Università
Ca'Foscari
Venezia

Corso di Laurea magistrale
in Relazioni Internazionali Comparate

Tesi di Laurea

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Energy and Environment

Between development and sustainability

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Anno Accademico
2013 / 2014

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ABSTRACT

Energia e ambiente risultano essere due elementi inscindibili nelle relazioni internazionali. Sin dall'antichità, svariate fonti energetiche sono state sfruttate per generare forza e calore, così permettendo l'evoluzione della società. Date le loro maggiori proprietà, il consumo dei combustibili fossili ha permesso un'accelerazione del progresso umano, tuttavia, tale incremento ha comportato seri problemi ambientali, prevalentemente legati all'immissione di agenti inquinanti nell'atmosfera. In particolar modo, l'aumento della concentrazione di gas serra ha determinato un incremento delle temperature medie terrestri con effetti distruttivi in alcune aree del pianeta. Il cambiamento climatico, generato dal surriscaldamento globale, è un problema comune, che deve essere affrontato in un contesto internazionale, se si vogliono evitare conseguenze irreversibili. Gli effetti del surriscaldamento non solo mettono a dura prova la vivibilità degli essere umani sul pianeta, ma costituiscono anche un freno per lo sviluppo delle generazioni presenti e future. Tale situazione peculiare ha fatto sì che venisse introdotto il concetto di sviluppo sostenibile, volto a garantire il progresso senza compromettere ulteriormente l'ambiente. La sostenibilità, infatti, punta sullo sfruttamento delle fonti di energia verde, in primis le rinnovabili, ma anche l'uranio, il cui impatto è senza ombra di dubbio nettamente inferiore a quello dei combustibili fossili. Oltre alle conseguenze ecologiche, un altro punto a favore delle fonti alternative è, fatta eccezione per l'energia nucleare, la loro capacità di rigenerarsi all'infinito.

La prima parte è interamente dedicata alla sicurezza energetica. Il primo capitolo fa chiarezza sul tema, il quale viene generalmente esplicato come la disponibilità di un'offerta energetica sufficiente a prezzi accessibili. Tale definizione si appresta a molteplici interpretazioni, che si rispecchiano nella composizione di altrettanto diversi mix energetici e nelle singolari problematiche che ogni nazione deve affrontare. Il secondo capitolo si concentra sulle principali fonti energetiche, i combustibili fossili. Dopo aver analizzato il ruolo fondamentale che essi hanno giocato, soprattutto nel corso del Novecento, vengono analizzate le tipologie esistenti di petrolio, gas e carbone, e il funzionamento delle rispettive industrie, al fine di evidenziare le componenti essenziali della sicurezza energetica. Il terzo capitolo indaga il

tema delle fonti alternative, separando l'energia nucleare da quelle rinnovabili. La descrizione dell'evoluzione e del ciclo del combustibile nucleare permettono di chiarire i nodi su cui si articola il dibattito sullo sfruttamento dell'uranio e sui rischi derivanti. Infine, dopo aver descritto le difficoltà di diffusione sofferte dalle energie rinnovabili, ne vengono descritte le più svariate soluzione di impiego.

La seconda parte esplora il tema della sicurezza ambientale. Il quarto capitolo fa chiarezza sul termine e sull'evoluzione degli studi sull'ambiente. In modo speculare al primo capitolo, vengono descritte le diverse interpretazioni proposte dalle scuole di relazioni internazionali. Vengono quindi analizzate le cause, sia naturali che antropogeniche, e gli effetti del mutamento ambientale, in particolare il cambiamento climatico. Il dibattito scientifico e politico inerente il surriscaldamento globale è al centro del quinto capitolo. Nonostante esista un ormai consolidato consenso nell'attribuire la responsabilità dell'innalzamento delle temperature medie terrestri alle attività umane, persistono ancora alcune voci discordanti, le quali criticano la marginalizzazione attribuita ai fenomeni naturali. A livello politico, il tema è oggetto di analisi da parte delle scuole di pensiero, oltre che da numerose conferenze internazionali, indette sotto l'egida delle Nazioni Unite. Di particolare importanza è indubbiamente la Conferenza di Rio, la quale ha aperto la strada agli incontri previsti dalla Convenzione sul Cambiamento Climatico, a volte conclusisi con l'adozione di fondamentali atti e documenti, tra cui il Protocollo di Kyoto.

La terza e ultima parte discute le prospettive che si presentano per il prossimo futuro. Nel sesto capitolo, vengono considerate le varie soluzione proposte per risolvere le cause e per ridurre l'impatto del cambiamento climatico. La loro implementazione non è tuttavia così semplice come potrebbe sembrare. L'esistenza di ostacoli di diversa natura, rende necessari uno studio accurato e una valutazione dei costi e dei benefici, al fine di permettere ai governi l'introduzione di una serie di misure volte a superare tali barriere. La sostenibilità è l'argomento portante del settimo capitolo. Lo sviluppo sostenibile costituisce una modalità per far fronte alla crescente domanda di energia e la salvaguardia ambientale. Le tre componenti essenziali della sostenibilità, ovvero economia, società e ambiente, vengono quindi analizzate all'intero di quattro progetti legati all'utilizzo dell'energia verde. Ognuno dei quali possiede delle caratteristiche peculiari con problematiche differenti. Tuttavia, l'inizio dei lavori dei primi tre e la realizzazione dell'ultimo fanno ben sperare sulle possibilità future di sfruttamento delle fonti rinnovabili per garantire i bisogni sia delle generazioni odierne sia di quelle future.

Diverse fonti sono state impiegate per la stesura del seguente lavoro. Il materiale in formato cartaceo, scritto da esperti delle tematiche affrontate, sono servite prevalentemente per la descrizione del contesto storico e per l'inquadramento della materia. Articoli di giornale e riviste, alcuni dei quali disponibili anche nei rispettivi siti web, sono stati presi in esame per descrivere la situazione attuale concernente il problema energetico, il surriscaldamento globale e il conseguente cambiamento climatico. Infine, si sono rivelati molto utili i siti sia di importanti organizzazioni governative internazionali, quali le Nazioni Unite e le agenzie da essa dipendenti, l'Unione Europea, e la Banca Mondiale, sia di organizzazioni non-governative che si occupano del problema ambientale, tra cui il World Wildlife Fund (WWF), Greenpeace, e la Croce Verde Internazionale. I materiali impiegati sono stati scritti da studiosi, politologi, economisti e giornalisti di differente nazionalità, così permettendo di evidenziare l'esistenza di diversi punti di vista concernenti la questione energetica e ambientale.

I temi trattati e le notizie più recenti permettono di trarre alcune considerazioni finali. Certamente notevoli passi in avanti sono stati fatti per salvaguardare l'ambiente senza compromettere la possibilità di sviluppo della popolazione mondiale. L'elevato prezzo del petrolio ha garantito maggiori investimenti nelle tecnologie rinnovabili, tuttavia il recente declino del greggio potrebbe compromettere la transazione verso un'economia verde. L'introduzione da parte dei governi di alcune importanti provvedimenti potrebbe comunque favorire il consumo di energia proveniente da fonti rinnovabili. Ciononostante, ulteriori progressi sono necessari anche in campo tecnologico, volti soprattutto a ridurre il maggiore costo dell'energia alternativa. A livello internazionale, il principale problema è stata la contrapposizione tra le due principali potenze economiche, ovvero gli Stati Uniti d'America e la Repubblica Popolare Cinese. L'accordo firmato dai rispettivi Presidenti sembra aver risolto l'impedimento basilare alla stesura di un trattato vincolante tra tutti i paesi del mondo, che dovrebbe essere approvato alla Conferenza delle Parti che si terrà a Parigi nel 2015 tra la fine di novembre e l'inizio di dicembre. Il mancato raggiungimento di un accordo e della successiva ratifica aumenterà il rischio per la stabilità politica, sociale ed economica, man mano che gli effetti del mutamento climatico si faranno sentire.

INTRODUCTION

Energy has always been extremely important for human beings. It is essential for life, economy, and trade. Moreover, energy is a necessary element for the development of a country. Nevertheless, energy raises important concerns about the future, regarding the availability of fossil fuels and the impact that their consumption have on the environment. As a result, both energy and environmental security are at the center of the political debate, in an attempt to find solutions to these issues at the national, regional and global levels. The lack of a concrete response cannot help but upset the precarious existing international balance, giving rise to potential conflicts between countries.

The development of humankind has been driven by energy. Since ancient times, sailboats and sailing ships have been exploiting the strength and intensity of winds. In Imperial Rome, hydropower was used to grind grain in the mills, but also to saw timber and stone. Throughout the Middle Ages, wood and biomass were burned to heat homes and to cook food, and water was channeled to irrigate fields. By the 14th century, post mills were largely in use in England, Spain and the Netherlands. During the Industrial Revolution, the Britons, first, and then the rest of the world, built steam engines fueled by coal.

The development of industry was possible thanks to the use of fossil fuels. The lack of timber, due to the widespread deforestation, led to the exploitation of coal.[1] Steam engines drove machineries in factories, powered pumping stations, and propelled railway locomotives, ships and cars. Different types of gases and petroleum were combusted to generate artificial light during night hours. In 1882, Thomas Edison opened the first coal-fired electric power plant in New York City.[2] Although this power plant was not able to produce much energy, it marked the beginning of the age of electricity.[3] In 1888, the inability of Edison's direct current electricity to travel far was overcome by Nikola Tesla's alternating current,

[1] Deron LOVAAS, *Balacing Energy Security and the Environment*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, Santa Barbara, Praeger Security International, 2009, p. 319.
[2] Ibid., p. 320.
[3] Jill JONNES, *Empires of Lights: Edison, Tesla, Westinghouse, and the Race to Electrify the World*, New York, Random House, 2004, p. 84.

which, by using a transformer, enabled the transmission of electricity over long distances, thus achieving significant economies of scale and lower costs.[4] Electricity permitted to increase industrial production and to improve living conditions.

Energy products are the largest traded commodities in the world. The eminent role played by fossil fuels is mainly the consequence of the mismatch between major consuming and major producing countries.[5] Most industrialized nations lack extensive reserves of hydrocarbons; consequently, they import them from regions rich in energy sources. Very often, the largest consumers are importers, since they require large amounts of energy to meet their needs. By contrast, many producers export part of their production to obtain a profit from the sale of fuels in the international market, in order to buy goods and services and to increase foreign exchange reserves.

The growing demand and consumption of fossil fuels is increasing the emissions of greenhouse gases (GHG). Although these gases are naturally occurring in the atmosphere, an excessive concentration can dramatically alter global temperatures, thus provoking disruptive effects on the environment, the society and the economy.[6] Nevertheless, global warming is just one of the repercussions fossil fuels have on the natural world. Climate change puts a strain on the survival of ecosystems by impoverishing biodiversity.[7] Species loss and habitat destruction is not simply the result of the discharge of polluting materials, but also a consequence of the degradation and excessive consumption of water.[8] In order to avoid apocalyptic scenarios, many countries have adopted environmentally friendly policies, such as plans to reduce the emissions of carbon dioxide and projects to increase the production of energy from renewable resources.

Several actions can be undertaken to response to global warming and climate change. Mitigation typically consists in the limitation of anthropogenic emissions of GHGs, but it also refers to all the policies that can help to reduce the risks associated with human activities.

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[4] Daniel YERGIN, *The Quest: Energy, Security, and the Remaking of the Modern World*, New York, Penguin Books, 2012, p. 351.
[5] Gawdat BAHGAT, *Energy Security: An Interdisciplinary Approach*, Chichester, John Wiley and Sons, Ltd., Publication, 2011, p. 1.
[6] John M. DEUTCH, *The crisis in energy policy*, Cambridge, MA, Harvard University Press, 2011, p. 27.
[7] Carlos PASCUAL and Evie ZAMBETAKIS, *The Geopolitics of Energy: From Security to Survival*, in Carlos PASCUAL and Jonathan ELKIND, *Energy Security: Economics, Politics, Strategies, and Implications*, Washington, D.C., Brookings Institution Press, 2010, p. 23.
[8] Marilyn A. BROWN and Benjamin K. SOVACOOL, *Climate Change and Global Energy Security: Technology and Policy Options*, Cambridge, MA, The MIT Press, 2011, p. 18.

Another counteraction is adaptation, also called resilience, which encompasses all the efforts taken to moderate the vulnerability of humans and ecosystems. Finally, climate or geo-engineering comprises the deliberate and extensive intervention in the Earth's climatic system.[9] Nonetheless, it is necessary to evaluate their potential negative impacts and unintended repercussions.[10]

The purpose of the following work is not simply to discuss their importance, but also to assess how they interact with each other and shape the future of the planet. The first two sections respectively explore energy and environmental security, while the last part focuses on the relationship between the future energy needs and the preservation of the ecosystem.

In chapter 1, in addition to the definition of energy security, the ongoing debate between realists and liberalists upon the issue is discussed. Moreover, it is explained what the energy mix is and which the main sources of energy are, that is to say how they are subdivided and classified. Finally, the growing risks and problems that leads to insecurity and uncertainty about the future are examined.

In chapter 2, the focus is on fossil fuels. A short historical evolution on the use of non-renewable resources is given to highlight their prominence in the energy sector. This part is followed by a description of how the industry of hydrocarbons is structured, referring also to the main producing and consuming countries. In addition, the differences existing between distinct categories of oil, natural gas and coal are illustrated. Moreover, the theory of peak oil is explained.

Chapter 3 is dedicated to alternative energy. Renewable resources are examined by distinguishing their peculiarities, in addition to drawing the evolution in their use. Besides, it is depicted the existing projects that exploit the electricity that can be produced from these sources. Nuclear power is analyzed separately to analyze the criticism and ongoing debate on its use. Moreover, the history and the potential evolution of the nuclear industry is explained.

Climate change and global warming are the central topics in chapter 5. After encompassing the broad range of interpretations given to the term environmental security, both the contribution of natural processes and human activities to climate change are examined. In addition, the causes and the effects that climate change and global warming have on the

[9] Ibid., pp. 125-127.
[10] Ibid., pp. 147-149.

environment are demonstrated.

Chapter 6 provides a framework on climate debate. The divergent ideas and opinions about climate change, which are the principal point of disagreement between scientists and policy-makers, are traced. Nonetheless, despite these different beliefs, the governments of several states and international organizations are cooperate in an attempt to reach an international agreement to deal with the problem. The annual conferences organized by the United Nations are of considerable importance. For the most important meeting, the intended aims and the results achieved are compared.

Chapter 7 encompasses the possibilities available to deal with the increasing demand for energy and the damaging consequences resulting from the consumption of fossil fuels. There are several policies that can be adopted to solve, or at least to mitigate, global warming, while ensuring energy requirements. Nonetheless, in considering these remedies, it is necessary to evaluate the existing barriers and ponder the possible solutions to their implementation.

Sustainability is the core of chapter 8. After giving a definition of the term, its history and its three dimensions (environmental, economic and social) are drawn. This part is followed by an analysis of the chance to guarantee a certain level of production of energy, respecting at the same time the ecosystem. To conclude, the future projects are depicted, evaluating their feasibility and their limits.

The concluding section consists of a summary of the main topics discussed in the previous three parts. Definitions, classifications and examples are resumed by contemplating the links between energy, environment and sustainability. Moreover, personal considerations and final remarks on these issues and the perspectives for the future are deduced.

Different sources were consulted for the writing. Several books and articles, written by academics, scientists and experts, were parsed to provide an overview on energy and environmental security. In addition, data published on the websites of both international organizations and energy companies were considered for a better understanding of the current situation. Nevertheless, it should be reminded that most estimates for the future are based on equations, whose results may be divergent depending on the entered inputs. Therefore, biases are possible. For this specific reason, it was also helpful to analyze conflicting versions about the same subject.

PART 1

ENERGY SECURITY

Chapter One
Energy Security

1.1 What is energy security?

1.1.1 Definition of energy security

The most accredited definition of energy security is "availability of sufficient supplies at affordable prices."[1] This is the explanation given by both energy experts and international organizations. On the website of the International Energy Agency, the definition of what energy security is also includes the notion of availability and affordability.[2] Similar, but somehow more complete, is the statement by the World Coal Association: "energy must be readily available, affordable and able to provide a reliable source of power without vulnerability to long- or short-term disruptions."[3]

Considering these interpretations, it is possible to assert that energy security is about the availability of sufficient energy sources at affordable prices from a reliable source for the near future to meet the needs of the community. Therefore, it is evident that energy security comprises at least three main elements: availability, reliability, and affordability. Lately, given the impact of energy consumption, in particular that of fossil fuels, on the environment, it is necessary to evaluate a forth characteristic: environmental sustainability.[4]

Nowadays energy security is a term that is widely used by both policy-makers and academics; therefore, it may seem that energy security has a unique meaning. Nevertheless, it is important to consider that a common definition of the expression does not exist. The different interpretations given to the concept are the result of distinctive perceptions of what

[1] Daniel YERGIN, *The Quest: Energy, Security, and the Remaking of the Modern World*, p. 268.
[2] INTERNATIONAL ENERGY AGENCY, *Energy security*, 2014, <www.iea.org/topics/energysecurity/>.
[3] WORLD COAL ASSOCIATION, *Coal & Energy security*, 2014, <www.worldcoal.org/coal-society/coal-energy-security/>.
[4] Jonathan ELKIND, *Energy Security: Call for a Broader Agenda*, in Carlos PASCUAL and Jonathan ELKIND, *Energy Security: Economics, Politics, Strategies, and Implications*, pp. 121.

energy security is.[5]

1.1.2 Elements of energy security

By availability, it is meant the accessibility of and readiness to use energy goods and services. Consequently, the existence of markets where energy goods and services are bought and sold is of extreme importance. Markets, regardless of their type, therefore also the energy ones, need a series of components to work. The essentials are the presence of goods and services to exchange, the existence of one of more buyers and sellers, and a place where traders can meet. In addition to these basic constituents, it should be included: physical resources, capital investments, the efficient application of technology, as well as proper legal frameworks.

Energy security is primarily focused on fossil fuels; thus, uncertainties exist over technological gaps, which might make abundant deposits of resources not exploitable; the costs necessary for the development of new sites; the location of fuel extraction, due to potential political disruptions; and environments that are not conducive to investments.[6] Accordingly, policy-makers should focus on these problems if they want to satisfy the availability dimension of energy security.

Reliability consists in the dependability on something. In the case of energy, the term refers to the degree to which its use is shielded from interruption. As a result, being energy so fundamental to economy, disconnections jeopardize the whole system. Reliability can be enhanced in several ways, including the diversification of sources, suppliers and transportation routes, the creation of emergency stocks, the reduction of energy demand, and the development of an extended infrastructure.[7] All these remedies can increase security and, as a consequence, reduce the risks associated with dependency from supplies deriving from only one source or one country.

The possibility to use energy is called affordability. Although consumers prefer low-cost energy, low prices are incompatible with energy security. Indeed, inadequate revenues to producers discourage investments in new and more efficient infrastructures, as well as in

[5] Sascha MÜLLER-KRAENNER, *Energy Security: Re-Measuring the World*, London and Sterling, VA, Earthscan, 2007, p. 20.
[6] Jonathan ELKIND, *Energy Security: Call for a Broader Agenda*, in Carlos PASCUAL and Jonathan ELKIND, *Energy Security: Economics, Politics, Strategies, and Implications*, pp. 121-124.
[7] Ibid., pp. 124-125.

research. At the same time, users are encouraged to increase their consumptions. As a result, it can be affirmed that prices are a fundamental part of this aspect of energy security. Nevertheless, it is not just a matter of low or high prices. Their tendency to vary often and widely, that is their volatility, is even more important. Prices influence consumptions and investments; hence, consumers are more vulnerable whenever there is a sudden change. Price shocks can also lead to economic, social and political instability.[8]

Even though the classic aforementioned definitions of energy security do not englobe it, it is essential to include a forth characteristic.[9] Sustainability is the property of a process or a state to be maintained at a certain level indefinitely. The greedy and constantly increasing depletion of fossil fuels is the main reason why this element is so much debated. Sustainable energy should satisfy the needs of the present without undermining the ability of future generations to meet their necessities.

1.1.3 Different interpretations of energy security

Each country faces a distinctive energy security position on the base of the aforementioned peculiarities. Certainly, the needs of a state are shaped by its uniqueness, which depends on its geographical location, its geological endowment, its international relations, its system of governance, and its economic development.[10] In broad terms, consuming countries seek a variety of sources, suppliers, and transportation routes; whereas producers try to expand their portfolio of clients by assuring that their production will be purchased.[11]

Despite these universal principles, it is still possible to split the interpretation given to energy security. In Europe and North America, it is basically the necessity to diversify sources and suppliers. Nonetheless, the United States, despite its current growing production, is more dependent on oil and on the Middle East, whilst Europe is more reliant on natural gas, mostly imported from Russia.[12] For China and India, it is about the availability

[8] Ibid., pp. 126-128.
[9] Ibid., pp. 121.
[10] Leon FUERTH, *Energy, Homeland, and National Security*, in Jan H. KALICKI and David L. GOLDWYN, *Energy and Security: Toward a New Foreign Policy Strategy*, Washington, D.C., Woodrow Wilson Center Press, and Baltimore, Johns Hopkins University Press, 2005, pp. 411-413.
[11] Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, Santa Barbara, Praeger Security International, 2009, p. 336.
[12] Carlos PASCUAL and Evie ZAMBETAKIS, *The Geopolitics of Energy: From Security to* Survival, in Carlos PASCUAL and Jonathan ELKIND, *Energy Security: Economics, Politics, Strategies, and Implications*, p. 9.

of enough resources, in order to reach their potential economic and social growth.[13] Even in this case, it is possible to make a distinction based on how the two states try to resolve their energy insecurity. While Chinese companies are acquiring international oil reserves and constructing pipelines, Indian firms are focusing on investments in several African countries and on commercial factors.[14] Japan is extremely poor in energy resources, thus, it is dependent on imports. However, compared to other countries in a similar situation, it has a diversified supply and is more efficient in its exploitation.[15]

Another possible distinction is based on the use of energy sources. The two principal uses of energy are electricity and transport; as a result, it is realistic to consider that countries have different perceptions of energy security. Some states are completely energy independent, as in the case of Russia and Saudi Arabia. Then there are those nations that are self-sufficient in one sector, but not in the other. The United States and France, for instance, completely satisfy their own electric needs, respectively thanks to oil and nuclear power production, but are still dependent on imports for the transportation sector. Instead, Brazil is heavily subjected to fossil fuels just for its electric consumption, but not for road vehicles, which are fueled by ethanol. Finally, there are vulnerable countries that rely on imports to serve their needs.[16]

In addition to the differences found at the national level, there are also discrepancies at the local level. Many people in sub-Saharan Africa, but also in Asia and Latin America, do not have access to energy. This peculiar situation, defined as energy poverty, consists in the lack of access to electricity; therefore, populations in those areas rely on firewood to heat their homes and cook food. Energy security to them, certainly, has a complete distinct meaning. According to data published by the International Energy Agency (IEA), globally over 1.3 billion people do not have access to electricity and 2.6 billion people do not possess cooking facilities, respectively equal to 18% and 38% of the worldwide population.[17] Thus, it is evident that a solution to this problem will contribute to human well-being and

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[13] Sascha MÜLLER-KRAENNER, *Energy Security: Re-Measuring the World*, p. 20.
[14] Amy MYERS JAFFE and Kenneth B. MEDLOCK III, *China, India, and Asian* Energy, in Jan H. KALICKI and David L. GOLDWYN, *Energy and Security: Strategies for a World in Transition*, Washington, D.C., Woodrow Wilson Center, and Baltimore, Johns Hopkins University Press, 2013, p. 289.
[15] Keiichi YOKOBORI, *Japan*, in Jan H. KALICKI and David L. GOLDWYN, *Energy and Security: Toward a New Foreign Policy Strategy*, p. 304.
[16] Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, p. 6.
[17] INTERNATIONAL ENERGY AGENCY, *Energy poverty*, 2014, <www.iea.org/topics/energypoverty/>.

development.

