Considerations on energy transition

Christoforos Benetatos*
Eloisa Salina Borello*
Costanzo Peter*
Vera Rocca*
Raffaele Romagnoli*

DIATI - Politecnico di Torino,
Torino, Italy.

In the future, we will experience a continuously increasing energy demand mostly due to the continuous growth of the world population. Today we use fossil fuels (coal, oil and gas) in order to cover the society's basic needs. This involves significant CO_2 emissions that contribute to the climate change by contributing to the increase of the global temperature. A great number of countries through international agreements are working on energy transition towards renewable energy resources targeting to a sustainable future. In reality though the path the world has to follow is still long and the transition towards a green future cannot be immediate. Some of the most populated countries still rely on coal as their main energy source while oil is still the most frequently used fuel in transportation. Furthermore, the passage to new energy sources would mean new facilities and new distribution networks that are not economically possible for many countries. In this energy transition natural gas can play an important role as the mid-point between traditional fossil fuels and renewable energy sources. It produces lower emissions than coal and oil, the facilities for its extraction and transportation already exist in many countries and can support the energy consumption needs of the modern society. In combination with CO_2 capture and sequestration applications it can provide a realistic (greener) transition towards a fossil-fuel free future.
Keywords: *energy transition, fossil fuels, green energy, natural gas.*

Divagazioni sulla transizione energetica *La crescita continua della popolazione mondiale implica una domanda di energia in costante aumento. Oggigiorno il fabbisogno energetico della società di fatto viene soddisfatto dai combustibili fossili (carbone, petrolio e gas), con significative emissioni di CO2, individuata come principale causa del cambiamento climatico. Il problema, di carattere globale, è oggetto di numerosi accordi interazionali finalizzati ad individuare ed ottimizzare il processo di transizione energetica verso risorse rinnovabile rivolte a un futuro sostenibile. In realtà, il processo è ancora lungo e la transizione verso un futuro verde non può essere immediata. Alcuni dei paesi fanno ancora affidamento sul carbone come principale fonte di energia mentre il petrolio resta il carburante più utilizzato nel settore dei trasporti. Inoltre, il passaggio a nuove fonti di energia pulita implicherebbe nuove strutture e nuove reti di distribuzione, attualmente ancora economicamente irrealizzabili in molti paesi. In questa fase di transizione energetica, il gas naturale è destinato a svolgere un ruolo-ponte fondamentale tra i combustibili fossili tradizionali e le fonti di energia rinnovabile. Infatti il gas naturale, paragonato al carbone e al petrolio, riduce le emissioni e le strutture per la sua estrazione e trasporto sono già presenti in molti paesi. Associato ad interventi di cattura e stoccaggio di CO2, il gas naturale può fornire un alternativa realistico (più verde) verso un futuro privo di combustibili fossili.*
Parole chiave: *transizione energetica, combustibili fossili, energia pulita, gas naturale.*

1. Introduction

For quite some time now, society has been dealing with the very broad issue of the "climate change" which immediately refers to the "energy" challenge; this path can be further branched into "energy transition" and "green energy". Undoubtedly, technological innovation has shaped modern society. Humanity's first use of energy was linked to the basic needs for survival that are food, heat and housing. From that time until the times of the industrial revolution, humanity has experienced dramatic changes of socio-economical aspects strictly related to the evolution of technologies and the main energy source evolution as well. Nowadays the basic energy consumption is used not only to cover our basic needs but also for many other aspects of everyday life like transportation, communication, industrial use and many more.

Energy transition can occur in a global scale for various reasons. Sometimes it can happen when the main energy source supplies run out or in other cases when the global cost of using this particular energy source becomes too high for the national economies to stand, also in terms of environmental impact. The pollution of the air, water and land has become more and more alarming during modern times so a change to a green (or greener) and sustainable (or more sustainable) energy source seems necessary. In many cases, this is accompanied or even driven by the technology achievements, which offer new possibilities of producing, storing and distributing energy (Solomon and Krishna, 2011). From the industrial revolution, the fossil fuel has been dominating the power generation and the continuous increase of the energy demand is proportional to that of the Earth's population. This has led a rapid growth in carbon dioxide (CO2) emissions that need immediate relief (Owusu *et al.*, 2016 and references therein). This is claimed to result in a significant impact on the climate; and our generation is leaving in an era where "climate change" is one of the main problems at a global scale.

