storage: this is based on the reaction of CO_2 with hydrogen (produced by electrolysis or by solar energy) for methane production (Power to gas technology P2G).

[14] Rongrong Li & Min Su, 2017. "The Role of Natural Gas and Renewable Energy in Curbing Carbon Emission: Case Study of the United States," Sustainability, MDPI, Open Access Journal, vol. 9(4), pages 1-18, April.

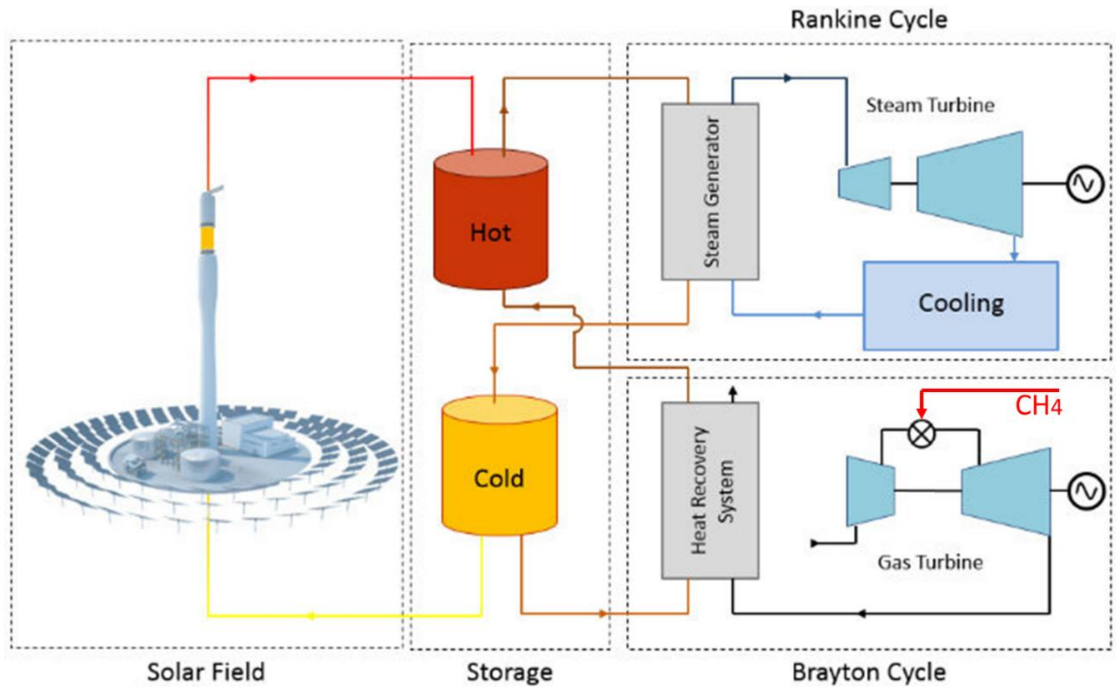

Figure 4 Configuration for a CSP (Concentration Solar Power) hybrid power plant using a central tower solar field