1.1.4 Theories about energy security

Energy security is also a matter of debate within International Relations theorists. Liberalism, realism and historical materialism have divergent opinions about what energy security really means. Subsequently, it is worth understanding their dissimilar interpretations.

Liberalism concentrates on the core constituents of international relations: peace and co-operation. Since the end of the Cold War, inter-state competition has decreased; as a result, war between the core powers is seen as an obsolete phenomenon. Liberalists affirm that states can collaborate in a win-win situation, in which each of them can gain something. According to this perspective, free trade benefits all participants, as it prevents conflicts and ensures strong partnerships and interdependence.[18]

In this context, energy resources cannot cause clashes between nations. While importing countries are reliant on fossil fuels, producers want to assure enough demand. A war would break the equilibrium between the economic interests of the two sides. Moreover, the liberal approach is market-oriented, meaning that governments should interfere with the market only in case of disruptions. Therefore, countries want to guarantee stability in the market, so to maintain and maximize their profits.[19]

In contrast with the liberal thought, realists are generally pessimistic and skeptic. They think that challenges will worsen, leading to another era of confrontation. Countries try to pursue their own interests and consider energy as an instrument of foreign policy; therefore, they will compete over the control of energy resources. Markets do not ensure peace and stability, as claimed by liberal thinkers. On the contrary, nationalistic sentiments prevail, leading to statism and neo-mercantilism. According to realists, the main problem of idealism is its belief in the rationality of markets, which underestimates the ability of producing countries to use their energy resources as a weapon.[20]

Historical materialists indicate that energy security can only be understood within the framework of global capitalism. Economic elites in the major industrialized countries

[18] Ruchita BERI and Uttam K. SINHA, *Africa and Energy Security: Global Issues, Local Responses*, New Delhi, Academic Foundation, 2009, pp. 183-184.
[19] Sam RAPHAEL and Doug STOKES, *Energy* Security, in Allan COLLINS, *Contemporary Security Studies*, Oxford, Oxford University Press, 2013, pp. 309-310.
[20] Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, pp. 340-341.

consider oil as the backbone of the current business system; therefore, capitalist states intervene to maintain the favorable conditions that support an unequal distribution of wealth and power to their own advantage. However, there are two different ideas about this control of oil supplies. States may act as pawns in oil-rich countries in order to meet the interests of the international oil companies (IOCs). Contrary to the blood-for-oil thesis, they may enjoy a relative freedom by operating for the capitalist interests.[21]

1.2 Diversification of the energy mix

1.2.1 Types of energy sources

Energy sources can be classified into different ways. These distinctions depend on which aspect of the resources is contemplated. Therefore, it is possible to distinguish sources based on their nature, their regeneration capacity, and their impact on the environment [Table 1].

The categorization of energy by nature considers the natural elements existing in the material world. Consequently, energy can be split into primary and secondary forms. The first term refers to accessible sources that can be used as they appear in the natural environment, the only exception being those that cannot be exploited directly. On the other hand, secondary energy derives from the conversion of primary sources into energy carries, mainly transportation fuels and electricity, so to be ready for final users' consumption. This final energy can be used in four main sectors: industrial, transportation, commercial, and residential.[22]

Natural resources have dissimilar regeneration capacities. This characteristic allows discerning between renewable and nonrenewable sources. The first group includes all those forms of energy that can freely regenerate, and whose reserves are practically limitless. Therefore, renewables are solar, wind, geothermal, hydropower, tidal energies, and biomass sources. The second cluster embraces sources that are finite, because their reserves

[21] Sam RAPHAEL and Doug STOKES, *Energy Security*, in Allan COLLINS, *Contemporary Security Studies*, p. 311.

[22] Alexandre ROJEY, *Energy and Climate: How to achieve a successful energy transition*, Chichester, John Wiley and Sons, Ltd, Publication, 2009, pp. 2-5.

are exhaustible. Accordingly, crude oil, coal, natural gas and natural uranium are all nonrenewable forms of energy.[23]

Energy resources can also be classified by their impact on the environment. Fossil fuels, that is oil, coal and natural gas, are formed by the decomposition of plants and animals buried by layers of rock, under a certain temperature and atmospheric pressure, over millions of years. When burned, the carbon they contain is released into the atmosphere, thus increasing the concentrations of greenhouse gases.[24] Alternative energies represent substitutes to fossil fuels. These energies, which are intended to address environmental concerns, are also called green energies. The group comprehends those sources that can be exploited with little pollution, namely some forms of nuclear power and renewable energy.

Table 1. Classification of energy sources.

<table>
<tr><th colspan="3">Primary energy sources</th><th>Main energy carrier by source</th></tr>
<tr><td rowspan="4">Non-renewable sources</td><td rowspan="3">Fossil fuels</td><td>Oil</td><td>Transportation</td></tr>
<tr><td>Coal</td><td rowspan="9">Electricity</td></tr>
<tr><td>Natural gas</td></tr>
<tr><td rowspan="7">Alternative energies</td><td>Uranium</td></tr>
<tr><td rowspan="6">Renewable sources</td><td>Solar energy</td></tr>
<tr><td>Wind energy</td></tr>
<tr><td>Geothermal energy</td></tr>
<tr><td>Hydropower energy</td></tr>
<tr><td>Tidal energy</td></tr>
<tr><td>Biomass sources</td></tr>
</table>

1.2.2 Definition of the energy mix

The energy mix is defined as the distribution in different proportions of the available energy sources that each country uses to meet its energy needs.[25] It mainly refers to primary

[23] U.S. ENERGY INFORMATION ADMINISTRATION, *Energy Sources*, 2014, <www.eia.gov/kids/energy.cfm ?page=2>.
[24] U.S. DEPARTMENT OF ENERGY, *Fossil*, 2014, <www.energy.gov/science-innovation/energy-sources/fossil>.
[25] PLANÈTE ÉNERGIES, *The Energy Mix*, December 3, 2013, <www.planete-energies.com/en/the-energy-of-tomorrow/the-energy-mix.html>.

sources of energy; however, it can also be related to energy carriers. In the latter case, the shares that contribute to the production of either transportation fuels or electricity are evaluated.

It is evident that each state and region in the world has a different composition of the energy mix. The different proportions primarily depend on both the geological endowment and the needs of a country. In addition, other factors must be assessed. For instance, economic growth, investments and the existing infrastructures can induce a nation to consume additional quantities of energy. Even demographic growth and changes in consumption behavior have an impact on the energy mix. In addition, the greater importance that the environment is receiving can alter the proportions of sources that are used, in particular by reducing the consumption of fossil fuels in favor of renewables. Finally, the energy mix depends also on the political choices taken by governments, which in some cases may prefer the exploitation or import of one fuel to the others.[26]

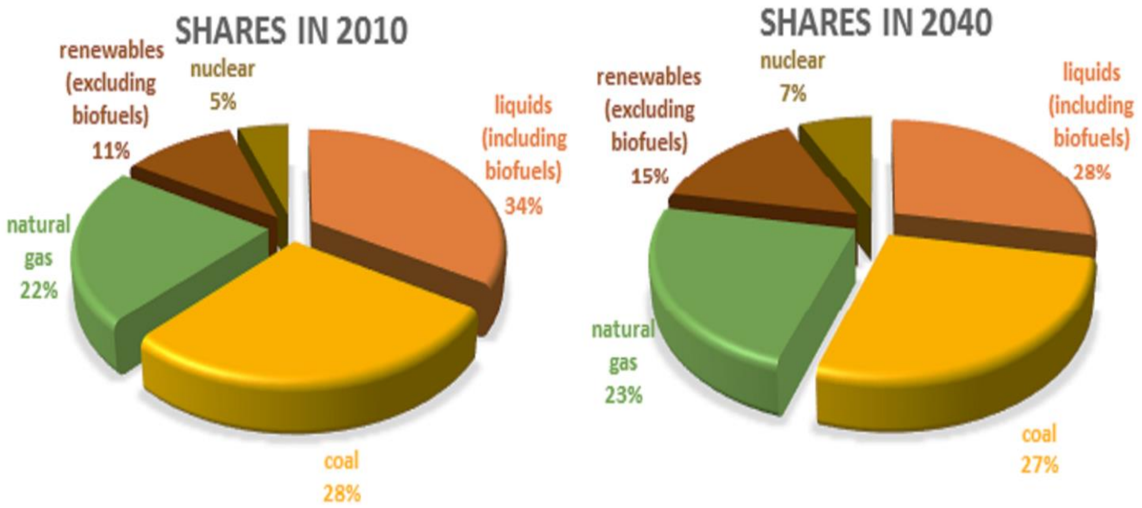
Since the Industrial Revolution, fossil fuels has supplied much of the energy used worldwide. According to estimates by the U.S. Energy Information Administration (EIA)[27], they are supposed to remain the largest sources of energy and their consumption is expected to increase. Nonetheless, renewables are projected to boost their shares and are already considered the world's fastest growing form of energy [Figure 1].[28] In 2012, energy consumption was dominated by fossil fuels, which generated about 87% of the worldwide utilization, whereas, excluding hydropower, renewables accounted for only 2% [Figure 2].[29]

Primary energy sources are processed to other forms that can be used by society. Consequently, in this case, the energy mix depends on the final utilization. The two principal energy carriers are transportation fuels and electricity. While fuels used in the transportation sector are mainly derived from oil, with little other possibilities, electricity is more flexible. In the electric sector, the most used sources are coal, natural gas, nuclear and hydropower energies.[30] It is, therefore, interesting to evaluate how each state produces electricity. For

[26] Ibidem.
[27] The U.S. Energy Information Administration (EIA) is an agency of the U.S. Department of Energy.
[28] U.S. ENERGY INFORMATION ADMINISTRATION, *International Energy Outlook 2011*, September 2011, <www.eia.gov/ieo/pdf/0484(2011).pdf>.
[29] BP, *BP Statistical Review of World Energy 2013*, June 2013, <www.bp.com/content/dam/bp/pdf/statistical-review/statistical_review_of_world_energy_2013.pdf>.
[30] Daniel YERGIN, *The Quest: Energy, Security, and the Remaking of the Modern World*, pp. 400-401.

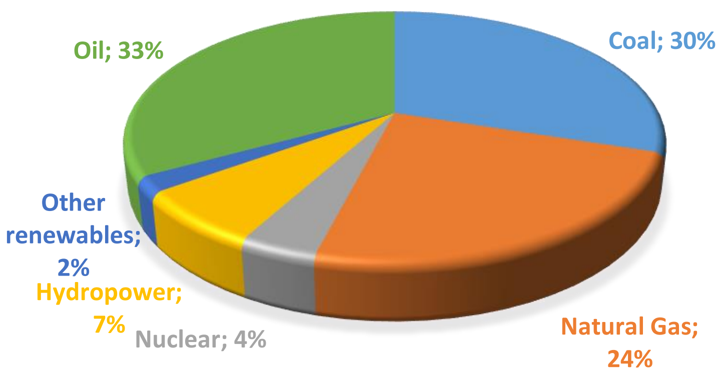
instance, France obtains more than 78% of its electricity[31] from the 58 nuclear reactors scattered throughout its territory.[32] Another outstanding example is that of Iceland, where geothermal energy is the largest component, being even larger than all the other energy sources combined.[33]

Figure 1. World Energy Consumption by Fuel in 2010 and Projections for 2040. Liquids and coal are expected to reduce their shares in comparison with renewables.



Data: EIA, International Energy Outlook 2013

Figure 2. World Energy Consumption by Source in 2012.Fossil fuels accounted for 87% of the global consumption of energy. With the exception of hydropower, renewables weighted for only 2%.



Data: BP Statistical Review of World Energy 2013

[31] Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, p. 302.
[32] Daniel YERGIN, *The Quest: Energy, Security, and the Remaking of the Modern World*, p. 380.
[33] ORKUSTOFNUN NATIONAL ENERGY AUTHORITY, *What are the sources of energy used in Iceland?*, 2014, <www.nea.is/the-national-energy-authority/energy-statistics/primary-energy/sources-of-energy/>.

1.3 Growing risks

1.3.1 Energy insecurity

Many people live in circumstances of energy insecurity. Energy insecurity refers to the condition in which energy security is undermined. Obviously, the problem tends to manifest differently around the world. In the industrialized North, energy insecurity is mainly about the uncertainty of future supplies, while in the rest of the world the principal concern is about the lack of energy, even in countries where sources of energy exist. This peculiar plight can be due to several reasons, for instance shortages, sabotage, and insufficient infrastructure. Consequently, energy insecurity has a deep impact on the quality of life for these communities.[34]

Energy insecurity can generally result from threats to energy security. These concerns can be clustered into four groups: geological, geopolitical, economic, and environmental.[35] The geological risk alludes to the shortage and depletion of energy sources, which, as a result, will not be able to meet future demand. The relations among states, in particular those between consumers and suppliers, and their competition for the control of proven or possible resources is at the core of the geopolitical concern. The economic threat focuses on the insufficient monetary means to invest in and the feasibility of new technologies and projects. Finally, the environmental risk concerns the impact that climate change and extreme natural events have on the energy infrastructures.[36]

The aforementioned threats imply that the energy problem is intertwined with the whole scale of security concerns. The governments of resource-rich states, in particular oil-rich countries, base their entire national economy on oil revenues, which, very often, are used to support the regime. In other words, they take advantage of traded oil to ensure their own regime security. This situation have a deep implication on development, as governments do not invest in other economic sectors, which represent a detriment for the local population. Moreover, the confrontation for the control of energy resources around the world, and the consequent militarization, can have significant consequences for both human and

[34] Sam RAPHAEL and Doug STOKES, *Energy* Security, in Allan COLLINS, *Contemporary Security Studies*, p. 307.
[35] Gawdat BAHGAT, *Energy Security: An Interdisciplinary Approach*, p. 2.
[36] Ibid., p. 36.

international securities. Finally, the increasing addiction to fossil fuels affect environmental security, resulting in extreme repercussions for society as a whole.[37]

The policy strategies, which can be adopted by executives, englobe three perspectives. Robustness aims on hazards that derive from foreseeable and largely controlled features of energy systems. It includes economic, technical, and natural factors. Sovereignty concentrates on disruptions deriving from deliberate actions of various actors. Therefore, it is associated with energy independence.[38] Lastly, resilience emphasizes unpredictable causes of any nature.[39]

1.3.2 Geological risk

The geological risk, which is the possible exhaustion of energy resources, is becoming more pressing. Indeed, the continuous consumption of fossil fuels is depleting reserves. According to BP[40], the global demand for energy, especially led by emerging countries, is forecasted to increase by 41% from 2012 to 2035. China and India alone are estimated to account for more than half of the increase. Although the energy mix is becoming more differentiated, it will continue to be dominated by fossil fuels.[41]

In the International Energy Outlook 2013, the U.S. Energy Information Administration claimed that demand will boost from 524 quadrillion British thermal units (Btu)[42] in 2010 to 820 quadrillion by 2040.[43] This rising demand coming from non-OECD countries is mainly due to their sustained economic growth.[44] Considering the finite nature of fossil fuels, it is obvious that the current projections pose a major problem for future generations.

Reserves are being consumed faster than they are renewed. Therefore, competition over the control of resources will become more probable. In addition, shortages of fuels will halt

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[37] Sam RAPHAEL and Doug STOKES, *Energy Security*, in Allan COLLINS, *Contemporary Security Studies*, p. 307.
[38] Energy independence refers to reducing imports of energy resources.
[39] Aleh CHERP and Jessica JEWELL, *Measuring Energy Security: From universal indicators to contextualized frameworks*, in Benjamin K. SOVACOOL, *The Routledge Handbook of Energy Security*, New York, Routledge, 2011, pp. 332-333.
[40] BP is a British multinational oil and gas company. It was formerly known as British Petroleum.
[41] BP, *Energy Outlook*, January 15, 2014, <www.bp.com/en/global/corporate/about-bp/energy-economics/energy-outlook.html>.
[42] British thermal unit (Btu) is defined as the amount of energy needed to change the temperature of one pound of water by one degree Fahrenheit (0.556° Celsius), equivalent to 1,055 joules.
[43] One quadrillion Btu corresponds to 172 million barrels of crude oil.
[44] U.S. ENERGY INFORMATION ADMINISTRATION, *EIA projects world energy consumption will increase 56% by 2040*, July 25, 2013, <www.eia.gov/todayinenergy&detail.cfm?id=12251>.

the development phase in many countries around the world, while, at the time, it will undermine the economic system of industrialized nations.

Governments, scientists and international oil companies proposed some solutions to deal with this increasing problem. These include finding more hydrocarbons, using energy wisely, and developing alternative energy. New technologies have enabled discovering new reserves, in addition to ensure the exploitation of proven deposits that were not previously attainable. Energy efficiency can help to reduce the waste of sources during extraction, transportation and consumption, thus saving part of them for future generations. Finally, the transition to other forms of energy, in particular renewable, can provide new raw materials for fuels and new sources of power.[45]

1.3.3 Geopolitical risk

The uneven distribution of hydrocarbon and coal reserves can destabilize the geopolitical equilibrium. The main risks are internal instability, terrorism, politically motivated interruption of energy provisions, territorial contention, maritime security, and transit states.[46]

Internal instability takes the form of insurgencies and civil wars. The tensions can have a varied nature, encompassing social breakdown, poverty, economic failure, famine, disease, racial and religious discrimination, institutional weakness, and environmental damages.[47] This precarious situation could affect a country's extractive capacity, leading to a lower production of fossil fuels. Moreover, given the uncertainty about the ability of that state to export in the future, the consuming countries will reduce their import quotas.

The case of Nigeria is significant. In the Niger delta, remarkable poverty and environmental deterioration has provoked both peaceful and armed protests. The Movement for the Emancipation of the Niger Delta (MEND) keeps accusing the Federal Government and the IOCs to enrich themselves at the expense of local populations and to destroy the ecosystem of the region. The oil drillings, in fact, has been polluting the soil, air and water, greatly reducing the fertility of the soil and lowering the reproduction of fish.[48] Through kidnappings, murders, sabotage of the oil network, MEND members demand a just share of oil revenues

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[45] CHEVRON, *Energy Supply and Demand*, Chevron, May 2014, <www.chevron.com/globalissues/energysupplydemand/>.
[46] Gawdat BAHGAT, *Energy Security: An Interdisciplinary Approach*, p. 15.
[47] Richard JACKSON, *Regime* Security, in Allan COLLINS, *Contemporary Security Studies*, pp. 162-164.
[48] Gawdat BAHGAT, *Energy Security: An Interdisciplinary Approach*, p. 122.

to be invested in the construction of roads, schools and hospitals.[49] From 2006 to 2009, their attacks reduced the country's oil output by almost one-third, considerably increasing global oil price. At the beginning of 2014, the group's spokesman, Jomo Gbomo, alleged the intention to completely cut Nigerian oil production by 2015, and to oust oil companies from the region.[50]

Another example is Iraq. According to estimates by the EIA, with a total of 141 billion barrels, Iraq holds the fifth-largest proven oil reserves in the world.[51] However, Iraqi production is far below its potential. Already compromised by the First Gulf War, the resumption of production has suffered a setback following the outbreak of the civil war between the Shiite and Sunni factions, and the insurgencies due to the high unemployment rate, after the fall of Saddam Hussein's regime. In the spring 2004, Iraqi output was equal to two-thirds of its capacity, and it was not until 2009 that it reached its prewar level.[52]

Terrorism is another menace to energy security. It encompasses armed assaults against energy facilities, as well as illegal activities orchestrated against them, if conducted to provide an economic bonanza or publicity to terrorist organizations. The main motives that push state or non-state actors to commit the attacks are the desire to disseminate panic among civil population, to make a government look unable to protect, and to harm a country's economy.[53] The whole energy system is very vulnerable. Therefore, it is necessary to increase security measures not only in the production, processing and transportation facilities, but also in the corporate offices and deposits. Moreover, even the personnel should be protected by potential assaults and kidnappings.