In the last decades, an effort from many countries is observed towards a sustainable future by attempting to move from traditional fossil-fuels to renewable energy sources such as solar energy, geothermal energy, or hydropower. These actions could eventually support the disengagement from coal and oil but currently, they can cover only partially the needs of the modern society. Furthermore, how "green" these solutions are and how many counter effects they bring to the social and economic sectors? Unfortunately, fossil free does not mean emission free. For instance, crystalline-silicon solar cell processing involves the use or release of chemicals such as phosphine, arsenic, arsine, trichloroethane, phosphorous oxychloride, ethyl vinyl acetate, silicon trioxide, stannic chloride, tantalum pentoxide, lead, hexavalent chromium, and numerous other chemical compounds (Zehner, 2012). In addition, the production, installation, and maintenance of any technological infrastructure will probably continue to be dependent on fossil energy. Consider industrial wind turbine, for example: the mass of an industrial wind turbine is 90% steel, which is CO_2 and energy intensive, and the transport of components for installation relays on road transport (Figure 1).

The aim of the present paper is to make the reader aware about the historical and future evolution of the energy mix, about the role played by renewable energy and natural gas in the energy transition process, and about the difference between the "green" and the "greener" energy. Experts in the energy industry are working to come up with solutions to energy needs and demand. As a society, we will have to decide the way forward, but this is only possible if our decisions are informed ones by technical knowledge and by further human-centered research methods. Sustainable development was a good starting point but we should probably take our future steps on a path paved with realistic and scientifically supported decisions.

Fig. 1. UK's Largest Onshore Turbine Blades, transport to Muirhall Wind Farm, South Lanarkshire (Wikimedia Commons, 2019).
Pale della più grande turbina inglese, trasporto al parco eolico Muirhall, Lanarkshire meridionale.

2. Worldwide energy panorama

The need for energy obeys the economic demand. Figure 2 (a) shows historical and forecast growth in energy demand expressed in equivalent tons of oil (toe) and Figure 2 (b) the relative shear of energy supply in the world panorama, according to the 2016/2017 Energy Outlook (BP p.l.c. 2016, 2017).

The growth of green energy (solar, wind, etc.) shows a positive and constant trend but it is far from replacing fossil fuels in the short to medium term. As a mature technology, hydropower is the leading renewable source for electricity generation globally. Important new development is concentrated in the emerging markets, such as Asia, which has the largest potential, China, Latin America and Africa: in fact, hydropower offers not only clean energy, but also provides a range of complementary benefits such

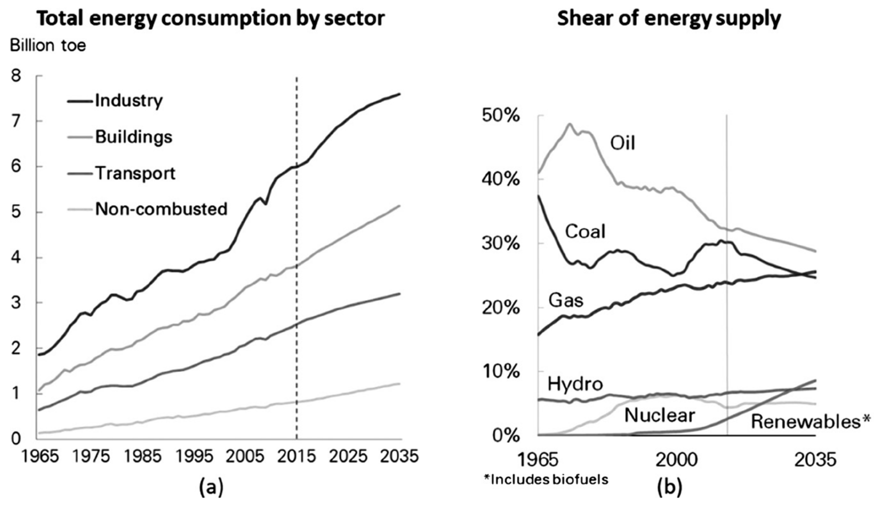

Fig. 2. Growth in energy demand and corresponding energy mix supply (BP p.l.c. 2017 and BP p.l.c. 2016).
Crescita della domanda energetica e corrispondente variazione delle fonti energetiche di approvvigionamento.

as water services, energy security and facilitates regional cooperation and economic development. As hydropower has good synergies with all generation technologies, its role is expected to increase in importance in the electricity systems of the future (Word Energy Resource 2016). However, the impact of hydropower, which implies building dams, diverting rivers, flooding emerged lands, is often not negligible and thus opposed by local populations as well as by environmentalists.