In February 2006, for instance, an attempt of terrorist attack took place in Abqaiq processing plant. Guards were killed and two pickups entered the facility. While one driver took a wrong way, and detonated himself in a parking lot, the other vehicle past his target, so the blast did not damage the infrastructures. Although without success, the attempt

[49] Caroline DUFFIELD, *Who are Nigeria's Mend oil militants?*, BBC News, October 4, 2010, <www.bbc.co.uk/news/world-africa-11467394>.
[50] Elisha BALA-GBOGBO, *Nigeria's MEND Rebels Threaten Future Attack on Oil Industry*, Bloomberg News, January 27, 2014, <www.bloomberg.com/news/2014-01-27/nigeria-s-mend-rebels-threaten-future-attack-on-oil-industry.html>.
[51] U.S. ENERGY INFORMATION ADMINISTRATION, *Iraq*, April 2, 2013, <www.eia.gov/countries/cab.cfm?fips=IZ>.
[52] Daniel YERGIN, *The Quest: Energy, Security, and the Remaking of the Modern World*, p. 160.
[53] Ali M. KOKNAR, *The Epidemic of Energy Terrorism*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, p. 19.

demonstrated the vulnerability of the facilities.[54]

Albeit organized to stop Iran from enriching uranium, the Stuxnet virus attack, orchestrated by the United States and Israel, proved the fragility of the cyberspace. The virus destroyed nearly 1,000 out of the 6,000 centrifuges in Iran by increasing their spinning to self-destruction.[55] If terrorists should use such kind of viruses, they could steal data, take control of and disrupt energy systems. Consequently, to protect the infrastructure from future cyber-terrorism, new cyber-security strategies should be released or uploaded.

Politically motivated interruption of energy provisions is a further geopolitical threat. A major producing and exporting country may decide to suspend supplies to one or more importers for political reasons. Alternatively, the imposition of an embargo on a producer may affect its ability to export. In both cases, there will be a reduction of energy goods on the market, which could also harm third parties. Probably the best-known examples are the 1973 oil embargo imposed by Arab countries on states supporting Israel during the Yom Kippur War, the repeated suspension of Russian gas supplies to Ukraine, the 1982-2004 US sanctions on Libyan oil, and the sanctions imposed by the United States and its international allies on Iran in 1979 and on Syria in 2011.

Countries may also compete over the control of reserves. These kind of disputes may arise from the absence of an international treaty establishing both terrestrial and maritime boundaries between neighboring countries, and the rivalry on deposits extending over the territories of both owners. Even the claims made by states to extend their continental shelf, and, in the case of the Caspian Sea, the lack of a universally accepted geographical definition, which makes it difficult to apply a specific legal framework, contribute to the occurrence of contentions.

The South China Sea has become the center of a territorial dispute over the Spratly Islands for the control of its hydrocarbon reserves. The archipelago, claimed by China, Vietnam, the Philippines, Malaysia, Brunei, and Taiwan, has been occupied by all these countries, with the only exception of Brunei. The U.S. Geological Survey (USGS) has estimated the undiscovered resources in the contested territory to be between 0.8 and 5.4 billion

[54] The Economist, *Terror attacks were planned on Saudi oil installations*, April 30, 2007, <www.economist.com/node/9099698>.
[55] Ellen NAKASHIMA and Joby WARRICK, *Stuxnet was work of U.S. and Israeli experts, official says*, The Washington Post, June 2, 2012, <www.washingtonpost.com/world/national-security/stuxnet-was-work-of-us-and-israel-experts-officials-say/2012/06/01/gJQAnEy6U_story.html>.

barrels of oil and between 7.6 and 55.1 trillion cubic feet of natural gas, mostly located in the section claimed by China, Taiwan and Vietnam.[56] Similar is the case of the Arctic, which is contested by Russia, Canada, the USA, Norway and Denmark. However, in the Northern Ocean, the perennial ice makes it difficult to exploit its rich deposits.

The Caspian Sea, the only example of its kind in the world, is worthy of examination. Indeed, the legal status of the body of water is still uncertain, as there is no agreement on its definition as a sea or a lake.[57] This distinction is very important because it determines the applicable international laws. In the first case, the 1982 United Nations Convention on Law of the Sea (UNCLOS)[58] would be relevant. The convention decrees littoral states to adopt a median line. In the other situation, international agreements of bordering states would regulate the use of the Caspian Sea. This unclear status has led to disputes for the control of resources and for the construction of underwater pipelines.

The term maritime security refers to the maintenance of freedom against threats in ships, harbors and high seas. From an energy perspective, the most critical points are represented by straits. When transported by sea, oil and liquefied natural gas (LNG) are particularly vulnerable to terrorist attacks and piracy. Therefore, transit chokepoints are critical for energy security. The Strait of Hormuz, between Iran and Oman, is the most important chokepoint with about 30% of all seaborne-traded oil. According to estimates, more than 85% of this petroleum is directed toward Asian markets, thus making the Strait of Malacca, between Indonesia, Malaysia, and Singapore, the second most relevant bottleneck. Other chokepoints are the Suez Canal in Egypt, the Bab el-Mandeb Strait between the Horn of Africa and the Arabian Peninsula, the Bosporus and the Dardanelles Straits connecting the Black and the Mediterranean Seas, and the Panama Canal in Central America. In addition, the Danish Straits are a relevant route for Russian oil exports to Western Europe.[59]

Energy products are not simply transported by tankers, but also through pipelines. In the

[56] U.S. ENERGY INFORMATION AGENCY, *South China Sea*, February 7, 2013, <www.eia.gov/countries/regions-topics.cfm?fips=scs>.

[57] The average salinity of the Caspian Sea is very low, one-third than that of most seawaters. This rate is almost zero in the northern part, close to the Volga delta. Based on this consideration, the Caspian Sea should be defined a lake; however, since ancient times, it was called sea due to its size.

[58] The United Nations Convention of the Law of the Sea (UNCLOS), signed on December 10, 1982 in Montego Bay, sets the extent of territorial waters, the contiguous zone, the exclusive economic zone (EEZ), and the continental shelf.

[59] U.S. ENERGY INFORMATION ADMINISTRATION, *World oil transit chokepoints*, November 10, 2014, <www.eia.gov/countries/regions-topics.cfm?fips=wotc>.

latter case, pipes usually cross one or more countries to transport hydrocarbons from producing facilities to destination markets. In some situations, transit countries pose an energy security problem. For example, the Indian government has been promoting the construction of a pipeline to import natural gas from Turkmenistan. However, the proposed Trans-Afghan Pipeline, which is expected to be operational by 2018, faces two main concerns. First, it should cross Afghanistan. Second, the tense relations between India and Pakistan risk compromising the whole project.[60]

1.3.4 Economic risk

The economic risk mainly refers to the business environment. Energy infrastructures need large investments. Investments materialize only if projects are considered profitable, that is they ensure a return-on-investment (ROI). To calculate it, the difference between the gain from and the cost of the investment is divided by the cost of the investment itself. If the result is positive, the investment should be undertaken. However, other factors are also evaluated, such as the taxation system and the legal framework. Of particular interest for companies are tax breaks offers or advantageous royalty terms.[61]

Another important economic risk, which countries should consider, is market volatility, especially that of price. Since the 1973 oil crisis, energy, in particular oil, prices have been more volatile than other commodity prices. Price volatility describes how quickly or widely prices can change in response to fluctuations in supply and demand. Therefore, it is an indicator of the uncertainty that reigns in the market, as well as a signal of scarcity or abundance. In general, low prices are detrimental to energy security, because they discourage investments in new technologies, foster consumption, and increase buyers' vulnerability to price shocks.[62]

1.3.5 Environmental risk

Environmental risk is fundamental in energy security in two ways. First, energy production

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[60] Saurabh CHATURVEDI, *India Approves Set Up of Company for Trans-Afghan Gas Pipeline*, The Wall Street Journal, February 7, 2013, <www.online.wsj.com/articles/SB10001422412788732459090457828995260131 7218>.
[61] Thomas F. "Mack" MCLARTY, *Latin America*, in Jan H. KALICKI and David L. GOLDWYN, *Energy and Security: Strategies for a World in Transition*, p. 353.
[62] Jonathan ELKIND, *Energy Security: Call for a Broader Agenda*, in Carlos PASCUAL and Jonathan ELKIND, *Energy Security: Economics, Politics, Strategies, and Implications*, pp. 127-128.

and consumption have a direct impact on the environment. The combustion of fossil fuels is emitting increasing rates of carbon dioxide and other pollutants into the atmosphere, thus contributing to global warming. In addition, nuclear waste can contaminate the soil, air and water. However, the impact of renewable energies on the environment should also not be underestimated. For instance, the manufacturing of solar photovoltaic cells release toxic substances, and the production of biofuels contribute to soil erosion and deforestation.[63]

Second, catastrophic natural events can damage energy infrastructures. The two hurricanes, Katrina and Rita, which hit the coasts of the southern-eastern United States along the Gulf of Mexico in the summer 2005, showed how fragile the energy infrastructures are to the extreme force of nature. Both offshore and onshore oil refining centers were severely damaged and flooded, reducing the US oil production and refining capacity respectively by 29% and 30%.[64] Consequently, IEA members, in order to control prices, released their strategic oil stockpiles, which were created to response to future disruptions after the 1973 oil embargo.[65]

Another example is the earthquake that stroke Japan on March 11, 2011. The resulting tsunami flooded the northeastern coast of the island of Honshu, damaging the reactors of the Fukushima Daiichi nuclear power plant. Due to the shortage of electricity, the pumps were unable to cool the uranium fuel rods. In the following days, a series of explosions occurred releasing radioactive material. The meltdown of three of the plant's six reactors is considered the worst nuclear accident since the 1986 Chernobyl disaster.[66]

1.3.6 Solutions

Three perspectives can be considered by policy-makers to deal with the aforementioned risks. These dimensions are sovereignty, robustness, and resilience.

Sovereignty consists in the protection of the energy system from disruptions provoked by external actors. Consequently, governments should increase the protection measures for both the infrastructures and the personnel. Moreover, countries should rely on their own

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[63] Ann FLORINI, *Global Governance and Energy*, in Carlos PASCUAL and Jonathan ELKIND, *Energy Security: Economics, Politics, Strategies, and Implications*, p. 155.
[64] Daniel YERGIN, *The Quest: Energy, Security, and the Remaking of the Modern World*, pp. 140-142.
[65] INTERNATIONAL ENERGY AGENCY, *How does the IEA respond to major disruptions in the supply of oil?*, 2014, <www.iea.org/topics/energysecurity/respondingtomajorsupplydisruptions/>.
[66] CNN, *Japan utility ups estimate of radiation released in Fukushima disaster*, May 24, 2012, <www.edition.cnn.com/2012/05/24/world/asia/japan-nuclear-disaster/index.html?ref=allsearch>.

domestic fuels or import them from trusted suppliers.

Robustness is the ability to protect from damages arising from predictable natural and technical factors. For instance, safer technologies should be adopted to defend facilities from failures and severe natural phenomena. In the case of resource depletion and the increasing demand of energy, switching to renewable energies is recommended, due to their abundance in comparison to fossil fuels.

Resilience consists in the ability to respond to various unpredictable changes. Specific responses are in common with sovereignty and robustness, which include the diversification of both supplies and suppliers, the creation of emergency stocks and decentralized systems, the transition toward more competitive energy markets, and the development of a redundant infrastructure.[67]

[67] GEA WRITING TEAM, *Global Energy Assessment: Toward a Sustainable Future*, Cambridge, Cambridge University Press, 2012, pp. 330-332.

Chapter Two
Fossil Fuels

2.1 History of fossil fuels

2.1.1 From the Industrial Revolution to the Second World War

The modern history of fossil fuels started with the Industrial Revolution. In the United Kingdom, the lack of wood, due to the widespread deforestation, led to the consumption of coal. This source was more energy efficient than wood, in addition it had the advantage of producing more heat. Coal was abundant and could be easily extracted from the ground. Nonetheless, the increasing consumption of the fuel made it necessary to dig deeper, so to enhance its availability. The main problem was that mines became filled with water. Thomas Newcomen resolved the issue by inventing a coal-steam engine to pump water. A few years later, James Watt improved the engine for other uses.[1] It marked the beginning of the industrial exploitation of fossil fuels.

The invention of the steam engine and the huge reserves of coal were the ingredient for the Industrial Revolution. The improvements made led to the construction of the first railroad and steamships. Not only it made easier to carry coal from the mines, but it also permitted to travel long distances. The revolution spread in Europe and in North America throughout the nineteenth century.[2] Coal started being used by electric companies in the United States to produce electricity, as soon as Nikola Tesla made alternating current more convenient for the transmission of electrical energy than Thomas Alva Edison's direct current.

The discovery of oil intensified progress. Although there is evidence of the use of oil in

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[1] POST CARBON INSTITUTE, *300 Years of Fossil Fuels in 300 Seconds*, 2010, <www.postcarbon.org/videos/>.
[2] U.S. DEPARTMENT OF ENERGY, *A Brief History of Coal Use*, February 12, 2013, <www.fe.doe.gov/education/energylessons/coal/coal_history.html>.

ancient times, the oil industry was born only in the 1800s. Its birth is debated. Some argue that the first drilling took place in 1848 in Azerbaijan, on the Apsheron Peninsula, northeast of Baku, by the Russian engineer F.N. Semyenov. Others claim that it was Colonel Edwin L. Drake in 1859 close to the small timber town of Titusville in Pennsylvania.[3] Nevertheless, what is certain is that since the 1850s, the oil industry began to grow unabated. Major production centers emerged in North America, Europe and Asia. Before the end of the century, the Germans Gottlieb Daimler and Karl Benz respectively invented the first engine and the first automobile working on petroleum.

Oil and coal production increased. Petroleum, besides being exploited by the car industry, became exploited by another invention, the airplane. Coke, a residue from the distillation of coal, was used in furnaces to make steel. Both fuels were transformed into chemicals and pharmaceuticals. The development of synthetic fertilizers and oil-powered tractors expand food output, thus contributing to global population growth.[4] On the other hand, natural gas, which was discovered with oil by Colonel Drake, was exclusively used to fuel lamps and, thanks to the invention of the Bunsen burner, to produce heat for cooking and warming buildings.[5]

Petroleum soon became the most important fossil fuel. An American company, the Standard Oil founded by John D. Rockefeller, dominated the growth of the oil industry but its success did not last long. Ineed, in 1906, President Theodore Roosevelt's administration charged the Standard Oil Trust, accusing it of restraining the trade under the 1890 Sherman Antitrust Act.[6] As a result, in 1911, the United States Supreme Court decreed the dissolution of the company into thirty-four separate companies, each with its own distinct management.[7] The most important successor companies were Standard Oil of New Jersey, Standard Oil of New York, Standard Oil of California, and Standard Oil of Indiana.[8]

Oil became a fundamental element in international relations just before the outbreak of the Great War. In 1911, Winston Churchill, the First Lord of the Admiralty, decided to power

[3] Colin John CAMPBELL, *The Coming Oil Crisis*, Brentwood, Essex, Multi-Science Publishing, 2004, p. 32.
[4] POST CARBON INSTITUTE, *300 Years of Fossil Fuels in 300 Seconds*.
[5] U.S. DEPARTMENT OF ENERGY, *The History of Natural Gas*, February 12, 2013, <www.fe.doe.gov/education/energylessons/gas/gas_history.html>.
[6] The Sherman Antitrust Act is the oldest antitrust law in the United States. It was introduced by President Benjamin Harrison in 1890 with the aim of limiting monopolies and trusts.
[7] Daniel YERGIN, *The Quest*, p. 89.
[8] The Economist, *Millennium issue: Antitrust: Standard ogre*, December 23, 1999, <www.economist.com/node/347251>.

the Royal Navy with oil instead of coal, to make the British battleships faster than the German ones.[9] The main supplier was Persia, where the Anglo-Persian Oil Company (APOC) had discovered petroleum a few years earlier. In exchange to secure the necessary oil, the British government injected £2 million of new capital into the company, thus acquiring a controlling interest and becoming the hidden power behind APOC.[10]

However, it was the Second World War that turned oil into a key resource. Oil was employed not only to fuel trucks, planes and battleships, but also to manufacture explosives for bombs and synthetic rubber for tires. Therefore, it became extremely important to both the Allies and the Axis. For this reason, both forces tried to gain control of strategic reserves of oil to fuel their own armies. The main targets were the rich oil fields in the Middle East, discovered throughout the 1930s, and those in the Caspian basin.

2.1.2 From the second half of the 20th century to present days

The Great Depression of the 1930s was partly caused by an overproduction crisis. In order to solve the situation, after the Second World War, in the United States advertisement executives created consumerism. By the 1950s, radios and televisions stimulated the purchase of products of all kinds. Production recovered and economy thrived. Consequently, fossil fuels became exploited at a faster rate. Nonetheless, a few Western companies controlled production in Middle Eastern countries, with no benefit for local population.

In 1951, the election of Mohammad Mossadeq as Prime Minister in Iran led to the nationalization of the concessions of the Anglo-Iranian Oil Company (AIOC).[11] The company was accused of running the southern part[12] of the country like a colony, depriving Iran of the huge profits derivable from oil. The economic and political crisis that followed the nationalization led to a military coup against Mossadeq, who was deposed in 1953. The export of Iranian oil resumed only the following year thanks to the formation of the so-called Consortium of Iran led by seven major oil companies.[13]

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[9] Daniel YERGIN, *The Quest*, pp. 266-267.

[10] BBC NEWS, *The Company File: From Anglo-Persian Oil to BP Amoco*, August 11, 1998, <www.news.bbc.co.uk/2/hi/business/149259.stm>.

[11] Anglo-Iranian Oil Company (AIOC) was the name with which the Anglo-Persian Oil Company (APOC) became known since 1935.

[12] During the Second World War, Iran was split into two areas of influence to keep it from German control. The northern part was occupied by the Soviet Union, while the United Kingdom had taken over the south.

[13] Odd Arne WESTAD, *The Global Cold War*, Cambridge, Cambridge University Press, 2010, pp. 120-122.

From the 1950s to the 1970s, the so-called Seven Sisters[14] controlled 85% of the global oil production.[15] The market was controlled by Standard Oil of New Jersey (Esso), Standard Oil of New York (Socony), Standard Oil of California (SoCal), Texas Oil Company (Texaco), Gulf Oil, British Petroleum Company (BPC)[16], and Royal Dutch Shell. The producing countries were not involved in production or pricing of crude oil, but merely received royalties and income taxes under a grant system.[17] For instance, the production in Saudi Arabia, until 1980, was ruled the Arabian American Oil Company, Aramco, controlled by SoCal, Texaco, Esso and Socony. However, the US companies were forced to sign an agreement with the Saudi government to share the profits 50/50, following King Abdulaziz's threat to nationalize the country's oil facilities in 1950.[18]

In 1960, the Organization of the Petroleum Exporting Countries (OPEC) was founded in Baghdad. The previous year, the First Arab Petroleum Congress was convened in Cairo, after the International Oil Companies (IOCs) reduced the price of crude oil by increasing production. The adopted resolution called on oil companies to submit price change plans to authorities of producing countries before unilaterally taking any decision. However, the Seven Sisters kept exercising their control over prices. As a consequence, delegates of the governments of Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela met in Baghdad and announced the foundation of OPEC. The main goal of the organization was to unify and coordinate members' policies, thus protecting their own interests.[19]

In the 1970s, a series of events changed the system that until then was in force in the oil industry. First, new IOCs began to compete with the Seven Sisters by offering more attractive financial terms. Second, the economic development of the 1960s in the industrial countries brought to a stronger dependence on OPEC supplies. Third, developed countries experienced two major energy crisis, due to substantial petroleum shortages.[20] These changes increased the role and the influence of the OPEC nations.

The first energy crisis took place in 1973 as consequence of a series of factors. First, the

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[14] The term 'Seven Sisters' was coined by Enrico Mattei after the Italian oil company AGIP was refused to join the 'Consortium of Iran' cartel.
[15] The Economist, *The global oil industry: Supermajordämmerung*, August 3, 2013, <www.economist.com/news/briefing/21582522-day-huge-integrated-international-oil-company-drawing>.
[16] British Petroleum Company (BPC) was the name adopted by Anglo-Persian Oil Company (APOC) in 1954.
[17] Gawdat BAHGAT, *Energy Security*, p. 176.
[18] Ibid., p. 85.
[19] Ibid., p. 176.
[20] Ibid., pp.176-177.

breakup of the Bretton Woods system.[21] On August 15, 1971, President Richard Nixon announced the suspension of convertibility of the US dollar into gold, in response to monetary inflation, the negative balance of payments, and the growing public debt. Second, the United States lost their capacity to produce more oil than necessary, thus increasing its national price.[22] Third, in October 1973, in response to US support to Israel, OAPEC, the Arab members of OPEC, imposed an oil embargo against the United States and other countries supporting Israeli troops. Moreover, they established a cut in production by 5% each month from the previous month's output until the total withdrawal of Israeli forces from the territories occupied during the Six-Day War. Forth, OAPEC countries tried to consolidate their control over production and prices by stopping granting new concessions and claiming equity participation in the existing ones.[23]

The crisis had short-term global consequences. Although the Arab countries were not the only oil producers, the other OPEC members participated in fixing the price of oil. Because of the reduced production, the price of oil quadrupled by 1974 to almost $12 per barrel. The demand for substitute raw materials caused a sharp increase in their price. The already precarious economic situation in developed countries worsened. High inflation, unemployment, and stagnation spread in all oil-importing countries. The energy crisis led to the creation of the International Energy Agency (IEA), which promoted the search for new sources of supply, such as natural gas and renewables.

The United States, which depended little on OPEC oil in comparison to its allies, took advantage of the crisis to strengthen the power of the dollar and the relations with the Arab exporters, especially Saudi Arabia. During his visit in Riyadh on July 15, 1974, President Richard Nixon agreed to protect the Al-Saud royal family; as long as the oil was sold in US dollars[24] and the resulting revenues were deposited abroad, mainly in American and British banks. Indeed, the exporting countries were amassing large surpluses of dollars, which they

[21] The Bretton Woods system was put in place in preparation for the reconstruction of the world economy after the end of the Second World War. In addition to the creation of the International Monetary Fund (IMF) and the International Bank for Reconstruction and Development (IBRD), nowadays the World Bank (WB), the system imposed a fixed exchange rate by tying national currencies to gold. As the US dollar was chosen as a reserve currency, countries pegged their currencies to the dollar that could be converted to gold. The gold-dollar exchange rate was $35 for ounce of gold.

[22] William R. CLARK, *Petrodollar Warfare: Oil, Iraq and the Future of the Dollar*, Gabriola Island, Canada, New Society Publishers, 2005, pp. 19-20.