Coal represents the second most important energy source, providing around 20% of the global energy consumption. China's contribution to global coal demand is 50%, and this massive use of coal has a huge cost in terms of pollution even though the Country is shifting to clean coal technologies. In addition, India's coal consumption is set to increase. Coal is predominantly an indigenous fuel, mined and used in the same countries, allowing for security of supply. It is used for power generation, iron and steel production, cement manufacturing and as a liquid fuel. It is forecasted to continue to supply a strategic share over the next three decades; however, its percentage in global energy mixt shows a constant and continuous decreasing trend due to factors like climate change mitigation demands, transition to cleaner energy forms and increased competition from other resources, in particular natural gas (Word Energy Resource 2016).

The leading energy supply remains oil: it covers around 30% of global consumption, predominantly in the transport sector. Its global share is in continuous and progressive decrement even if the developing counties face an opposite trend because of the growth of population (Word Energy Resource 2016).

Natural gas is the only fossil fuel whose share of the primary energy mix is expected to grow. It has the potential to play an important role in the world's transition to a cleaner energy due to its high-energy content together with lower emissions of carbon and volatile organic compounds at combustion compared to coal and oil. The global market orientation is also affected by rise of unconventional gas production, such as shale gas and CBM (Coil Bed Methane). However, it is very important to explore the worldwide panorama, or at least the key driving economies, to appreciate how the evolution of energy supply and the future mixing scenario is strictly "geographically" dependent (Fig. 3).

The evolution of the energy mix is affected by factors related to socio-economical-political contests the analysis of which is beyond the scope of the present paper. However, it is not trivial to mention the importance of quantitative availability of the different energy sources. Figure 4 shows the worldwide historical evolution of the proved reserves for oil, gas and coal between 1995 and 2015 (Word Energy Resources, 2016). The term "reserves" refers to discovered quantities of hydrocarbons, which are economically extractable at prevailing prices and current technologies. The term proved reserves is more specific and refers to that portion of reserves, which can be estimated to be recoverable with a very high degree of confidence. Therefore, global and local market changes and the technological improvement affect the evolution of the reserve estimation. Developments in unconventional gas and oil (shale, heavy oil, light tight oil and tar sands), deep offshore exploration and the increased number of mature fields, coupled with the need to optimize the operational efficiency in order to minimize production costs, has necessitated an advancement in technology within the oil industry. Such technologies include greater use of digital technology in oil fields (Hacker, 2008; Saputelli *et al.*, 2013), nanotechnologies (Cocuzza *et al.*, 2011; Cocuzza *et al.*, 2018), real-time drilling optimization (Frenzel *et al.*, 2014; Kumar *et al.*, 2017), High-pressure, High-temperature (HPHT) drilling (UK Health and Safety Executive, 2005; DeBruijn *et al.*, 2008), development in flow assurance for mature fields,integrated reservoir modelling (e.g. Benetatos and Viberti, 2010), and in-well fiber optics and diagnostics (Kragas *et al.*, 2002; Sanni *et al.*, 2018). In 2016, the World Energy Resources report stated: "Unconventional oil recovery accounts for 30% of the global recoverable oil reserves and oil shale contains