[23] Gawdat BAHGAT, *Energy Security*, p. 177.

[24] Prior to 1973, oil sales were denominated in US dollars; however, producing countries were not precluded to sell oil in their local currency.

could not invest in their own countries, because of the small local population or the early stages of industrialization. This process, known as petrodollar recycling, had destabilizing effects on the entire global economic system, as the deposited dollars where used by banks as loans in Third World countries.[25]

The Iranian Revolution was at the core of the second oil shock. During internal revolts, oil production dropped significantly. The fled of the Shah Mohammad Reza Pahlavi and the seizure of power by the Ayatollah Ruhollah Khomeini led to the expulsion of the international oil companies, making more difficult the recovery of exports. In addition, the establishment of a Shiite theocracy worried neighboring Iraq. Therefore, Saddam Hussein launched a pre-emptive strike against Iran in the hope to prevent Iraqi Shiites to make a similar revolution and destabilize the new Iranian regime, thus turning Iraq into a hegemonic power in the Middle East. As a consequence, oil production in both Iran, which at the time was the second largest producer after Saudi Arabia, and Iraq nearly stopped, causing prices to soar, reaching a peak in April 1980.[26]

The 1980s were characterized by volatility in both oil prices and supplies. Supply uncertainties at the beginning of the decade led to a significant increase in the price of oil, resulting in higher revenues for OPEC members. High prices were detrimental to industrialized countries. Inflation grew enormously and economic growth decreased by two-thirds. The following years, prices slowly declined. On the one hand, the demand for oil diminished thanks to greater conversation and improved efficiency, pursued by importing countries following the 1973 oil crisis, and the adoption of alternative sources of energy, such as ethanol in the United States. On the other hand, oil supply came from non-OPEC countries, which started extracting petroleum at the beginning of the 1970s, because of the higher prices. Accordingly, the dependence on Middle East oil declined. Despite the declining oil prices, production stayed high, due to the appreciation of the US dollar, the small fraction of production costs in the cost structures, and the dependence on oil to refund foreign debts.[27] From 1987 to the beginning of the next decade, prices plateaued.

The 1990s were marked by two events. First, the invasion of Kuwait by the Iraqi troops and the subsequent Gulf War affected oil prices. However, this time IEA members released

[25] William R. CLAKR, *Petrodollar Warfare,* pp. 20-22.
[26] Siamack SHOJAI and Bernard S. KATZ, *The Oil Market in the 1980's: A Decade of Decline*, New York, Praeger Publishers, 1992, pp. 71-72.
[27] Ibid., pp. 74-77.

their strategic oil stockpiles to compensate the loss of oil due to the sanctions imposed on Iraq. Second, Asian financial crisis in 1997 made clear the glut of petroleum supply over demand. Consequently, prices collapsed from $10 to $6 per barrel. The 1997 OPEC meeting, which took place in Jakarta, highlighted the hazard of raising production whenever demand is declining or even just uncertain. The so-called Jakarta Syndrome reshaped the oil industry, making it more efficient through mergers, which gave rise to the supermajors.[28]

The supermajors arose from mergers between major oil companies. The term englobes six firms: BP, Chevron, ExxonMobil, Total, Royal Dutch Shell, and ConocoPhillips.[29] Nevertheless, compared with those who formed the group of the Seven Sisters, these IOCs do not control most of the world's oil production and reserves, which is mainly controlled by national oil companies (NOCs), such as Saudi Aramco (Saudi Arabia), Petronas (Malaysia), Petrobas (Brazil), and the China National Petroleum Corporation (CNPC).[30]

The beginning of the new millennium was peculiar. From October 2003 to July 2008, oil prices continued to grow, reaching a peak of $147.30. After a short decline at the end of 2008, prices started inflating again. Although it is still difficult to assess the real causes, some reasons can be identify. First, the rapid development of some countries, especially those forming the BRIC group[31], have made oil demand more sustained. Second, strikes and riots, mainly in Middle Eastern countries, have contracted supply. Third, the war in Iraq, first, and the civil war in Libya, then, as well as resource nationalism have reduced the availability of petroleum in the market. Forth, natural disasters, such as the 2005 hurricanes Katrina and Rita, have reduced the US productive and refining capacity. Finally, the pessimistic outlook about reserves.[32]

2.2 Types of fossil fuels

2.1.2 Conventional and unconventional oil

Crude oil can be split into two different categorizes. Conventional oil consists of crude oil

[28] Daniel YERGIN, *The Quest*, pp. 85-89.
[29] Ibid., passim Chapter 4 "*Supermajors*".
[30] U.S. ENERGY INFORMATION ADMINISTRATION, *Who are the major players supplying the world oil market?*, September 30, 2014, <www.eia.gov/energy_in_brief/article/world_oil_market.cfm>.
[31] The BRIC group is formed by Brazil, Russia, India and China.
[32] Alexandre ROJEY, *Energy and Climate*, pp. 90-91.

that is extracted with traditional oil well techniques. The IEA defines conventional oil as "a category of oil that includes oil and natural gas liquids and condensate liquids, which are extracted from natural gas production."[33] Differently, unconventional oil englobes a broader variety of liquids, extracted from mineral sources, using non-traditional methods. They include oil shales, oil or tar sands, coal-based liquid supplies, biomass-based liquid supplies, gas-to-liquids (GTL).[34] Nonetheless, it should be noted that this distinction would change over the years. By the time new oil resources will be discovered, unconventional oil will be considered part of the conventional category, as it happened with hydrocarbons extracted through offshore drilling.[35]

The petroleum industry typically classified oil by two measures. The first one is density. It quantifies how heavy or light petroleum liquid is compared to water. Therefore, crude oil can basically be classified as light, medium or heavy. Being light oil less dense and having short hydrocarbon chains, it can be simply distillated. On the other hand, heavy oil, which is more dense and have long hydrocarbon chains, needs severe refining processes. The second measure is the sulfur content. If crude oil contains high quantities of sulfur is considered sour, in the opposite case it is sweet.[36] The lighter and the sweeter, the more valuable crude oil is [Table 2].

Table 2. Classification of oil.

Resource	**Measure**	**Classification**	**Most common category**
OIL	*Density*	*Light*	Conventional oil
		Medium	Conventional oil
		Heavy	Unconventional oil
	Sulfur content	*Sweet*	Conventional oil
		Sour	Unconventional oil

[33] INTERNATIONAL ENERGY AGENCY, *Oil*, 2014, <www.iea.org/aboutus/faqs/oil>.
[34] Peter C. GLOVER and Michael J. ECONOMIDES, *Energy and Climate Wars: How naive politicians, green ideologues, and media elites are undermining the truth about energy and climate*, New York, The Continuum International Publishing Group, 2010, p. 85.
[35] Daniel YERGIN, *The Quest*, p. 265.
[36] Gawdat BAHGAT, *Energy Security*, pp. 5-6.

For many years, unconventional oil has not been exploited. Unconventional oil is extra-heavy, very viscous, and rich in sulfur and other metals, thus requiring its dilution before use. This peculiarity has made it less attractive compared to the conventional form. Indeed, the recovery and processing are very expensive. However, the inflated price of oil has led to greater investments in technologic research, which facilitated its extraction.[37] In addition, the growing global demand for oil and the dependency on a small number of producing countries has made unconventional oil, whose reserves are estimated to be more abundant, more appealing.

Tar sands is the most abundant kind of unconventional oil. They consist of semi-solid, mostly superficial sand or slate mixed with clay, water, and saturated with oil. The extraction of the bitumen raise a number of issues. Due to the high viscosity, the refining costs are very high. Moreover, the industry is also very energy-expensive, since oil sands must be heated or diluted before they can flow. Nevertheless, the principal concern is the impact that the production of oil from these sands have on the environment. Indeed, trees are felled to make place to the facilities; rivers are diverted because high quantities of water, in the form of steam, are necessary to liquefy bitumen; and finally, pollutants are emitted into the atmosphere through deforestation and combustion.[38] There are different techniques to exploit tar sands. Superficial deposits can be extracted by strip surface mining, like coal; however, being most of the deposits far below the surface, various in-situ technologies are used, although Steam Assisted Gravity Drainage (SAGD) is the most common [Table 3].

The major deposits are concentrated in the Province of Alberta, in Canada, and in the Orinoco Belt, in Venezuela. Canada is the major producer of oil sands and its estimated 174 billion barrels reserves made the country the holder of the second largest proven deposits.[39] The reserves of Venezuela are considered even larger; nonetheless, the lack of investment, due to the political climate, and the requirement of advanced technology, due to the greater porosity of the sands in the Orinoco, has not yet enabled their exploitation.[40]

The other two major typologies of unconventional oil are tight oil and oil shale. The former, sometimes called shale oil, not to be confused with oil shale, is petroleum trapped, usually

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[37] Melanie A. KENDERDINE and Ernest J. MONIZ, *Technology Development and Energy Security*, in Jan H. GALICKI and David L. GOLDWYN, *Energy and Security*, pp. 381-384.
[38] Sascha MÜLLER-KRAENNER, *Energy Security*, pp. 6-7.
[39] Gal LUFT, *United States: A Shackled Superpower*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, p. 148.
[40] Daniel YERGIN, *The Quest*, p. 121.

with gas, in relatively low porous and permeable rock. The latter consists of fine-grained sedimentary rocks enclosing a solid organic substance, kerogen, not yet entirely converted into oil. Tight oil is extracted by hydraulic fracturing and horizontal drilling. Hydraulic fracturing induces the rock to fracture by using a pressurized liquid, composed of chemicals and sand suspended in water, and then the well is drilled horizontally. Differently, in a process called retorting, kerogen evaporates at high temperatures and once condensed becomes oil.[41]

Table 3. Conventional and unconventional oil.

Resource	Category	Main typology	Main extraction technique
OIL	*Conventional*	*Conventional oil*	Traditional vertical drilling
	Unconventional	*Tight/shale oil*	Hydraulic fracturing and horizontal drilling
		Oil shale	Retorting
		Tar/oil sands	Strip surface mining and SAGD

2.2.2 Types of natural gas

Natural gas is a hydrocarbon gas mixture consisting mainly of methane. It typically contains also a blend of various alkanes, organic compounds of carbon and hydrogen, such as ethane, propane, butane, and in very small quantities also pentane. Moreover, small percentages of non-hydrocarbon gases are present, carbon dioxide, oxygen, noble gases, nitrogen and hydrogen sulfide.

The classification of natural gas is mainly based on three aspects. The concentration of hydrocarbons in its composition enables to distinguish between dry and wet gas. While the former is almost pure methane with very little traces of other gases, the latter is abundant of other hydrocarbons gases in different percentages. Moreover, natural gas can also be categorized as either sweet, if there are low traces of hydrogen sulfide, or sour in the opposite situation. Finally, based on the kind of deposits where natural gas is recovered, it can be

[41] COLORADO OIL & GAS ASSOCIATION, *Oil Shale vs. Shale Oil*, June 18, 2013, <www.coga.org/pdf_Basics/Basics_OilShale.pdf>.

considered as associated or non-associated depending on whether oil is also present in the geological reservoir.[42] This associated natural gas was initially considered a problem in the extraction of oil; therefore, it was typically ignited and wasted. Nowadays, this kind of gas is returned to the reservoir using injection wells to improve the extraction of oil [Table 4].

Table 4. Classification of natural gas.

Resource	**Measure**	**Classification**
NATURAL GAS	*Concentration of hydrocarbons*	*Dry*
		Wet
	Hydrogen sulfide	*Sweet*
		Sour
	Geological reservoir (presence of oil)	*Associated*
		Non-associated

Natural gas, like oil, can be differentiated between conventional and unconventional sources. The distinction between conventional and unconventional sources of natural gas is not based on real physical or chemical differences as it is for oil. The term unconventional is simply used to refer to natural gas recovered in atypical geological locations. Indeed, unconventional gas is mainly found in extremely thick rock or coal seams.[43] Therefore, it is possible to identify three main kinds of sources: shale gas, tight gas, and coal seam gas. Both shale and tight gases are trapped under a layer of very low porous and permeable rock. The difference between the two depends on the reservoir rock. While shale gas is trapped in rock formations, tight gas is found in low-porous and impermeable sandstones. The technology used for the extraction of these types of gas is hydraulic fracturing and horizontal drilling, so to break the porous rocks and free the entrapped gas.[44] Finally, coal seam gas, also called coalbed methane (CBM), is methane, which can be extracted, as its name

[42] Gawdat BAHGAT, *Energy Security*, p. 6.
[43] TOTAL, *Why is it called unconventional gas?*, 2014, <www.total.com/en/energies-expertise/oil-gas/exploration-production/strategic-sectors/unconventional-gas/why-it-called-unconventional-gas?%FFbw=kludge1%FFbw=kludge1%FF>.
[44] SHELL, *Understanding Tight and Shale Gas*, 2014, <www.shell.us/aboutshell/shell-businesses/onshore/shale-tight.html>.

suggests, from coal deposits in some geological basins.[45] Consequently, it is a kind of dry gas. In addition, it is classified as sweet because of the origin of this methane, which is usually devoid of hydrogen sulfide. Due to the serious safety risk that the presence of CBM in underground coal mining presents, methane is typically recovered through a drainage system before mining begins.[46] [Table 5].

Table 5. Conventional and unconventional natural gas.

Resource	Category	Typology	Extraction technique
NATURAL GAS	*Conventional*	*Conventional natural gas*	Traditional vertical drilling
	Unconventional	*Shale gas*	Hydraulic fracturing and horizontal drilling
		Tight gas	
		Coalbed methane (CBM)	Drainage systems

2.2.3 Classification of coal

Coal is the most abundant of the three fossil fuels. It consists of dead plants that over millions of years, altered by heat and pressure, petrified and consolidated with other rocks. Its main component is carbon, but it also contains hydrogen, nitrogen, sulfur, and oxygen.[47]

Coal, unlike oil and natural gas, cannot be distinguish between conventional and unconventional. Indeed, the distinction between different types of coal depends on four characteristics: the typology of vegetation from which coal was originated, the depth of burial, the temperature and pressure under which the coal was formed, the extent of the petrification process. Consequently, the geological formation of coal enhance to cluster it into six grades. In general, the highest the rank, the greatest the heat value, due to the highest presence of carbon compared to hydrogen and oxygen.[48] [Table 6].

[45] TOTAL, *Three main sources of unconventional gas*, 2014, <www.total.com/en/energies-expertise/oil-gas/exploration-production/strategic-sectors/unconventional-gas/presentation/three-main-sources-unconventional-gas>.
[46] WORLD COAL ASSOCIATION, *Coal Bed Methane*, 2014, <www.worldcoal.org/coal/coal-seam-methane/coal-bed-methane/>.
[47] WORLD COAL ASSOCIATION, *Coal*, 2014, <www.worldcoal.org/coal/>.
[48] WORLD COAL ASSOCIATION, *What is Coal?*, 2014, <www.worldcoal.org/coal/what-is-coal/>.

Peat is considered a precursor of coal. It is a deposit composed of vegetable remains sunk in and soak of water that, because of the acidity of the environment, cannot decompose completely. In addition to vegetable, it may also include many other types of organic material, such as insects and bodies of other animals. Peat is soft and compresses easily; therefore, if pressed, it leaks the water contained inside.[49]

Lignite, also called brown coal, is the lowest grade of coal. It is formed from naturally compressed peat. Lignite has high relative humidity and its coalification process is never entirely completed, thus resulting quite soft to the touch. These characteristics make brown coal almost exclusive (79%) used to produce electricity. Other uses englobes synthetic natural gas generation and fertilizer products production.[50]

The persistent incidence of temperature and pressure transform lignite into so-called sub-bituminous coal. Its properties are intermediate between those of lignite to those of bituminous coal. It is mainly used as fuel in steam-electric power generation.[51] Since it pulverizes quite slowly, when burning inside the turbines, it produces a lot of smoke. It can be either soft, crumbly and dark brown or blackish, if extracted in the lower layers, or hard, but clearer in the upper layers.

The following stage is that of bituminous or hard coal. Bituminous coal is dense, generally black, but sometimes dark brown, often with well-defined stripes of light and friable material. It is employed to produce electricity, to heat and to manufacture coke, a solid reside of coal.[52] Like sub-bituminous coal, it produces a lot of smoke during combustion. In addition, it easily decomposes when exposed to air.

The accelerating organic maturity generates anthracite and graphite. Anthracite is the highest, the heaviest and the hardest rank of coal. It has a black color and metallic luster. Moreover, it develops much heat when burned.[53] Nonetheless, the difficulty to recover anthracite makes it very expensive and, as a consequence, less employed than the other types of coal. Finally, graphite, which technically is the highest grade, is difficult to ignite; therefore, it is not used as a fuel.

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[49] INTERNATIONAL PEAT SOCIETY, *What is peat?*, 2014, <www.peatsociety.org/peatlands-and-peat/what-peat>.
[50] LIGNITE ENERGY COUNCIL, *About Lignite*, 2014, <www.lignite.com/about-lignite/>.
[51] WORLD COAL ASSOCIATION, *What is coal?*, 2014, <www.worldcoal.org/coal/what-is-coal/>.
[52] Ibidem.
[53] Ibidem.

Table 6. Classification and extraction techniques of coal.

Resource	Characteristics of the geological formation	Classification	Main extraction techniques
COAL	1) typology of vegetation 2) depth of burial 3) temperature and pressure 4) extent of the petrification process	*Peat*	1) opencast / surface mining: • strip mining 2) deep / underground mining: • room-and-pillar mining • longwall mining
		Lignite / Brown coal	
		Sub-bituminous coal	
		Bituminous / Hard coal	
		Anthracite	
		Graphite	

2.3 The fossil fuels industry

2.3.1 The hydrocarbons industry

The hydrocarbon industry involves several operations that are clustered into three groups, each with its own peculiarities. The upstream sector is the set of processes that originates the production activities; consequently, it is also referred to as the exploration and production (E&P) sector. It is followed by the midstream and the downstream sections. While the midstream sector includes the transportation and storage, the downstream section encloses those procedures that make oil products available for sale [Table 7].

The upstream operating process is divided into a few phases. Exploration is the first step. Geologists conduct a series of researches and experiments to verify the presence of hydrocarbons in the rock formation of the area. The geological analysis can be done either directly or indirectly. In the first case, seismic surveys are executed by the hydrocarbon company; otherwise, they are purchased by other companies. The investigation is based on induced vibrations and the subsequent registration by special sensors of the seismic waves. The acquisition of exploitation rights is the following phase. The term covers a wide extent of permissions to drill a well and start production activities, in exchange of the payment of royalties and income taxes, as well as the commitment to restore the area when the reserve has been completely exhausted. Granted the authorization, exploratory wells, commonly called wildcats, are drilled. Blowout preventer (BOP) devices are employed to prevent uncontrolled releases. Geologists analyze the rock formations to establish their porosity, permeability and other properties. If hydrocarbons are found and tests demonstrate that the discovery is of economic interest, the wildcat becomes a discovery well. Once the company has obtained the exploitation concession, called development lease, it can start oil and gas production. The upstream is the most profitable sector, because of the greater risks.[54]

The other two sectors concern the delivery of hydrocarbons to final users; therefore, at times, they are considered as just a unique process. The midstream sector covers the transportation of hydrocarbons from the production plant to refineries and storage facilities. The most common way to transport hydrocarbons is by pipeline. Nevertheless, piping hydrocarbons involves a series of risks. First, for either gas or oil to travel long distances, the pressure inside the pipeline should be kept through its whole length. Second, pipelines can cross a great variety of terrains, each with its own peculiarities, which should be considered before construction can begin, since pipes cannot be moved or diverted. Third, a crucial challenge is maintenance, not only because of potential geopolitical conflicts, but also because of the costs and the possible environmental damages. Finally, in many circumstances, pipelines cross more than one country. Subsequently, it is necessary to obtain the construction and maintenance rights, in exchange of royalties. Nevertheless, geopolitical confrontation between countries can complicate the situation.[55] This is especially a main concern for the transportation of natural gas, since there is no other way to move it in its gaseous state. Indeed, while oil can be transported by truck, barge and rail, natural gas can only travel by pipeline.[56]

The last stage is the downstream process. The sector includes the refining, the processing, the marketing and the distribution of products derived from oil and natural gas. Consequently, this is the closest stage to consumers. The most common products associated with downstream are gasoline, kerosene, diesel, asphalt, liquefied natural gas (LNG), synthetic rubber, plastics, pharmaceuticals, fertilizers and pesticides. All these products are not only used by people, but also by other industries to manufacture further goods and to

[54] PETROLEUM SERVICES ASSOCIATION OF CANADA, *Industry Overview*, 2014, <www.psac.ca/business/industry-overview/>.
[55] STI GROUP, *The Three Oil and Gas Energy Markets: What Is Midstream?*, February 1, 2013, <www.setxind.com/midstream/energy-markets-what-is-midstream/>.
[56] Sascha MÜLLER-KRAENNER, *Energy Security*, pp. 7-9.

provide services. The distribution methods includes trucks, rails, barges and pipelines. Nevertheless, as already mentioned, natural gas can only be transported by pipeline unless liquefied. Natural gas liquefies under high pressure at -256°F/-160°C, so to be shipped by tanker. However, the process is costly and requires both a liquefaction and regasification plants; accordingly, this is the main obstacle to the creation of a global market for gas.[57]

Table 7. The hydrocarbons industry.

Activity	**Sector**
Exploration *Perforation* *Extraction*	UPSTREAM
Transportation *Storage*	MIDSTREAM
Refining *Distribution*	DOWNSTREAM

2.3.2 The extraction and transportation of coal

Coal is extracted in a different way compared to oil and natural gas. Once extracted, coal does not need to be refined like hydrocarbons; consequently, it can be delivered directly to the final consumer. The extraction depends on the depth of the burial, the quality of the coal seam, the geology and environmental factors. The two methods employed by the coal industry are opencast and deep mining. Although the latter is preferred for superficial coal, some pits occur at greater depths [Table 6].

Opencast, also called surface, mining is typically selected when coal is superficial. This is also the cheapest way to extract coal. The use of explosives and draglines, or alternatively shovels and trucks, remove the top layer, thus exposing the coal seam. Then the seam is drilled, fractured and thoroughly mined in strips. Finally, the coal is transported by truck to

[57] STI GROUP, *The Three Oil and Gas Energy Markets: What Is Downstream?*, February 5, 2013, <www.setxind.com/downstream/oil-and-gas-energy-what-is-downstream/>.

either the coal preparation plant or to the final destination of use. This method enables to recover greater quantities of coal, even more than 90%, compared to deep mining.

Coal can be buried too deep for opencast mining, thus deep mining is required. Deep or underground mining accounts for about 60% of the global coal production. This method can be split into two main processes: room-and-pillar, and longwall. Room-and-pillar mining consists in creating a series of chambers along the seam, while pillars and timber support the roof of the mine. The pillars, which are made of rock, represent up to 40% of the residual coal. Once it is no longer possible to proceed in the development of the mine, miners can start removing the coal from the pillars. This process, named second or retreat mining, recovers as much residual coal as possible. Longwall mining requires careful planning, since a whole section of the seam is extracted using mechanical shearers.[58]

From the extraction mine, coal is carried on trucks to a plant where it is crushed. Then the smaller pieces of coal can be delivered to a final destination by truck, ship, railroad or barge. Like oil and natural gas, even coal can travel by pipeline. In this case, the coal is blended with either oil or water, forming a mixture called slurry.[59]

2.3.3 The fossil fuels market

In economics, the term market indicates the place, also figuratively, and the time when economic exchanges and trades of raw materials, goods, services, money, and securities are realized. It could be defined as the meeting point of supply and demand. Demand relates the quantity of a good or service that buyers desire, whilst supply refers to the offered quantity by producers on the market. Therefore, the market provides the opportunity to make transactions between buyers and sellers at a specific price. In a free market economy, the market price reflects interaction between supply and demand; nevertheless, it may be distorted by additional factors.

The price of oil is shaped by two primary factors. Having oil a physical dimension, its price is established by supply and demand. Accordingly, prices will raise whenever supply decreases, or alternately, demand increases in order to maintain the equilibrium. In the opposite condition, prices will fall. Demand is influenced by the global economic growth, but

[58] WORLD COAL ASSOCIATION, *Coal Mining*, 2014, <www.worldcoal.org/coal/coal-mining/>.
[59] U.S. DEPARTMENT OF ENERGY, *Coal Mining and Transportation*, February 12, 2013, <www.fe.doe.gov/education/energylessons/coal/coal_mining.html>.

also by weather conditions and the exchange value of the US dollar. Indeed, being the US dollar the currency in which oil is traded, its depreciation[60] tends to increase oil demand. Supply depends on production, on disruptions and on policies adopted by producers, mainly OPEC countries, since they still control more than 40% of the worldwide production.[61] The price is also determined by the investors' attitude toward future quantities. In this respect, data and news about oil reserves, changes in consumption habits, economic performance and potential disruptions are considered and evaluated. Nevertheless, since the late 1980s, oil has acquired the properties of a financial asset. Consequently, its price is determined in special markets, named Futures Exchange. Futures trading are almost exclusively done by speculators, whose aim is to gain a large profit by anticipating future price movements.[62] While speculators take a risk, hedgers try to reduce, or eliminate if possible, the risk on futures markets. Futures contracts are uniform agreements on financial instruments, with which the parties agree to exchange a certain amount of a financial asset at an established price at a specified date in the future. Therefore, in such a contract, the quantity, the quality, the delivery data, the cash settlement and delivery point are already determined.[63]

The two main markets for the exchange of oil are the New York Mercantile Exchange (NYMEX) in New York City and the Intercontinental Exchange (ICE)[64] in Atlanta. In these two markets oil contracts, whose unit of exchange is indivisible lots of 1,000 barrels[65], are respectively listed for two kinds of light sweet crude oil, West Texas Intermediate (WTI) for delivery at Cushing, in Oklahoma, and Brent Blend[66] for delivery at Sullom Voe, in the United Kingdom. While the former is mainly used in the Americas, the latter is predominant in Europe, Africa and the Middle East.[67] Although contracts for these two oils constitute only a

[60] Depreciation is defined as the reduction in the value of a currency under a floating exchange rate regime. It corresponds to a reduction in the exchange rate with a foreign currency.
[61] U.S. ENERGY INFORMATION ADMINISTRATION, *Oil Prices and Outlook*, 2014, <www.eia.gov/energyexplained/index.cfm?page=oil_prices>.
[62] Paul KOSAKOWSKI, *What Determines Oil Prices?*, in INVESTOPEDIA, 2014, <www.investopedia.com/articles/economics/08/determing-oil-prices.asp>.
[63] CME GROUP, *Fundamentals Of Energy Trading*, December 7, 2010, <www.cmegroup.com/education/interactive/webinars-archived/fundamentals-of-energy-trading.html>.
[64] Previously Brent was quoted at the International Petroleum Exchange (IPE) in London, which has been incorporated by the Intercontinental Exchange (ICE).
[65] CME GROUP, *Fundamentals Of Energy Trading*.
[66] The Brent Blend consists of a basket of 15 oils extracted in the North Sea.
[67] Other two common benchmarks are Dubai-Oman, used for Middle East sour crude exported to Asia, and the OPEC Reference basket, a weighted average of oil blends from OPEC countries, mainly used by Saudi Arabia.

small part of the total trade, they are the most common used benchmarks[68] for all other transactions. Consequently, different prices depend on the quality of crude oil and in the delivery cost [Table 8].

The price of oil have effects on the economy. Prolonged high prices of oil increase the production costs and thus induce firms to raise prices. Consequently, higher prices will reduce the quantities demanded by consumers, as well as production. The lower production and the rising costs will force firms to fire workers; as a result, the unemployment rate will increase. Therefore, high oil prices can be detrimental to economic development.[69]

Natural gas prices also depend on market demand and supply. The absence of a natural gas market created isolated regional markets with different systems to establish its price. Nonetheless, the expansion of LNG as a way to transport natural gas is changing the current situation; consequently, prices will follow global demand and supply trends. The existing various regional markets use different benchmark prices. In North America, the market is considered mature; subsequently, the price of natural gas is established on spot and futures markets, exactly like oil. However, unlike oil, natural gas prices are somehow predictable, because of the greater demand during winter months, compared to the summer season, when demand is low and storages are replenished. In broad terms, on the spot market, prices depend on daily supply-demand balances. Nevertheless, most transactions materialize in the so-called bid week, the last five business days of a month, during which the physical quantity to deliver throughout the following month is determined. Futures contracts at NYMEX fixes the price of physical delivery of 2,500 million British thermal units at Henry Hub, in Louisiana.[70] The same system is exploited in Northwestern Europe, where the hub pricing and traded markets system has spread from the United States via the United Kingdom. The main benchmark price is the cost of natural gas delivery at Zeebrugge, in Belgium. In addition, other benchmarks are based on virtual places, such at the National Balacing Point (NBP), in the United Kingdom, and the Title Transfer Facility (TTF), in the Netherlands.[71]

[68] The benchmark is an objective reference parameter, constituted by reference to financial indicators developed by third parties and in common use.
[69] Olivier BLANCHARD, *Macroeconomics*, Upper Saddle River, New Jersey, Pearson Prentice-Hall, 2005, pp. 162-166.
[70] NATURALGAS.ORG, *Marketing*, September 20, 2013, <www.naturalgas.org/naturalgas/marketing>.
[71] Romain DAVOUST, *Gas Price Formation, Structure & Dynamics*, Institut Français des Relations Internationales, April 2008, <www.ifri.org/files/Energie/Note_Davoust.pdf>.

The dominant mechanism in Continental Europe and in Asia is the oil-indexation system. Long-term contracts, which typically expire after twenty-five years, are concluded through intergovernmental agreements. The price of natural gas is pegged to that of oil, considering the fluctuations of the previous six to nine months. These contracts contain two important clauses. One of them forbid the possibility to split unilaterally the contract, with the only exception being prolonged force majeure. Nevertheless, the most important clause is the take-or-pay (ToP) commitment, which imposes a consumer to pay for the gas whether it imports it or not.[72] In such a mechanism, prices are only partly negotiated in open markets. The main reason for the adoption of this kind of contracts in the 1960s was to guarantee the use of the infrastructures, in particular of the expensive pipelines. Nevertheless, the futures markets are consolidating also in Europe [Table 8].

In Asia, natural gas prices are higher. The reason why prices are generally higher in Asia are the result of the market structure and the transportation costs. Natural gas is typically imported to South Korea and Japan from Australia, Indonesia and Qatar in the form of LNG. The long-haul shipping, the absence of competitive piped gas, and the charges applied by LNG terminals increase prices by one dollar for million British thermal unit.[73] Moreover, the high price of natural gas is driven by increasing demand, since many Asian countries preferred this source to coal or, in the case of Japan, because of the decision undertaken by the government to reduce electricity production from nuclear power plants.

The price of coal also depends on the equilibrium between demand and supply. Nonetheless, it is fixed in the same way oil prices are determined. Daily contractions on the spot market establish the price on the base of four features: transportation costs, extraction costs, quality (exactly as it happens for oil and natural gas), and its heat content. Consequently, a higher ranked type of coal has a higher price, for this reason, anthracite is more expensive than lignite.[74] Other additional factors that influence on coal prices are the prices of natural gas, the freight rates, the exchange rates of the US dollar, temperatures and weather conditions, changes in mining extraction and electric power productions, industrial utilization, especially steel production, and environmental regulations. For what concerns the futures markets, the NYMEX trades coal futures contracts quoted in US dollars for a trading unit of

[72] GAZPROM, *Europe*, 2014, <www.gazprom.com/about/markting/europe/>.
[73] Romain DAVOUST, *Gas Price Formation, Structure & Dynamics*.
[74] U.S. Energy Information Administration, *Coal Prices and Outlook*, July 18, 2014, <www.eia.gov/energyexplained/index.cfm?page=coal_prices>.

1,550 short tons (1,410 tons)[75] of Central Appalachian (CAPP) coal for delivery in the CAPP Delivery Zone location, on the tri-border Ohio-Kentucky-West Virginia. The ICE trades coal futures contracts for a trading unit of 5,000 tons (5,500 short tons) for delivery in Rotterdam for Europe, Richards Bay, in South Africa, for Africa, and Newcastle, Australia, for the Asia-Pacific region. Even in the former cases, quotations are made in US dollars.[76] [Table 8].

Table 8. The market of fossil fuels.

Resource	**Price determina-tion**	**Benchmark**	**Delivery**	**Unit**	**Currency**
OIL	Spot and futures markets	NYMEX: WTI	Cushing, OK	1,000 barrels	US dollar
		ICE: Brent	Sullom Voe, UK		
NATURAL GAS		NYMEX	Henry Hub, LA	2,500 MMBtu	US dollar
		ICE			
			NBP, UK	1,000 therms[77]/day	British pound
			-Zeebrugge, Belgium -TTF, Netherlands	1 MW/day	Euro
	Long-term contracts	Oil-indexation	Depending on the contract		
COAL	Spot and futures markets	NYMEX: CAPP	CAPP Delivery Zone, OH-KY-WV	1,500 short tons	US dollar
		ICE	-Rotterdam, Nether-lands -Richards Bay, South Africa -Newcastle, Australia	5,000 tons	

[75] The difference between a short ton and a ton depend on the metric system. The different denomination are employed just to distinguish them. A short ton is equivalent to 2,000 pounds or approximatively 907.18 kilo-grams, while a ton corresponds to 1,000 kilograms or 2,204.62 pounds.
[76] The Intercontinental Exchange (ICE), *The Growth of ICE Coal*, 2012, <www.theice.com/publicdocs/ICE_Coal_Infographic.pdf>.
[77] A therm is equivalent to 100,000 Btu or 29.3071 kW/hour.

2.4 The peak oil theory

The fear that the world will deplete its fossil fuel reserves, due to their finite nature, constitutes a major concern. The rate of production of each limited resource cannot grow indefinitely but will reach a maximum value, the peak of production, beyond which begins to decline. The theory of peak oil was formulated in 1956 by the American geologist M. King Hubbert in his essay "*Nuclear energy and the fossil fuels*". Although he talked about oil, the theory is applicable to whatever kind of finite resource, thus including both natural gas and coal.

The evolution of the production rate is described by a bell-shaped curve, in which four phases can be distinguished. The first is characterized by an exponential growth and occurs when the deposits are still plenty and extraction requires modest investments. In the second phase, more difficult to extract resources are accessed with a significant increase of costs. Although the rate of production continues to grow, it raises less rapidly than in the previous phase. It is evident that increasing investments are necessary. The following gradual exhaustion of reserves leads to the peak. In the last phase, production declines; therefore, production continues, but at decreasing rates.[78]

By observing past production levels and discoveries, Hubbert predicted that the oil production in the United States would peak around 1970. His forecast was correct; indeed, the production reached a peak in 1971. Since then, this point has been called Hubbert peak. Nevertheless, the rapid and continuous descent of oil prices after the energy crisis of the 1970s, questioned Hubbert's theory. Two main critical elements emerged. The theory did not consider the impact of technological change on the estimation of available reserves and neglected the influence of price on demand and supply of oil.[79] In fact, an increase in demand causes a growing price, thus promoting improvements in extraction techniques and stimulating a more efficient exploitation of the resource. Furthermore, high prices induce consumers to seek for alternative sources.

[78] M. KING HUBBERT, *Nuclear energy and the fossil fuels*, San Antonio, Drilling and Production Practice, 1956, <www.oilcrisis.com/hubbert/1956/1956.pdf>.
[79] William STEWART, *Climate of Uncertainty: A balanced look at global warming and renewable energy*, Flagler Beach, Florida, Ocean Publishing, 2010, pp. 96-100.

Since the creation of the modern oil industry, four times an oil peak has been predicted. The first time that fear diffused was during the very first years of the oil industry, when some fields around Titusville, Pennsylvania, drained for inexplicable reasons at the time. Nonetheless, soon after, new fields were discovered in Ohio, Kansas, Oklahoma and Texas. During the First World War, the need for oil increased substantially, and in order to save it, in the United States an appeal for Gasolineless Sundays was made. However, with the end of the world, the fear vanished. The break of the Second World War marked the third time that peak oil production was expected. Nevertheless, it was not until the 1970s that the panic really disseminated. The United States were no longer self-sufficient, and the Middle Eastern production came to a halt during the Arab embargo and the Iranian Revolution. In addition, in 1972, the Club of Rome[80] published a book entitled "*The Limits to Growth*". The report predicted the consequences of continued population growth on the terrestrial ecosystem, including the increasing consumption of resources. The consequences were a frenetic search for new supplies and suppliers, as well as the promotion of more efficient energy systems, especially in the transportation sector. Nowadays, the growing energy demand coming from developing countries, led by China and India, is questioning the extent of future supplies.[81]

The main question is when the world will deplete its fossil fuel reserves. The answer is that nobody can predict it. According to BP estimates, at the end of 2013 the global proved oil reserves were 1687.9 billion barrels, sufficient to meet other 53 years of global production. In the case of natural gas, reserves are estimated to be 185.7 trillion cubic meters (tcm), enough for other 55 years. Coal reserves, on the other hand, are so abundant that current production could last for 113 years.[82] Nonetheless, there are differences between the different regions of the world and a sharp increase in production could severely deplete the reserves faster.

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[80] The Club of Rome is a non-governmental, nonprofit association of scientists, economists, businessmen, civil right activists and politicians.
[81] Daniel YERGIN, *The Quest*, pp. 229-235.
[82] BP, *BP Statistical Review of World Energy*, June 2014, <www.bp.com/content/dam/bp/pdf/Energy-economics/statistical-review-2014/BP-statistical-review-of-world-energy-2014-full-report.pdf>.

Chapter Three
Alternative Energy

3.1 Nuclear Energy

3.1.1 History of nuclear energy

The pursuit of atomic power for electricity production began after the discovery of the huge quantities of energy that radioactive elements could grant. Nevertheless, it took almost half a century before Albert Einstein's principle of mass-energy equivalence could turn into reality. The discovery of nuclear fission and the neutron in the 1930s represented the first steps toward the creation of the nuclear industry.

The first experimental reactor achieved criticality[1] on December 2, 1942. Chicago Pile-1, as it was named, was built underneath the Stagg Field football stadium of the University of Chicago under the supervision of Italian physicist Enrico Fermi. Two years later, the first heavy-water reactor, denominated Chicago Pile-3, achieved criticality.[2] Both reactors were part of the Manhattan Project.[3] The power of nuclear energy became evident to the world after the use of the two atomic weapons on the Japanese cities of Hiroshima and Nagasaki.

In 1951, for the first time, a nuclear reactor generated electricity. Initially nominated CP-4, the Experimental Breeder Reactor-I (EBR-I) was designed, built and operated by the Argonne National Laboratory in Idaho. The EBR-I was able to produce enough electricity to power its building.[4] In addition, in 1953 President Eisenhower proposed a cooperation, known as Atoms for Peace, between the United States and the Soviet Union to generate

[1] Criticality indicates the amount of material required so that a nuclear chain reaction can self-sustain autonomously.
[2] ARGONNE NATIONAL LABORATORY, *Reactors Designed by Argonne National Laboratory: Early Exploration*, November 10, 2014, <www.ne.anl.gov/About/reactors/early-reactors.shtml>.
[3] The Manhattan Project was a research and development project intended to produce nuclear weapons during the Second World War.
[4] ARGONNE NATIONAL LABORATORY, *Reactors Designed by Argonne National Laboratory: Fast Reactor Technology*, November 18, 2014, <www.ne.anl.gov/About/reactors/frt.shtml>.

electricity from nuclear power. For the first time nuclear energy was diverted from warlike purposes; however military research continued.

In 1954, the connection to the electric grid of the small nuclear power plant in Obninsk, near Moscow, crossed the line; it was the first time that nuclear energy was employed to produce electricity for civilian use.[5] In 1956, Queen Elizabeth II officially opened Calder Hall plant, thus marking the beginning of the exploitation of nuclear energy on an industrial scale. The following year, even the United States started exploiting nuclear power when the powerhouse in Shippingport, in Pennsylvania, went into operation.[6]

Throughout the 1960s, the construction of nuclear power stations increased quickly. However, the arising building costs and the relative cheap price of fossil fuels after the Arab oil embargo in 1973 made this kind of energy less attractive. Still, there were exceptions. France and Japan, which were highly dependent on oil for their own electric generation capability, decided not to take the risk of another oil crisis, and, as a result, invested in nuclear power production.

Health and safety concerns started arising after the 1979 accident at the Three Mile Island, near Harrisburg in Pennsylvania. The operators of the plant, misled by the instrumentation, shut down the pumps that were feeding water to one reactor to keep it cool. Without the working emergency cooling system, the reactor core overheated and partly melted. The disaster led to the creation of the Institute of Nuclear Power Operation (INPO) and the decision of the United States to halt the construction of new reactors had a bandwagon effect on other countries.[7]

The deadliest nuclear catastrophe took place in 1986. At the time, 25 reactors were active in the Soviet Union using two different typologies. These two categories were a pressurized light-water reactor and the RBMK[8]. The latter was also the one in operation at the Obninsk plant. Although Soviet scientists informed the lack of safety of this type of reactor, the authorities preferred it because of its low costs. RBMKs were also in use in the V.I. Lenin station, near the town of Chernobyl. A series of mistakes, during an experiment intended to

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, *From Obninsk Beyond: Nuclear Power Conference Looks to Future*, June 24, 2004, <www.iaea.org/newscenter/news/obninsk-beyond-nuclear-power-conference-looks-future>.
[6] Daniel YERGIN, *The Quest*, p. 371.
[7] Ibid., pp. 374-375.
[8] The Russian acronym RBMK stands for High Power Channel-type Reactor (Реактор Большой Мощности Канальный – Reaktor Bol'shoj Moshchnosti Kanal'nyj).

increase the security of the plant, provoked two explosions, one of which uncovered reactor no. 4. The lack of a full containment vessel contributed to the dispersion of radioactive contaminants into the atmosphere.[9]

Chernobyl disaster had several effects. Despite the disaster occurred on April 26, 1986 the Soviet leaders denied and hide the accident until May 14, when the Secretary General Mikhail Gorbachev admitted what had happened. Radioactive substances had already been detected in several Western European countries. The reaction in Europe had the same effect the Three Mile Island accident had had in the United States. In the Soviet Union, the nuclear catastrophe dealt a huge blow to the political leadership of the country, contributing to its dissolution. However, the worst damages were recorded close to the nuclear reactor. Many people suffered from acute radiation sickness (ARS).[10] In addition, both flora and fauna were deeply affected.

The International Atomic Energy Agency (IAEA), founded in 1957 to promote the peaceful use of nuclear energy, introduced in 1990 the International Nuclear and Radiological Event Scale (INES). The scale is intended to guarantee prompt safety information in case of nuclear accidents. The scale consists of eight levels ranging from zero, the lowest, to seven, the highest [Figure 3]. So far, only two major nuclear disasters were classified as a level seven accident, due to the major release of radioactive material with subsequent widespread health and environmental effects. The first one happened in Chernobyl, while the second disaster took place in the Fukushima Daiichi nuclear power plant.

On March 11, 2011, a magnitude 9.0 earthquake hit northern Japan. The quake caused the automatic shutdown of nuclear power plants by emergency systems. However, the cooling systems were damaged by the following tsunami, causing an uncontrolled heating. The fuel rods of reactor no. 1 of the Fukushima Daiichi underwent melting, leading to an explosion, which caused the collapse of part of the external structures. The following day, the same problem occurred at reactor no. 3. Despite the attempt to slow the reaction by sprinkling the fuel rods with seawater and boric acid, dangerous gases, containing radioactive ions of iodine 131[11], were released into the atmosphere. On the night of March 15, an

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[9] WORLD NUCLEAR ASSOCIATION, *Chernobyl Accident 1986*, November 24, 2014, <www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Chernobyl-Accident/>.