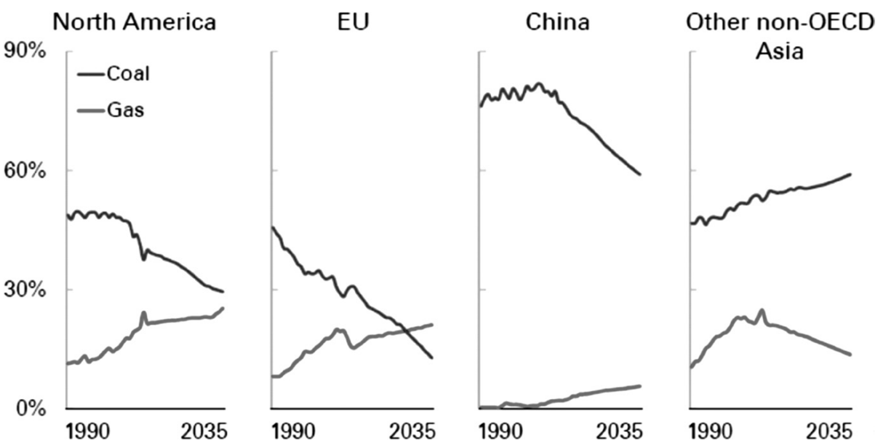

Fig. 3. Different energy mixes (OECD = Organisation for Economic Co-operation and Development) (BP 2014).
Evoluzione del mix energetico

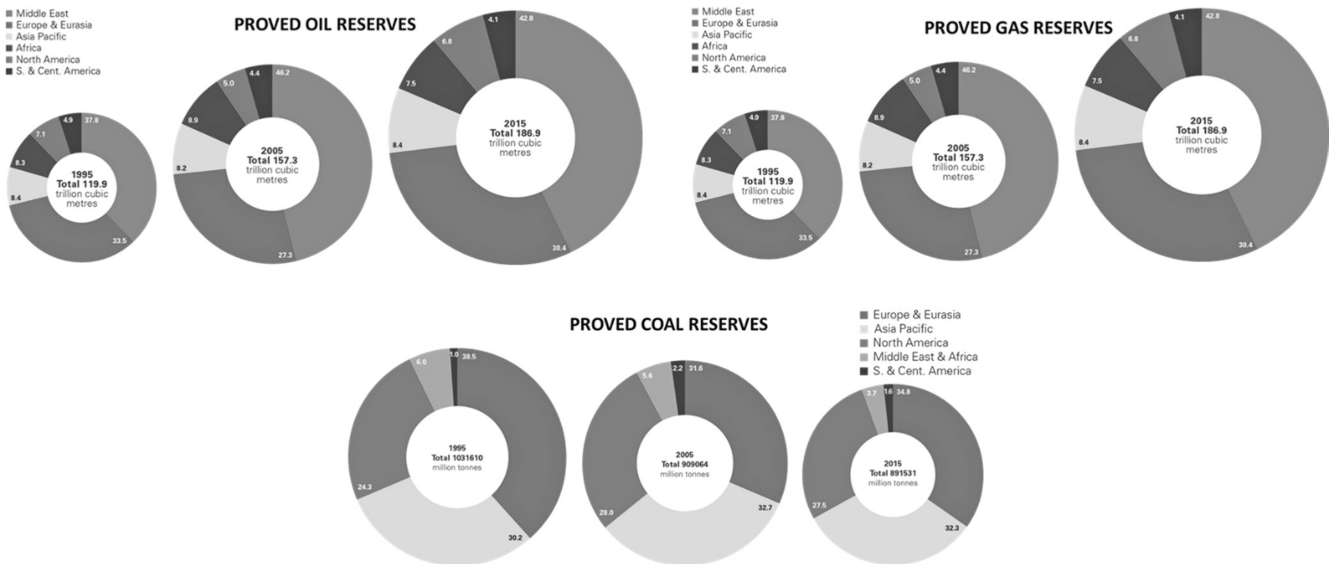

Fig. 4. Historical evolution (1995; 2005; 2015) of proved reserves (BP, 2016).
Evoluzione storica delle riserve 'proven'.

at least three times as much oil as conventional crude oil reserves, which are projected at around 1.2 trillion barrels".

3. *The role of natural gas*

Among the many energy transition alternatives, natural gas has gained quite the momentum because it is considered more environmentally acceptable than its counter parts (especially coal) and it has greater energy return on energy invested (Taylor *et al.*, 2012). Nevertheless, it has also been suggested that to meet global energy demand natural gas alone will not suffice so a combination with other sources is foreseen under specific circumstances and potential candidates range from geothermal power (Taddia *et al.*, 2018) to wave energy (Friis-Madsen *et al.*, 2019). Thus from an economic viewpoint, some experts believe the role of gas in the transition will follow two steps: first, an increased market share for gas as it replaces dirtier fuels; and second, a decreasing share for gas as it is replaced by the combination of renewables and storage (Townsend, 2019). Conversely, others believe that gas along with other renewables will have to coexist for quite some time to maintain industries running before the formers can actually replace the latter (Isaacs, 2006; Bessi, 2018). In addition, there is already an operational and physical infrastructure for natural gas production and distribution in many regions. A situation that would allow splitting investment between enhancing existing facilities (creating new facilities remains a complex and costly issue in countries with little or no infrastructure, e.g. China and India), and promoting more research and development in renewables and the technologies to support them. In fact, an important sector for innovation includes CO_2 Capture and Storage (CCS), that allow the reduction of CO_2 emissions in the atmosphere from large stationary sources, such as power plants fueled by fossil fuels, through its capture and subsequent storage in an underground geological formation (IPCC, 2005); the more recent Carbon Capture and Utilization (CCU) that combines CO_2 capture with its reuse both as a technological fluid and as a reagent for the production of chemical substances, plastics or fuels, thus obtaining a product of commercial value able to balance the costs necessary for CO_2 capture (Boot-Handford *et al.*, 2014); and the Capture Cache and Convert (CCC) that aims at CO_2 recycling by the use nanomaterials (Bocchini *et al.*, 2017).

To this end, for instance, the International Energy Agency (IEA) has outlined a major transformation of the global energy system in its Sustainable Development Scenario (SDS) to show how the world could change course to meet three of the United Nation's energy-related sustainable development goals (SDGs), namely: 1) to achieve universal access to modern energy; 2) to reduce the severe health impacts of air pollution; 3) to tackle climate change.An ambitious plan that sees natural gas playing a major role in a cleaner energy mix while accepting its drawbacks. Fatih Birol, Executive Director of the IEA, also believes that natural gas can contribute to a cleaner global energy system even though it must face its own challenges, such as remaining price-competitive in emerging markets and reducing methane emissions along the supply chain (IEA, 2019).The main strategy is a complete switch to natural gas from other fossil fuels, mostly from coal, which is still widely used for power generation by many countries (as already mentioned before China and India but even the U.S. and Europe). The success of this strategy will largely depend on the right combination of technical and non-technical factors. For instance, in countries like the U.S. the coal-to-gas switch has relied largely on the so-called shale gas revolution (even though a revival of the coal industry is currently under discussion). The switch has been responsible for around 18% of carbon emission reduction since 2010, albeit emissions from natural gas grew by 10% in 2018, highlighting that increased reliance on gas, on its own, does not necessarily provide a pathway to lower emissions. The situation in Europe is different because gas infrastructure is meant to meet significant peaks in its energy service demand, which means gas fulfils security as well as seasonal balancing functions that cannot be easily replicated by a renewables-based power system (Verga, 2018). An interesting case study can be found in Italy, with its long-standing natural gas infrastructure it is now also aiming at the possibility of using renewable energy in offshore Oil & Gas platforms for power supply optimization (Serri *et al.*, 2017). Conversely, as aforementioned, China and India continue to rely on coal for power generation, in fact these countries have developed incredibly efficient coal fleets to meet their respective energy demands. This shows how the different local conditions and policies determine how far they might be from a path to cleaner energy systems. For instance, Huang and Jhong (2013) presented an analysis of the supply chain, market, application development, and trend of green energy industries in Taiwan; their work was triggered by the Fukushima nuclear disaster after an earthquake hit Japan in 2011.

4. Conclusions

For quite a while now, experts and non-experts worldwide have highlighted and supported the need for a transition towards green energy, or should we say greener energy. Green energy does not mean "clean" energy. Green energy is just cleaner energy when compared to that coming from coal and oil fuels, but the problem of emissions would remain even if a transition were to be completed. Among the many energy transition alternatives, natural gas surely represents an appealing lower-carbon, lower-cost path to a yet-to-be-determined final solution. The main strategy of the next decades is a complete switch to natural gas supported by renewable energy from other fossil fuels, mostly from coal, which is still widely used for power generation by many countries (e.g. China, India but even the U.S. and Europe). Nevertheless, natural gas still emits carbon dioxide. In this perspective, an important sector for innovation for gas-fired power generation is CO_2 conversion – likely through capture, storage and re-use process.

Truth is, we should acknowledge that to really make a difference, the implementation of any new technology should be accompanied by revisions of our living habits in a more sustainable low-energy perspective.

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