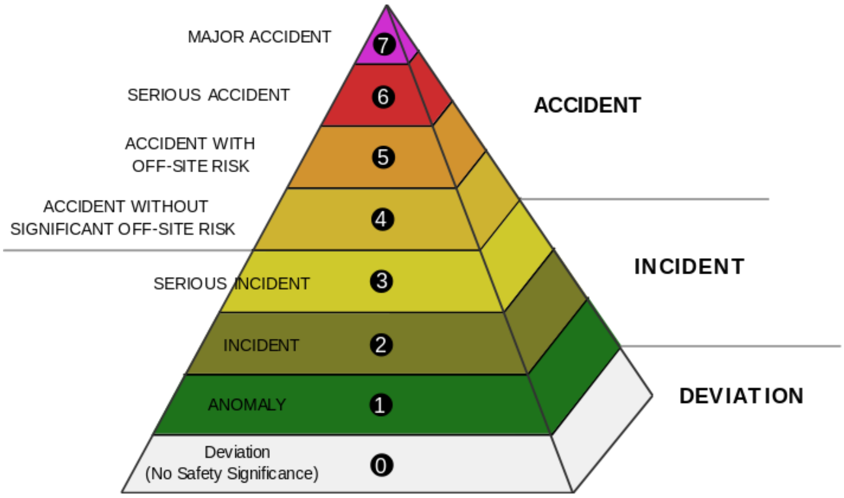
[10] Radiation poisoning causes cellular degradation, whose effects can extent from nausea and headaches to skin changes and mortality.

[11] The artificial radioisotope ^{131}I is a product of the fission of uranium and plutonium.

explosion occurred at reactor no. 4. Fires and radioactivity made access problematic for engineers to regain control of the systems. Nonetheless, the vessels withstood the explosions.[12]

The disaster led to the shutdown of Japan's 54 nuclear power plants. This decision resulted in a 30% loss in electricity generation, which was compensated with imports of liquefied natural gas.[13] In Europe, many countries decided to ban or phase out nuclear energy, namely Italy, Spain, Belgium, Germany, and Sweden.[14] On the other hand, some countries chose to continue with their nuclear programs. For instance, China is expected to activate between 40 to 50 new nuclear power plants by 2020. In the United States, the Obama administration keeps supporting the construction of two new nuclear stations in Georgia.[15]

Figure 3. The seven levels identified by the International Nuclear and Radiological Event Scale (INES).



Source: Operational Performance Information System (Korea Institute of Nuclear Safety).

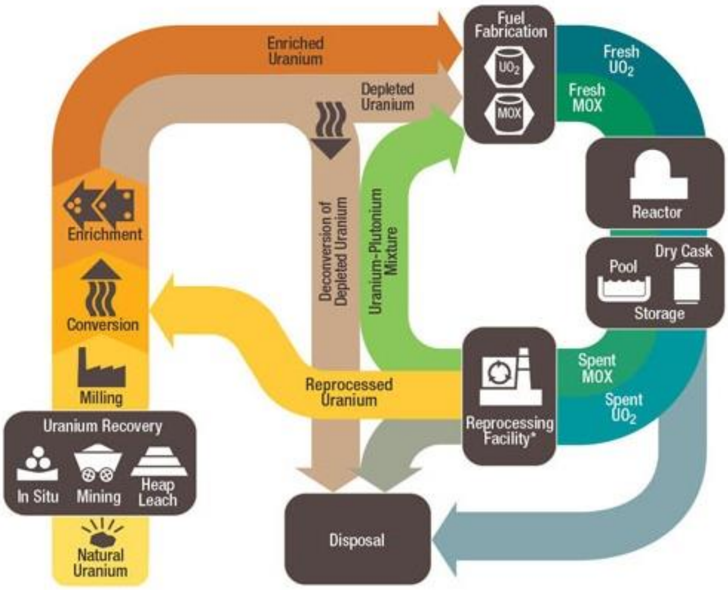
3.1.2 Nuclear Industry

The nuclear industry is not simply the generation of electricity and heat from a thermal power plant. The processes that composed the industry are part of the so-called nuclear life cycle. This cycle usually comprehends different phases: the mining of uranium, the fabrication of

[12] WORLD NUCLEAR ASSOCIATION, *Fukushima Accident*, November 2014, <www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Fukushima-Accident/>.
[13] Mikkal E. HERBERG, *Japan, Southeast Asia, and Australia*, in Jan H. KALICKI and David L. GOLDWYN, *Energy Security*, pp. 307-308.
[14] Charles D. FERGUSON, *A Nuclear Renaissance?*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, p. 302.
[15] Daniel YERGIN, *The Quest*, pp. 417-418.

the fuel, the generation of energy, the waste disposal or alternatively the reprocessing of spent fuel, and, just in this latter case, recycling [Figure 4].

Figure 4. The nuclear fuel cycle from extraction to disposal in a reprocessing system.



Source: U.S.NRC – United States Nuclear Regulatory Commission

Uranium mining is not much different from fossil fuels exploration. Once a deposit of uranium has been discovered, it is evaluated how much material is extractable and whether it can be profitable. Uranium ore extraction is identical to mining of other metals. There are four main extraction techniques: open pit, underground uranium mining, in-situ leach (ISL), and heap leaching. Like in the case of coal, uranium ores can be either superficial or deep. In the former case, the metal is accessed by the removal of rocks and the creation of a pit. In the latter, tunnels are excavated to reach the deposit, with less environmental impact. In-situ leach (ISL), also referred to as in-situ recovery (ISR), consists in the dissolution of the uranium minerals present in sands enclosed in underground aquifer. Then, the leached uranium is pumped to the surface. This is the mining method with least environmental impact. Finally, in heap leaching, the broken ore is piled on an impermeable pad. Afterwards, it is moistened with acid solution over many weeks. The collected liquid is treated so to recover the uranium. Once the depleted material is removed, it is replaced with a new ore.[16]

[16] WORLD NUCLEAR ASSOCIATION, *Uranium Mining Overview*, May 2012, <www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Mining-of-Uranium/Uranium-Mining-Overview/>.

Before being transported to a nuclear reactor, the ore are milled and processed. The ore is usually grinded to liberate the mineral particles. The uranium is recovered by leaching the crushed ore material with sulfuric acid to dissolve the uranium oxides. Finally, the partially radioactive yellowcake, U_3O_8, is transported to a conversion plant. Through chemical processes, the uranium oxides are converted into uranium hexafluoride, UF_6, which is then used to enrich uranium. Conversion plants are operating in the United States, France, Canada, Russia and China.[17] The most common isotope of uranium found in nature is uranium-238 (^{238}U or U-238). Nonetheless, having an even number of neutrons[18] is less desirable because it is not fissile. Indeed, fission consists in the ability of a nucleus to split in two smaller-sized radioactive nuclei, through the absorption of a neutron, thus releasing a large amount of energy. That is the reason why uranium-235 (^{235}U or U-235) is more desirable. Nevertheless, this isotope is less abundant. Accordingly, through nuclear fission, the concentration of U-235 has to be increased in a process termed enrichment.[19]

Enriched uranium is a critical component for both civil nuclear energy generation and military nuclear proliferation. The enrichment process can be split into two main grades: low-enriched uranium (LEU) and highly enriched uranium (HEU). Natural uranium is 99.283% U-238, 0.711% U-235 and 0.0054% U-234. LEU has between 1 or 2% and 20% concentration of U-235 and it is used mainly in commercial light water reactors. On the hand, HEU ranges from 20% to more than 90% concentration of U-235, which is employed for the construction of nuclear weapons.[20] [Figure 5]. The enriched uranium constitutes the nuclear fuel, while the U-238 remaining after enrichment is the depleted uranium (DU). Enriched UF_6 is converted into uranium dioxide (UO_2) powder, which is pressed inside small fuel pellets. The pellets are heated before being inserted into zirconium tubes to form fuel rods.[21]

The nuclear fuel is assembled in different ways for distinct reactors. Most reactors are light-water reactors (LWRs). The two main models are pressurized-water reactors (PWRs)

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[17] WORLD NUCLEAR ASSOCIATION, *Conversion and Deconversion*, October 2014, <www.world-nuclear.org /info/Nuclear-Fuel-Cycle/Conversion-Enrichment-and-Fabrication/Conversion-and-Deconversion/>.

[18] Whereas the number of protons, which determines the atomic number, is unique for each element, the atomic mass, which is the number of protons and neutrons in an atom, can vary, resulting in different isotopes of the same element.

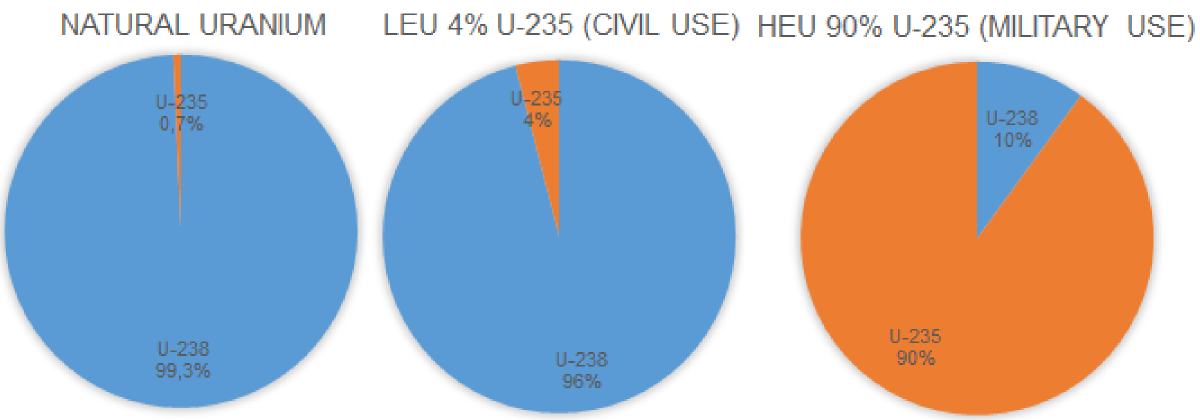
[19] Charles D. FERGUSON, *A Nuclear Renaissance?*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, p. 296.

[20] Ibid., p. 297.

[21] WORLD NUCLEAR ASSOCIATION, *Nuclear Fuel Fabrication*, September 2014, <www.world-nuclear.org/ info/Nuclear-Fuel-Cycle/Conversion-Enrichment-and-Fabriacation/Fuel-Fabrication/>.

and boiling-water reactors (BWRs)[22], respectively developed by Westinghouse and General Electric.[23] Another kind of reactor, used in Canada, employs heavy water, deuterium bound to oxygen, as a moderator, to compensate the exploitation of natural uranium, instead of LEU. This model is called Pressurized Heavy Water Reactor (PHWR), or alternatively CANDU.[24] Inside the reactor, the critical mass undergoes a self-sustaining fission chain reaction in a stable manner. Metal control bars, able to absorb the excess neutrons released by the reaction, avoid that the reaction becomes uncontrollable leading to the core melt.

Figure 5. Comparison between natural, low enriched (LEU) and high-enriched (HEU) uranium.



Most nuclear power plants comprehend more than just one reactor. The heat produced by controlled fission is used to raise steam, which is converted by a turbine into mechanical energy. Subsequently, the kinetic energy is transformed into electricity by a generator. Most nuclear reactors can produce 1,000 MW. However, the most modern reactors are able to generate up to 1,600 MW. A 1,000 MW reactor could provide enough electricity for a half-million people city in the developed world.[25] According to data published by the International Atomic Energy Agency (IAEA), 438 nuclear power reactors, mostly PWRs, are in operation 31 countries.[26]

[22] Gawdat BAHGAT, *Energy Security*, p. 30.
[23] Daniel YERGIN, *The Quest*, p. 372.
[24] Charles D. FERGUSON, *A Nuclear Renaissance?*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, p. 297.
[25] Ibid., p. 300.
[26] INTERNATIONAL ATOMIC ENERGY AGENCY, *Power Reactor Information System*, November 24, 2014, <www.iaea.org/PRIS/home.aspx>.

The spent fuel can either be recycled or disposed in geological repositories. Nuclear reprocessing consist in the separation of plutonium from spent fuel. Indeed, reactors can produce plutonium-239 (Pu-239) from non-fissile U-238.[27] Depleted uranium can be mixed with the plutonium obtained by reprocessing for the production of mixed oxide (MOX) nuclear fuel, whose physical behavior is similar to that of the original fuel. Consequently, it can be used together with uranium to produce electricity in fast breeder reactors.[28] The uranium fuel rods produce power for a few years, afterwards the nuclear wastes need to be treated and disposed in interim storages and deep underground repositories.

Nuclear wastes can be categorized in three groups. The fuel rod, which becomes exhausted after three years spent in the reactor, is classified as a high-level waste. Indeed, it is the most radioactive, 95%, although it represents just 3% of the total volume of nuclear wastes. Intermediate-level wastes encompass components of the reactor. They are enormously less radioactive, 4%, than the spent fuel, but they constitute a slightly greater percentage, 7%, of the total volume. Finally, low-level wastes are tools and clothes used from nuclear power plant operation. They are lightly contaminated, only 1% of the total radioactive content, but comprises the majority, 90%, of nuclear wastes [Table 9].

Table 9. Nuclear wastes.

Category of nuclear waste	**Components**	**Contamination percentage**	**Volume percentage**	**Deposit**
High-level waste	*Fuel rods*	95%	3%	Deep underground geological repositories
Intermediate-level waste	*Components of reactors*	4%	7%	Closer-to-surface repositories
Low-level waste	*Tools and clothes*	1%	90%	

The different waste are managed in several ways. The extremely hot and radioactive spent fuel must be cooled and shielded. It is dislodge underwater and relocated into a storage pool, where it can stay up to fifty years. However, after five years, it can be moved into

[27] Charles D. FERGUSON, *A Nuclear Renaissance?*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century* p. 298.
[28] WORLD NUCLEAR ASSOCIATION, *Mixed Oxide (MOX) Fuel*, May 2013, <www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Fuel-Recycling/Mixed-Oxide-Fuel-MOX/>.

dry ventilated concrete containers. Alternatively, the majority, 97%, of the spent fuel can be reprocessed into MOX, with the residual 3% being waste. The high-level wastes need to be disposed in geological repositories located deep underground. Conversely, both intermediate- and low-level wastes are dumped in closer-to-the-surface depositories.[29]

3.1.3 Debate on the use of nuclear power

The use of nuclear power to produce electricity for civilian purposes is highly controversial and debated. It sees two opposing sides, one supporting and one opposing the exploitation of nuclear energy. The debate began in the late 1970s, after the Three Mile Island accident, and peaked in the late 1980s, as a consequence of the Chernobyl explosion. Lately, reflections about the exploitation of nuclear energy have intensified, on the one hand because of the threat of global warming, and on the other due to the Fukushima disaster. The different views focus mainly on several issues, encompassing energy security, costs, environmental effects, safety, and proliferation risk.

From an energy security perspective, the question is whether nuclear power can substitute fossil fuels. Supporters claim that uranium is a stable, reliable and relatively protected from price volatility source.[30] Moreover, it is much more efficient in terms of consumption of raw materials.[31] The overall energy outcome of one nuclear fuel pellet is equivalent to three barrels of oil, or alternatively one ton of carbon.[32] On the other hand, nuclear power can exclusively be used to generate electricity, but cannot substitute oil as a transportation fuel. Although hydrogen fuel is expected to be produced by hydrolysis in the future[33], technological difficulties still exist. Military submarines and combatant ships are the only exception. In 1954, the U.S. Department of Defense commissioned the construction of the first nuclear-propelled submarine, USS Nautilus.[34] In addition, like fossil fuels, even uranium is a finite source; therefore, renewable energies would be a better solution to deal with the energy security problem.

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[29] WORLD NUCLEAR ASSOCIATION, *What are nuclear wastes and how are they managed?*, 2014, <www.world-nuclear.org/Nuclear-Basics/What-are-nuclear-wastes-/>.
[30] Gawdat BAHGAT, *Energy Security*, p. 44.
[31] William STEWART, *Climate of Uncertainty*, p. 116.
[32] Charles D. FERGUSON, *A Nuclear Renaissance?*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Centurty*, p. 296.
[33] Sascha MÜLLER-KRAENNER, *Energy Security*, p. 122.
[34] Daniel YERGIN, *The Quest*, p. 370.

The construction costs of thermal power plants are enormous. It is estimated that the capital costs for building a new plant fluctuate between $5 to $12 billion. The required safety measures and the additional years requested to implement them are more and more responsible for the increasing capital expense. Despite the need of huge investments, the operating costs are very low, thus making nuclear energy cost competitive compared to other fuels employed for the generation of electricity.[35] Nonetheless, facilities must be decommissioned after thirty to forty years of activity. It is claimed that the decommissioning process costs vary between $300 million to $5.6 billion. Obviously, the most expensive to demolish are those sites which have undergone a serious accident.[36] This costs make gas- and coal-fired plants more competitive and, consequently, preferable.

Under an environmental point of view, the debate is about two issues: the greenhouse gas emissions and the radioactive wastes. Nuclear power plants do not directly emit carbon dioxide (CO_2), sulfur or other greenhouse gases[37], if not indirectly due to the trucks and other vehicles used in the extraction of uranium.[38] Nevertheless, a leak in the infrastructure or a potential disaster can release radioactive gases and liquids into the environment, which can be transported very far by winds. The other problem is the disposal of radioactive wastes. This is considered the Achilles' heel of the nuclear power industry. Indeed, the high-level radioactive wastes must find a permanent storage. Although, deep-underground repositories have been identified as the ideal option, little progress has been made. The government of the United States have chosen the Yucca Mountain site in Nevada as storage facility.[39] Nevertheless, doubts remain as the area, on the border with California, is highly seismic. Another strategy, which can reduce the amount of wastes, is reprocessing. Fast breeder reactors, projected for this specific aim, exist only in a very few countries, namely Japan, France, India, Russia, and the United Kingdom.[40]

Another central question in the debate about nuclear power concerns safety. The thermal power industry has improved the safety of reactors. Even though new safer designs have

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[35] Toni JOHNSON, *Nuclear Power Expansion Challenges*, Council on Foreign Relations, March 18, 2011, <www.cfr.org/publication/16886/nuclear_bottlenecks.html>.
[36] Benjamin K. SOVACOOL, *Contesting the Future of Nuclear Power: A Critical Global Assessment of Atomic Energy*, Singapore, World Scientific, 2011, pp. 118-119.
[37] William STEWART, *Climate of Uncertainty*, p. 116.
[38] Sascha MÜLLER-KRAENNER, *Energy Security*, p. 121.
[39] Gawdat BAHGAT, *Energy Security*, p. 31.
[40] Charles D. FERGUSON, *A Nuclear Renaissance?*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, p. 301.

been proposed and introduced, there is still no guarantee that nothing dangerous can happen. In particular, doubts remain about the increasing adoption of nuclear energy by countries with weak legal frameworks and with poor construction practice.[41] However, the Fukushima accident queries whether an advanced economy with a long experience in the field, such as Japan, can master nuclear safety. Not even increasing controls by the World Association of Nuclear Operators (WANO), which emphasizes the highest possible safety standards[42], can protect from potential accidents. The main fear about nuclear safety regards the exposure to radiation and the increase risk of cancer, even without the occurrence of a calamity.[43]

Finally, a key factor of preoccupation is nuclear proliferation. The nuclear fuel cycle arises the risk of proliferation in two stages. Highly enriched uranium can be used to fuel atomic bombs if a 90% concentration of U-235 is reached. The enrichment centrifuges can be used both to produce LEU for civilian purposes and HEU for nuclear weapons. The difference between the two depends on the duration and the frequency of the centrifuge.[44] Accordingly, nobody can distinguish whether enrichment plants are used for commercial or military goals.

This problem is now most evident in the case of the Iranian nuclear program.[45] The other essential fissile component of a nuclear weapon is plutonium, which can be extracted from the spent fuel during the aforementioned reprocessing phase. The Non-Proliferation Treaty (NPT)[46] promotes the peaceful research and development of nuclear energy; however, it is difficult to prevent the construction of a nuclear arsenal. In addition, some countries, namely India, Pakistan, Israel and North Korea, are not parties in the treaty, although they have declared possessing nuclear weapons. In order to preempt the proliferation risk, also coming from terrorist groups, additional measures were taken. In particular, the International Atomic

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[41] Deron LOVAAS, *Balancing Energy Security and the Environment*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, pp. 328-329.

[42] Charles D. FERGUSON, *A Nuclear Renaissance?*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, p. 299.

[43] Gawdat BAHGAT, *Energy Security*, p. 9.

[44] Charles D. FERGUSON, *A Nuclear Renaissance?*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, pp. 297-298.

[45] According to the IAEA data, since 2011 a nuclear reactor is in operation in Bushehr. Other two reactors should be completed in the next years and new plants are in construction to cover a total requirement of 20,000 MW. A report by IAEA affirmed that Iran was conducting research related to the enrichment of uranium to build nuclear weapons.

[46] The Treaty on Non-Proliferation of Nuclear Weapons was signed in New York in 1968 and became effective in 1970. The three objectives of the treaty are non-proliferation, disarmament and the right to peacefully use nuclear technology.

Energy Agency (IAEA) constantly monitor the production and storage of both U-235 and Pu-239.[47] In 2006, the creation of a Global Nuclear Energy Partnership (GNEP) was proposed. GNEP would divide the world into two groups: fuel supplier nations, which supply U-235 and deal with spent fuel, and users nations, which operate thermal power plants.[48] Nevertheless, pessimists highlight that, despite the existence of international agreements and the increasing measures adopted by several organizations, the risk persists. Indeed, the rising number of nuclear-weapons nations and the failure of deterrence, which is the threat of retaliation, will make the outbreak of a nuclear confrontation more likely.[49]

3.2 Renewable resources

3.2.1 History of renewable resources

Renewables were the first resources to be used by man. Prior to the exploitation of coal during the Industrial Revolution, nearly all energy came from renewable sources. Wood and other biological materials were, and in some parts of the world are still, employed not only to heat houses, but also to cook food. Water wheels and watermills were built to grind grain so to produce flour, or alternatively to saw timber and stone. Moreover, water was also pivotal to irrigate fields. Wind was essential to move ships, but also to triturate wheat inside mills, since in northern Europe water froze in the winter. Furthermore, large areas of the Rhine River delta were drained thanks to windmills.

The Industrial Revolution eclipsed the use of renewable sources to the benefit of fossil fuels. In the mid-nineteenth century, fossil fuels were available in large quantities. Besides, they could provide large amount of energy with little fuel. By contrast, it was too complex to harness energy from sustainable fuel sources. Therefore, fossil fuels were more energy efficient that alternative sources. Hydrocarbons were more stable, as they were immediately available and it was also possible to store them. In general, it was easier to exploit fossil

[47] James J. WIRTZ, *Weapons of Mass Destruction*, in Allan COLLINS, *Contemporary Security Studies*, Oxford, Oxford University Press, 2013, p. 258.
[48] Charles D. FERGUSON, *Nuclear Energy: Balancing Benefits and Risks*, New York, Council on Foreign Relations, 2007, p. 23.
[49] Michael SHEEHAN, *Military Security*, in Allan COLLINS, *Contemporary Security Studies*, Oxford, Oxford University Press, 2013, pp. 154-155.

fuels than green energies to generate power and heat. Despite these advantages, natural elements kept being exploited, although in smaller amounts. Wind and hydropower, especially, were employed to produce electricity since the 1880s.

The 1970s marked the rebirth of natural resources. The energy crisis, caused by the 1973 Arab oil embargo and the 1979 Iranian Revolution, pushed many countries to invest in alternative energies, so to gain a major stability for the future. While some countries, like Japan and France, decided to fund the construction of nuclear power plants, others, especially the United States, considered a transition toward clean energy due the abundance and the wide distribution of green resources. In addition, the environmental effects of increasing consumption on fossil fuels became evident.[50] To emphasize the need for conservation of natural resources, on April 22, 1970 was celebrated the first Earth Day. In that date, environmental scientists evaluated, through a series of experiments, the problems of the planet, such as pollution and depletion of non-renewable resources. Given the results obtained and published, President Richard Nixon established the creation of the Environmental Protection Agency (EPA).[51]

The modern renewable energy industry was born in 1974. President Jimmy Carter proposed a transition to solar energy with the dual objective of safeguarding the environment and reducing the dependence on oil. Accordingly, the first solar energy bill went into law. In addition, Carter appointed James Schlesinger to find a solution against energy insecurity. The result was the creation of the Department of Energy (DoE), a combination of several governmental agencies into a unified organization. The DoE introduced fiscal incentives and granted loans to industries interested in developing research and projects on renewables. Furthermore, the DoE founded a national research laboratory consecrated to green energy, the National Renewable Energy Laboratory (NREL).[52] Even the government of Japan launched a similar project, the so-called Sunshine Program, with the specific aim of conducting research for the development of an efficient solar energy industry. In 1979, as a consequence of the second energy crisis, the New Energy and Industrial Technology Development Organization (NEDO) was established.[53]

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[50] Daniel YERGIN, *The Quest*, pp. 527-528.
[51] Ibid., pp. 530-531.
[52] The National Renewable Energy Laboratory (NREL) was known as Solar Energy Research Institute until 1977, since at the very beginning research were conducted just in the solar energy field.
[53] Daniel YERGIN, *The Quest*, pp. 530-540.

Renewables sources, however, were not able to grow in scale. Lack of incentives, efficiency and competition from fossil fuels brought to a period of stagnation in the green energy industry. Many start-ups went bankrupt. Disillusion and disappointment reigned in the following decades.[54] Nonetheless, the situation changed at the beginning of the new millennium. More than the increasing effect of global warming and climate change, what induced governments of many countries to rethink their energy policies was the growing price of oil. Indeed, high prices are beneficial to investments and research in new technologies. In addition, some countries adopted approaches to reduce the emissions of pollutants, such as the Emission Trading Scheme (ETS) introduced in 2005 by the European Union.[55] Finally, a series of international conferences and treaties is pushing the world to undergo a transition toward clean energies.

3.2.2 Forms of renewable energies and their exploitation

There are many forms of renewable energies. By definition, renewables are all those energies obtained from natural sources, which can regenerate as fast as they are consumed. Since their consumption does not emit carbon dioxide (CO_2) or any other pollutant into the atmosphere, they are also called green energies. Therefore, renewable energies are solar, wind, hydropower, marine, geothermal energies, and biomass [Table 10].

It could be argued that the sun is the most important existing source of energy. Solar energy, which is the heat and the light produced by the sun, has made our planet habitable, and has permitted the evolution of life and the progress of humanity. The Earth’s average temperature is caused by the absorption of solar radiation, which raises the temperature of oceans, making their water to evaporate. The drops of evaporated water condense into clouds, which, together with other gases in the atmosphere, reflect and trap part of the incoming sunlight, ensuring mild temperatures, ideal for the development of life. Furthermore, by photosynthesis, plants convert solar energy into chemical energy, which is used by organisms to synthesize carbon dioxide and water. Besides, plants produce carbohydrates, which are either stored in or used to fuel their activities, and release oxygen, an essential and necessary element to sustain terrestrial life. Some of them yield edible fruits and wood, which can be ignited to warm up and roast food. Lastly, dead organisms undergo a series

[54] Ibid., *The Quest*, p. 528.
[55] Alexandre ROJEY, *Energy and Climate*, pp. 29-31.

of processes and slowly decompose. In absence of oxygen, this procedure is called anaerobic digestion, which, after millions of years, transform them into fossil fuels.[56]

Solar energy can be used to generate electricity (photovoltaic) or to produce heat (solar thermal). There are three main technologies employed to convert radiant light and heat of the sun into exploitable energy. Solar water heating (SWH) technology, also referred to as solar hot water (SHW), exploits the solar rays to heat a liquid with peculiar characteristics, usually a mixture of water and glycol, contained inside a solar thermal panel, which transfers heat to water stored in a tank. Photovoltaic (PV) technology produces electricity from sunlight captured from a solar panel. The absorption of solar particles, called photons, makes the PV cells to free electrons, which produce electricity in their attempt to flux from the negatively charged layer to the one positively charged of a semiconductor, generally silicon. Finally, the concentrated solar power (CSP) system is composed by a series of parabolic mirrors and lenses for conveying the sunlight onto a receiver tube in which flows a heat transfer fluid. The heated liquid produces steam, which turns a turbine, thus generating electricity. A different version of the same system consists in reflecting the rays from the mirrors and concentrate them at the end of a tower in which is placed a boiler filled with salts that melt because of the heat. Indeed, in both cases, the fluids are heated to very high temperatures, up to 400°C/750°F or even higher.[57]

Wind energy, as the name suggests, is the mechanical power and electricity generated by the intensity and strength of the wind. Wind energy could be considered as a form of solar energy, since winds are engendered by solar radiation. Nevertheless, other elements, which contribute to the generation of winds, are the rotation of the planet, the cooling effect of the oceans, icecaps and glaciers, and the irregularities of the terrestrial surface. Across the world, there are two main categories of wind energy power stations, commonly referred to as wind farms, offshore and onshore or near shore. They both work in the same way. Wind pushes the blades, usually three, of a turbine, whose rotation spin a shaft connected to an electric generator. [58] The quantity of electricity produces depends on three main variables: the speed of the wind, the blade radius, and air density. The stronger the winds, the

[56] William STEWART, *Climate of Uncertainty*, p. 11.
[57] SOLAR ENERGY INDUSTRIES ASSOCIATION, *Solar Technology*, 2014, <www.seia.org/policy/solar-technology>.
[58] AUSTRALIAN RENEWABLE ENERGY AGENCY, *Wind energy*, 2014, <www.arena.gov.au/about-renewable-energy/wind-energy/>.

larger the radius of the blades, the higher the pressure of the air, the more energy is produced. Accordingly, offshore wind farms produce more electricity, since winds are regular, blow faster and air is denser. In addition, bigger blades, up to a diameter of 200 meters/650 feet, can be installed.[59]

Hydropower derives from the strength of falling and running water, which can be exploited to generate electricity. A dam or a penstock is usually built to accumulate water, which is funneled to strike the blades of turbines connected to electric generators. Nevertheless, there are three main hydropower stations. Run-of-river facilities have little or no reservoir, and as a result, it provides a constant supply. Storage stations exploit a reservoir created by the construction of a dam or a lake, so to produce additional electricity during peak hours. Lastly, pumped-storage hydropower provides a continuous supply of electricity, since the falling water is recycled thanks to a system of pumps.[60]

A peculiar form of hydropower is marine energy. Ocean power harnesses the mechanical energy of ocean waves, tides and currents, the differences in temperature between the warmer sea surface and the cooler deep ocean, and the disparity in salinity rate between fresh water and seawater.[61] Consequently, within this category, it is possible to distinguish five groups: marine current power, osmotic power, ocean thermal power, tidal energy, and wave energy. For each of them, a different kind of turbine can be identified. A marine current device is similar to an upside-down windmill, with the only exceptions that the rotors are pushed by currents instead of winds and are smaller due to the less density of water compared to air.[62] There are two main types of these turbines: horizontal-axis (better suited to constant ocean currents) and vertical-axis (for currents that change direction). The two methods available of obtaining osmotic energy are reverse electrodialysis (RED) and pressure retarded osmosis (PRO). In RED, electricity is created from osmotic pressure, the flow of opposite charges[63], when sea and fresh water mix in an attempt to create an equilibrium between their respective salt concentrations.[64] In PRO, fresh water flows, through a

[59] THE EUROPEAN WIND ENERGY ASSOCIATION, *How a wind turbine works*, 2014, <www.ewea.org/wind-energy-basics/how-a-wind-turbine-works/>.
[60] INTERNATIONAL HYDROPOWER ASSOCIATION, *Types of hydropower*, 2014, <www.hydropower.org/types-of-hyropower>.
[61] Alexandre ROJEY, *Energy and Climate*, p. 76.
[62] MARINE CURRENT TURBINES, *Tidal Energy*, 2014, <www.marineturbines.com/Tidal-Energy>.
[63] Sodium chloride is composed of a positive ion, sodium (Na^+), and a negative ion, chloride (Cl^-).
[64] REAPOWER, *Reverse Electrodialysis Technology*, 2014, <www.reapower.eu/project-scope/reverse-electrodyalisis-technology.html>.

semi-permeable membrane, towards a fixed volume compartment containing saltwater. The consequent increasing in volume causes the pressure to rise in the range of 11-15 bars, equivalent to a column of water of 100-145 meters/330-475 feet. Its release spins turbines generating electricity, like in a traditional hydropower plant.[65] Ocean Thermal Energy, also indicated by the acronym OTE or OTEC, uses three systems. In a closed-cycle system, a working liquid, typically ammonia, evaporates when warm surface seawater is pumped through an evaporator. The vapor pressure sets in motion a turbine, which turns a generator making electricity. The lower pressure vapor passes through a condenser, in which deep cold seawater is pumped, before repeating the cycle.[66] An open-cycle system uses only seawater to produce electricity. Since the steam does not contain salt, this method can also be used to desalinize seawater. The hybrid system is a mix between the two to generate both electricity and desalinated water. Tidal power turbines work in a way similar to those employed in energy production from hydropower and other marine energy forms. The main methods consist in lifting of a weight against the force of gravity, compressing of the air in appropriate ducts, moving paddle wheels, filling and emptying reservoirs. The last system differentiates from the one employed in traditional hydroelectricity production, because water, entrapped by dams at the river estuaries, is released only when the tide recedes. Finally, in wave energy oscillating water columns, attenuator systems, and overlapping devices are used. While the latter makes electricity from falling water, the other two creates it from hydraulic pressure.[67]

Geothermal energy is the exploitation of the natural heat of the planet released in processes of nuclear decay of different natural radioactive elements such as uranium, thorium and potassium.[68] A geothermal reservoir consists of hot water and heat trapped in porous and permeable rocks. This reservoir can be used either to generate electricity (hydrothermal) or to produce heat (geothermal direct heating). In both cases, a well is drilled and a pump delivers a constant hot stream. The only difference is that, in the former case, the

[65] EUROPEAN COMMISSION-COMMUNITY RESEARCH AND DEVELOPMENT INFORMATION SERVICE, *Power production from the osmotic pressure difference between fresh water and seawater*, July 28, 2005, <www.cordis.europa.eu/documents/documentlibrary/82766661EN6.pdf>.
[66] MAKAI OCEAN ENGINEERING, *OTEC – Ocean Thermal Energy Conversion*, 2014, <www.makai.com/otec-ocean-thermal-energy-conversion/>.
[67] William STEWART, *Climate of Uncertainty*, pp. 131-133.
[68] AUSTRALIAN RENEWABLE ENERGY AGENCY, *Geothermal energy*, 2014, <www.arena.gov.au/about-renewable-energy/geothermal-energy/>.

geothermal water or steam is converted into electricity at a geothermal power plant like in a traditional hydroelectric station. Nevertheless, a new system, which is currently being developed and tested, attempts to generate electricity without the presence of a geothermal reservoir. The system is called Enhanced Geothermal System (EGS) in North America and Hot Dry Rock (HDR) in Europe. First, a highly pressurized water is pumped into a well drilled in an impermeable hot basement rock. The injection and the consequent water infiltration cause the fracture, due to the higher pressure, and the enhanced permeability of the rock, thus creating a reservoir. Finally, heat water is recovered through a second borehole and electricity is generated like in a traditional geothermal power plant. Once the water has turned into a liquid and cool state, it is re-injected into the ground.[69]

Bioenergy is the power obtained from a biomass, which is an organic matter that has stored energy through photosynthesis. Biomass can be converted into heat through combustion (thermal conversion) or, alternatively, into a biofuel (chemical conversion) for the transportation sector. These biofuels can be categorized into two broad classes, first and second generation, depending, respectively, on whether they derive from living organisms or not. First generation biofuels are made by fermentation of carbohydrates and distillation of sugar and starch, like for the production of alcoholic beverages, or by isolation of some acids contained in natural oils. Second generation, also known as advanced, biofuels derive from lignite, agricultural residues and waste through a process called pyrolysis, which is the thermochemical decomposition of organic material in the absence of oxygen. Recently, a third generation is also contemplated, referring just to algae due to their higher yield compared to other biofuels.[70]

[69] U.S. DEPARTMENT OF ENERGY, *How an Enhanced Geothermal System works*, 2014, <www.energy.gov/eere/geothermal/how-enhanced-geothermal-system-works>.
[70] INTERNATIONAL ENERGY AGENCY, *Biofuel Production*, January 2007, <www.iea.org/techno/essentials2.pdf>.

Table 10. Renewable resources and exploitation techniques.

Resource	Energy	Energy carrier	Technologies
Sun	Solar Energy	*Electricity*	-Photovoltaics (PV) -Concentrated Solar Power (CSP)
		Heat	-Solar water heating (SWH) / Solar hot water (SHW)
Wind	Wind energy	*Electricity*	-Onshore wind turbine -Offshore wind turbine
Water (rivers and lakes)	Hydropower	*Electricity*	-Run-off-river facility -Storage station -Pumped-storage station
Water (seas and oceans)	Marine energy	*Electricity*	
1-Marine current	*1-Marine current energy*		-Horizontal-axis turbine -Vertical-axis turbine
2-Salinity differential	*2-Osmotic energy*		-Reverse electrodialysis (RED) -Pressure retarded osmosis (PRO)
3-Temperature differential	*3-Ocean thermal energy*		-Closed-cycle system -Open-cycle system -Hybrid system
4-Tides	*4-Tidal energy*		-Horizontal-axis turbine -Vertical-axis turbine -Oscillating hydrofoil -Enclosed tip -Archimedes' screw -Tidal kite
5-Waves	*5-Wave energy*		-Attenuator -Point absorber -Oscillating wave surge convertor -Oscillating water column

			-Overtopping/terminator device -Submerged pressure differential -Rotating mass
Earth's heat	Geothermal	*Electricity*	-Hydrothermal -Enhanced Geothermal System (EGS) / Hot Dry Rock (HDR)
		Heat	-Geothermal direct heating
Biomass	Bioenergy	*Heat*	-Thermal conversion
		Biofuel	-Chemical conversion
1-Living organisms		*1-First generation*	1-Fermentation and distillation 1-Acid isolation
2-Non-living organisms		*2-Advanced / Second generation*	2-Pyrolysis

PART 2

ENVIRONMENTAL SECURITY

CHAPTER FOUR
ENVIRONMENTAL SECURITY

4.1 What is environmental security?

4.1.1 Definition and evolution of environmental security

The end of the Cold War marked a transition toward a new conception of international security. What became to be known as traditional security, especially realism, which focused on the state as a referent object, was inadequate to define rising threats. Consequently, besides military and power, which were the main subjects of analysis by realists, additional and alternative referent objects were examined by post-realist schools. Nontraditional security introduced a new way of thinking about security, contemplating also social instability, health, poverty and environment as security risks. Besides widening the study of security, including various concerns, the nontraditional approach deepened the quest by expanding the focus of the matter, exploring a complete new range of objects to be secured.[1]

The Copenhagen School emerged among the main approaches to security studies. The leading book of the school, *Security: A New Framework for Analysis*, published in 1998 by Barry Buzan, Ole Wæver and Jaap de Wilde, introduced two pivotal notions: Barry Buzan's sectorial analysis and Ole Wæver's social constructed perspective, called securitization. According to these academics, security is a speech act, a necessary element to convince the audience about the existence of potential threats to a referent object. Securitization is, therefore, a two-stage process promoted by securitizing actors, political leaders, governments, lobbyists, bureaucrats and media, who claim that extraordinary measures must be taken, so to protect the referent object. In such an approach, it is evident that just if the speech act is successful, a politicized issue turns into a security problem. Furthermore, the sectorial

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[1] Niloy Ranjan BISWAS, *Is the Environment a Security Threat?: Environmental Security beyond Securitization*, in «International Affairs Review», Vol. XX, No. 1, Winter 2011.

method broadened the concept of security. Buzan identified five categories of security: military, political, economic, societal, and environmental, respectively considering as referent objects the state, national sovereignty, national economies, identities, and habitats.[2]

Environmental security, as the name suggests, consists in the protection of the surrounding habitat. However, it is important to understand that, besides being an object to be protected, the environment can also be a source of risk, as it will be explained. Environmental security arose as a nontraditional notion of security thanks to a series of events since the 1960s. First, many leaders in Western countries developed a consciousness about the environment. Some important nongovernmental organizations, such as the World Wildlife Fund (WWF) in 1961, Greenpeace in 1971, and the United Nations Environmental Programme (UNEP) in 1972 were established. Furthermore, international conferences and agreements were signed in the attempt to protect the environment from degradation, especially highlighting the risk that environmental change could bring to both individuals and development. Moreover, since the end of the Cold War, many scholars published books and reviews about the existing connection between environment and common security.[3]

The expression environmental security may have several meanings. Because of the ambivalence of the terms, the concept is indeterminate; consequently, six dominant interpretations can be investigated [Table 11]. The first meaning that comes to mind is that of ecological security. In this case, the threat is constituted by human activities, which have repercussions on the ecosystem. Nevertheless, as it has already been mentioned, there is an unbreakable bond between environment and common security. Environmental degradation and climate change are international problems, which affect, although in different proportions, the whole planet, meaning that all countries are at risk. Subsequently, it is possible to highlight the existence of an environment-threat-vulnerability nexus. Indeed, the integrity of the ecosystem is fundamental not only for the sustainability of livelihood, but also for the integrity of the state, since environmental calamities can influence economic growth and social cohesion, thus destabilizing regimes in some countries. Hence, environmental security is an important component of both human and national security. Migrations and political tensions, due to environmental degradation, can sour international relations, eventually leading to a conflict. Finally, both during warfare and peace times, the armed forces have

[2] Ralf EMMERS, *Securitization*, in Allan COLLINS, *Contemporary Security Studies*, pp. 132-135.
[3] Jon BARNETT, *Environmental Security*, in Allan COLLINS, *Contemporary Security Studies*, pp. 190-194.

several impacts on the environment. In particular, they can degrade the habitat during fighting or exercises, by contributing to the consumption of natural resources and pollution. Despite the existing link between the local, national and global levels, environmental security is still mainly interpreted as a risk to the state as a whole, thus not contemplating the threat to individuals, other states, and especially to the environment itself.[4]

Table 11. Interpretations of environmental security.

<table>
<tr><th>Interpretations</th><th>Source of risk</th></tr>
<tr><td>Ecological security</td><td>Human activities</td></tr>
<tr><td>Common security</td><td rowspan="3">Environmental change</td></tr>
<tr><td>Human security</td></tr>
<tr><td>National security</td></tr>
<tr><td>Environmental violence</td><td>Environmental degradation</td></tr>
<tr><td>Armed forces-environment nexus</td><td>Military activities</td></tr>
</table>

4.1.2 History of environmental studies

Environmental change encompasses all the changes that occur in the environment provoked by either natural events or human activities. Climate change and global warming are, either directly or indirectly, the main reasons behind environmental variations. Throughout the years, many scientists studied the causes and the effects that climatic mutations have on the ecosystems, with consequences that can affect, as already mentioned, local, national and international security.

The first observations on climate began toward the end of the 18th century. The founder of alpinism, the Swiss naturalist and physicist Horace-Bénédict de Saussure, conducted studies on mountain climate and made meteorological observations during seven Alpine trips, described in his four-volume *Voyages dans les Alpes* (Trips in the Alps). Saussure examined, using both barometers and thermometers, the percentage of atmospheric humidity, solar radiation, the temperature, the transparency and composition of air at various altitudes. In his *Essai sur l'hygrométrie* (Essay on hygrometry), published in 1983, he described the experiments made using different kind of hygrometers to analyze the humidity

[4] Ibid., pp. 198-205.

of air. Nevertheless, one of his main contribution was the invention of a device, the first example of solar cooker, similar to a mini greenhouse, which entrapped thermal radiation.[5]

During the first half of the 19th century, two important contributions to the study of global warming materialized. Based on experiments conducted by Saussure, Jean-Baptiste Joseph Fourier claimed that due to the distance between the Earth and the Sun, the planet should be much colder and that another factor, present in the atmosphere, should explain the temperature. The cause became to be known as greenhouse effect. The terrestrial atmosphere is transparent, thus enabling solar radiation to hit the surface of the planet; however, part of the re-radiated sunlight is trapped by the presence of some gases. Consequently, average global temperatures, which are neither too cold nor too hot, make life possible.[6] The second significant theory was advanced by biologist Louis Agassiz. He asserted that the Earth had experienced an ice age in the past, due to a drop in the average temperature of the planet. He also declared that ice ages, during which the Earth's surface is covered with polar ice caps of varying extension, are part of a cyclical system. As evidence of his claims, in an expedition to North America he showed that the Great Lakes were dug by the growth and subsequent withdrawal of the glaciers.[7]

Experiments were contacted leading to new discoveries in the following years. In 1859, the Irish physicist, John Tyndall, discovered, using a spectrophotometer, that some gases blocked the infrared radiation, suggesting that changes in their concentration may cause climate changes. He was the first scientist to demonstrate the existence of the greenhouse effect.[8] Influenced by both Fourier and Tyndall, Svante Arrhenius studied the effects of carbon dioxide, CO_2, on climate. He noticed that increasing emission of CO_2 could provoke global warming. Furthermore, he examined the role of water vapor in the amplification of the phenomenon.[9]

At the beginning of the 20th century, the Serbian climatologist Milutin Milankovitch conducted two major studies. He described and calculated the climate of the planets of the

[5] Estelle LUCIEN, *Horace-Bénédict de Saussure, à l'assaut des Alpes*, in «Tribune de Genève», June 19, 2009, p. 28.
[6] Alexandre ROJEY, *Energy and Climate*, pp. 22-23.
[7] Daniel YERGIN, *The Quest*, pp. 430-431.
[8] NASA EARTH OBSERVATORY, *John Tyndall (1820-1893)*, 2014, <www.earthobservatory.nasa.gov/Features/Tyndall/>.
[9] NASA EARTH OBSERVATORY, *Svante Arrhenius (1859-1927)*, 2014, <www.earthobservatory.nasa.gov /Features/Arrhenius/arrhenius_2.php>.

solar system based on the solar radiation they received. In addition, he claimed that the differences in the intensity of insolation in various areas of the planet resulted in climatic variations. The second contribution made by Milankovitch consists in the analysis of the correlation between long-term climate changes with the orbital eccentricity, the tilt of the Earth's axis and the precession of the equinoxes. The periodic fluctuations in climate, known as Milankovitch cycles, helped to explain the recurrence of glaciation in the history of the planet and to predict future climate change.[10]

In accordance with Arrhenius' predictions, Guy Stewart Callendar argued that increasing concentrations of carbon dioxide in the atmosphere were responsible for global warming. Nevertheless, his theories were criticized by the American scientists Roger Revelle. Revelle asserted that temperature rise could not be caused by carbon dioxide, since oceans absorbed larger quantities than the atmosphere. Further studies on oceanography proved that Revelle was partially wrong. Indeed, the dissimilar temperatures at different depths suggested that oceans absorbed limited amounts of CO_2, or alternatively, at a much slower pace than previously expected.[11]

A milestone in the study of climate change was the International Geophysical Year (IGY). The project was held from July 1957 to December 1958, in order to coincide with a period of strong solar activity. The IGY consisted in a worldwide coordinated set of research to understand the physical properties of the planet and its interactions with the Sun. Data collected by David Keeling on Mauna Loa, in Hawaii, led him to the conclusion that there was a strong fluctuation in carbon dioxide levels throughout the year. In fact, during spring and summer, plants absorbed carbon dioxide and emitted oxygen. Consequently, the concentrations of CO_2 resulted much lower than during winter. Moreover, his measurements showed, in what became known as Keeling Curve, the growing percentage of carbon dioxide levels in the atmosphere since 1958.[12] According to the most recent detection by the Scripps Institution of Oceanography, on December 6, 2014, carbon dioxide concentration at Mauna Loa Observatory was of 398.20 parts per million (ppm).[13]

[10] NASA EARTH OBSERVATORY, *Milutin Milankovitch (1879-1958)*, 2014, <www.earthobservatory.nasa.gov /Features/Milankovitch/>.
[11] Daniel YERGIN, *The Quest*, pp. 438-439.
[12] Rob MONROE, *The History of the Keeling Curve*, Scripps Institution of Oceanography, April 3, 2013, <www. scripps.ucsd.edu/programs/keelingcurve/2013/04/03/the-history-of-the-keeling-curve/>.
[13] SCRIPPS INSTITUTION OF OCEANOGRAPHY, *The Keeling Curve*, December 6, 2014, <www.scripps. ucsd.edu/programs/keelingcurve/>.

In 1988, the United Nations established the Intergovernmental Panel on Climate Change (IPCC) in order to study global warming. The IPCC does not make research or monitor the climate on its own, but bases its work on available scientific literature. The evaluation reports published to date are five. The *First Assessment Report*, printed in 1990, concluded that the planet was warming. Consequently, the United Nations General Assembly convened an international summit to restrict the emissions of greenhouse gases.[14] The *Second*, *Third* and *Fourth Assessment Reports*, respectively published in 1995, 2001 and 2007, highlighted that human responsibility was very probable, that temperatures were rising and that there was no time to adapt or to mitigate climate change. In 2007, *The Stern Review of the Economics of Climate Change* specified that the costs of inaction would be much greater than dealing with the problem.[15] The most recent report, available since November 2014, observed that the impact of human activities on the environment is certain and the consequences of global warming are evident on every continent. Future projections will depend on policies adopted by governments; nevertheless, the latter they are implemented, the greater the risks will be, leading to irreversible changes.[16]

4.2 Environmental change

4.2.1 Natural causes of environmental change

In past and present times, environmental change has been the consequences of several factors. Part of the causes result from naturally occurring phenomena, such as solar activity, orbital variations, ocean variability, natural greenhouse gases, volcanism and plate tectonic. Nevertheless, according to data published by the IPCC, the majority of current environmental problems derive from human activities, especially electricity supply, transportation, agriculture and forestry, industrial emissions, and wastes.

Milutin Milankovitch asserted that climate is influenced by astronomical factors. Although the intensity of their impact is still debated, what is certain is that they also constitute a cause

[14] Alexandre ROJEY, *Energy and Climate*, p. 23.
[15] Daniel YERGIN, *The Quest*, pp. 501-502.
[16] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), *Climate Change 2014: Synthesis Report*, November 2014, <www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_SPMcorr1.pdf>.

of climate change. Everybody knows that the tilt of the planet produces thermal changes in the four seasons. As a consequence, alterations in the tilt can affect global temperatures, resulting in warmer summers and cooler winters whenever the inclination of the terrestrial axis increases, or cooler summers and warmer winters in the opposite situation. The Earth's tilt naturally shift between 22 and 25 degrees[17] approximately every 41,000 years. Furthermore, seasons and temperatures depend on the Earth's orbit around the Sun. The elliptical orbit of planets causes them to have a perihelion and an aphelion, respectively the closest and farthest approach to the Sun. The current difference in Earth-Sun distance between perihelion and aphelion is roughly 5 million kilometers/3.1 million miles. Because of a 6.8% increase in solar radiation reaching the Earth at perihelion[18], which occurs around January 3-4, boreal winters are a little milder than in the austral hemisphere. Moreover, since the Earth moves faster when in perihelion, fall and winter are shorter than spring and summer in the northern hemisphere. Nevertheless, changes in the orbital eccentricity over a period of 410,000 years, as well as the movement of the orbital ellipse, due to the gravitational force of the Sun and other planets, mainly Jupiter and Saturn, over an interval of 21,000-25,000 years, affect the length of the seasons and their beginning; it is the so-called precession of the equinoxes. Finally, the Earth's axis of rotation changes direction every 26,000 years, because of the gravitational forces of the Sun and the Moon, resulting in more extreme differences between the seasons for the hemisphere pointing toward the Sun in perihelion. For this reason, the northern hemisphere have milder seasons than the southern hemisphere.[19]

Another important natural factor of climate change is solar activity. The number of sunspots[20] that appear in a more or less intense way on the solar surface in cycles of 11 years determines solar activity. When on the surface a large number of spots are visible, the Sun releases more energy in the space. According to many scientists, solar radiation apparently is not sufficient to explicate global warming[21]; however, there is a consensus that the

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[17] According to NASA, the Earth's axial tilt is 23.4 degrees.

[18] Solar radiation between perihelion and aphelion can reach a difference over 25% when the orbit is at its most elliptical.

[19] Jill S.M. COLEMAN, *Milankovitch Cycles*, in S. George PHILANDER, *Encyclopedia of Global Warming and Climate Change*, Los Angeles, SAGE Publications, 2012, pp. 927-928.

[20] Sunspots are areas on the solar surface characterized by a lower temperature and a stronger magnetic activity. The thermal contrast makes them clearly visible as dark spots.

[21] Peter FOUKAL, Claus FRÖHLICH, Hendrik SPRUIT and Tom M.L. WIGLEY, *Variations in solar luminosity and their effect on the Earth's climate*, in «Nature», September 14, 2006, pp. 161-166.

influence of the Sun on terrestrial climate is tied more to the sunspot number than to the energy emitted. Some scientists demonstrated that even a little intensification in solar activity influences the climate in the tropical area, resulting in stronger winds and precipitations.[22] Besides, another important phenomenon is the flux of cosmic rays that affect the concentration of clouds. When solar activity is more intense, there are fewer clouds; consequently, more energy reaches the Earth's surface, contributing to global warming.[23] Nonetheless, the relation between cosmic rays and global warming is still highly debated, and new studies are being conducted.

The greenhouse effect is also a natural phenomenon. As already mentioned, it is the ability of the planet to retain in its atmosphere part of the incoming solar radiation, thus maintaining stable temperatures over long periods. The principal greenhouse gases (GHGs) are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). Despite what is commonly believed, the main proponent of the effect is water vapor. According to NASA, water vapor has a heat-amplifier effect, so strong to double global warming.[24] Nevertheless, water vapor has lifetime of just one week and its mass remains constant through the water cycle, while particles of other GHGs can float in the atmosphere between ten years to over a century, and their concentration can vary depending on both natural and anthropogenic factors.[25] For instance, natural CO_2 sources are respiration of living organisms, volcanic eruptions, natural fires, the global carbon cycle, which is the exchange of carbon among the biosphere, hydrosphere and atmosphere. Natural occurring CH_4 is generated by wetlands and rice fields, ruminant animals' digestion, and plants. Finally, N_2O, which is one the gases with the longest lifespan, about 114 years, and whose molecules has a global warming ability 298 times than CO_2 over a century, is mostly due to microbial processes.[26]

[22] Tony PHILLIPS, *Solar Variability and Terrestrial Climate*, NASA, January 8, 2013, <www.science.nasa.gov/science-news/science-at-nasa/2013/08jan_sunclimate/>.
[23] EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN), *CERN's CLOUD experiment shines new light on climate change*, October 6, 2013, <www.press. web.cern.ch/press-releases/2013/10/cerns-cloud-experiment-shines-new-light-climate-change>.
[24] Kathryn HASEN, *Water Vapor Confirmed as Major Player in Climate Change*, NASA, November 17, 2008, <www.nasa.gov/topics/earth/features/vapor_warming.html>.
[25] U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA), *Climate Change Indicators in the United States*, July 2, 2014, <www.epa.gov/climate/climatechange/science/indicators/ghg/index.html>.
[26] U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA), *Methane and Nitrous Oxide Emissions From Natural Sources*, April 2010, <www.epa.gov/outreach/pdfs/Methane-and-Nitrous-Oxide-Emissions-From-Natural-Sources.pdf>.

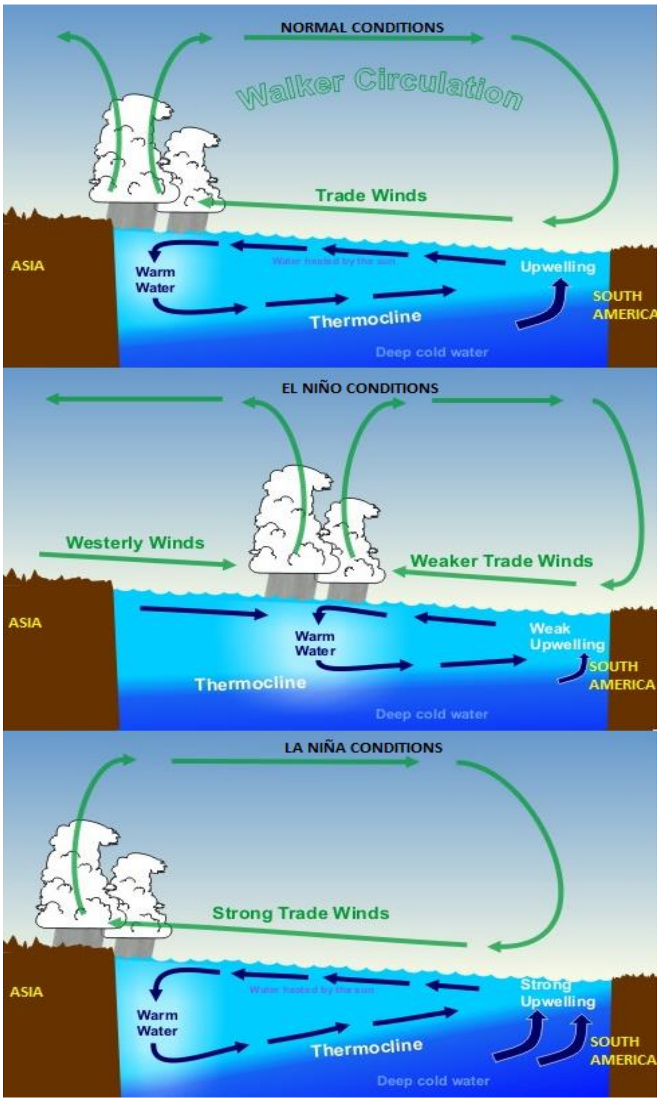
The oceans, especially their variability and circulation, also influence climate change. The oceanic currents depend on the thermohaline circulation, also called great ocean conveyor or global conveyor belt, caused by change in density of water masses, in other words the temperature and salinity of water. This phenomenon supplies heat to the polar region, where water sinks because of the low temperatures and the high salinity provoked by the formation of the ice pack. The cold water, moving toward the equator, interacts with other water, reducing its density and, therefore, rising to the surface.[27] Nevertheless, warming and cooling cycles of 30 years can increase water temperatures strengthening the speed of the process. The flow of warmer water in the polar regions melts ice, thus mixing fresh and salt water. Since the density of water is reduced, the thermohaline circulation slows.[28]

An important impact of the correlation between ocean and atmosphere is the El Niño Southern Oscillation (ENSO) [Figure 6]. ENSO is composed by two phases, a warm one, named El Niño[29], and a cold one, called La Niña. In normal conditions, the warmer surface water of the tropical Pacific Ocean is pushed by winds from South American coasts westward. Consequently, sea level is higher, about 0.5 meters/1.5 feet, and water is warmer, about 8°C/14°F in Asia, thus affecting weather conditions. At the same time, the colder water rises from the deep ocean to the surface along the coastlines of Peru, Ecuador and northern Chile, increasing the presence of fish in the area. During El Niño, which occurs at irregular intervals of three to seven years, winds weaken, thus making water flowing eastward. Fish die or migrate, rainfall increases, leading to floods in Southern America, while in Australia and Asia agriculture is threatened by drought. In North America, the West coast experiences colder winter, whereas temperatures are warmer in the Midwest. Moreover, El Niño prevents the formation of hurricanes in the Gulf of Mexico.[30] Nonetheless, the phenomenon does not always have the same intensity and, although it typically lasts nine to twelve months, can persists for years. [31] Its counterpart is La Niña, which does not necessarily follows the warm

[27] NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTARTION (NOAA), *The Global Conveyor Belt*, November 5, 2012, <www.oceanservice.noaa.org/education/tutorial_currents/05conveyor1.html>.
[28] Niina HEIKKINEN and CLIMATEWIRE, *Oceans Hid the Heat and Slowed Pace of Global Warming*, Scientific American, August 22, 2014, <www.scientificamerican.com/article/oceans-hid-the-heat-and-slowed-pace-of-global-warming/>.
[29] The name El Niño derives from the occurrence of the phenomenon around Christmas.
[30] NATIONAL GEOGRAPHIC, *El Niño: El Niño-Southern Oscillation (ENSO)*, 2014, <www.education.nationalgeographic.com/education/encyclopedia/el-nino/?ar_a=1>.
[31] NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA), *What are El Niño and La Niña*, September 4, 2014, <www.oceanservice.noaa.gov/facts/ninonina.html>.

phase. During the cold phase, the sea surface temperature is colder than usual and stronger winds push more surface water westward. Consequently, the monsoon season in Asia tends to be wetter, because of the increasing precipitations, which are also recorded in Africa, while the Americas experience drier winters.[32]

Figure 6. The El Niño Southern Oscillation (ENSO): comparison in weather conditions between normal, El Niño and La Niña conditions.



Source: National Oceanic and Atmospheric Administration (NOAA).

Volcanism is responsible for both global cooling and global warming. During eruptions, volcanoes expel enormous quantities of gases and ashes. Whilst ashes remain suspended

[32] NASA EARTH OBSERVATORY, *The Effects of La Niña*, 2014, <www.earthobservatory.nasa.gov/Features/LaNina/la_nina_2.php>.

in the atmosphere for a few weeks at most, carbon dioxide and sulfur dioxide increment the layer of greenhouse gases. Sulfur dioxide converts into sulfuric acid forming thin aerosols, nongaseous particles, which enhance the albedo effect, the reflectivity of solar radiation, thus cooling global temperatures. For instance, the eruption of Mount Pinatubo, in the Philippines, on June 15, 1991 emitted so much sulfur dioxide into the stratosphere to lower the Earth's temperature for the following three years.[33] The amount of CO_2 ejected by volcanoes is more than 130 million tons per year. Although the quantity released by eruptions is inferior to anthropogenic emissions, thus contributing little to global warming, the high concentration can be lethal to animals and plants.[34] Nonetheless, the relation between volcanic eruptions and global change is still disputed.

Finally, plate tectonics play a primary role in the climate system over periods of millions of years. The movement of the Earth's crust have an impact on the distribution of landmasses, the elevation of continents, and the concentration of CO_2. Equatorial areas receive more solar radiation than higher latitudes; as a result, an increased presence of water would increment both the albedo effect and water evaporation. Similarly, more land at high latitudes facilitates the accumulation of snow and ice, which enhance reflectivity. These changes also affect the aforementioned ocean currents. Alterations of the topography influence temperatures, precipitations and wind circulation. Moreover, as previously mentioned, volcanisms can release additional particles of gases into the atmosphere.[35]

4.2.2 Anthropogenic causes of environmental change

The impact of human activities on the environment are probably the best known. However, they do not simply include the emissions of additional gases into the atmosphere due to industrial production and transportation, but also agricultural work, livestock and wastes. Although global warming can be partly attributed to natural reasons, it is undoubtedly clear that the human influence has accelerated the phenomenon since the beginning of the Industrial Revolution, simultaneously enhancing natural effects.

[33] U.S. GEOLOGICAL SURVEY (USGS), *Volcanic gases and Climate Change Overview*, January 27, 2012, <www.volcanoes.usgs.gov/hazards/gas/climate.php>.
[34] U.S. GEOLOGICAL SURVEY (USGS), *Volcanic Gases and Their Effects*, June 11, 2010, <www.volcanoes.usgs.gov/hazards/gas/index.php>.
[35] Robert M. DECONTO, *Plate Tectonics and Climate Change*, May 23, 2008, <www.geo.umass.edu/climate/papers2/deconto_tectonics&climate.pdf>.

Human activities contributes to the concentration of greenhouse gases (GHGs) in the atmosphere. The largest anthropogenic sources of emissions are electricity production, transportation, industry, commercial and residential, agriculture and forestry, primarily deriving from burning fossil fuels.[36] The influence of human beings have both a warming and a cooling effect, since most aerosols do not allow sun rays to reach the Earth's surface, but some of them trap heat. The main problem of greenhouse gases is related both to their concentration and to their lifespan in the atmosphere. In addition to the natural occurring GHGs, they are a few that are exclusively manmade, such as chlorofuorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and bromofluorocarbons (BFCs). These gases are also the most dangerous since they are responsible for the depletion of the ozone layer and persist in the atmosphere up to 50,000 years.[37]

Production of electricity is probably one of the most debated concerns. In the first chapter, it has been asserted that energy is essential for global growth; however, energy involves environmental risks. Even though most people think that just fossil fuels are polluting, it should be specified that all sources are environmentally damaging. Nevertheless, different energy sources harm the ecosystem in diverse ways. Coal is probably the worst source, since it is detrimental to the quality of both water and land, when extracted, especially whether open pit mining is preferred, and to air, when burned, because of the release into the atmosphere of its main components: carbon dioxide, sulfur dioxide and mercury. Oil and gas production can destroy the natural habitat of many species, especially, but not only when a major accident occurs, not to mention the enormous quantity of wasted water for the extraction of their respective unconventional sources.[38] Furthermore, there is the possibility of contaminating the aquifers and causing earthquakes through hydraulic fracturing.[39] Nuclear power plants produce radioactive wastes, which are dangerous to people and the surrounding environment. Accidents can release toxic particles into air or water. Moreover, high amount of water is needed to keep the fuel rods cool. The production of biofuels leads

[36] U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA), *Sources of Greenhouse Gas Emissions*, August 20, 2014, <www.epa.gov/climatechange/ghgemissions/sources.html>.
[37] PARLIAMENT OF AUSTRALIA, *Human contribution to climate change*, November 15, 2010, <www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/Browse_by_Topic/ClimateChange/whyClimate/human>.
[38] Marilyn A. BROWN and Benjamin K. SOVACOOL, *Climate Change and Global Energy Security*, pp. 18-19.
[39] David G. VICTOR, *The Gas Promise*, in Jan H. KALICKI and David L. GOLDWYN, *Energy and Security*, pp. 101-102.

to soil erosion, deforestation, and increased use of herbicides to grow plants. Dams built to exploit the strength of water alter water temperature and flow, contributing to the acidification of reservoirs and mortality of fish. The production of cells used in photovoltaic systems generates toxic materials, which are very often dispersed in the environment. Wind turbines can provoke bird and bat mortality due to collisions, especially when the blades are larger and rotating at a faster speed. Geothermal plants emit very little quantities of carbon and sulfur dioxides; therefore, it is the most environmentally friendly resource.[40]

Transportation is highly dependent on petroleum products. The growing number of vehicles burns additional quantities of gasoline and diesel, thus contributing to global warming through emissions of carbon dioxide and nitrous oxides. Unlike electricity productions, transportation means still have no or very little alternatives to oil. The largest emitters are road vehicles, which are considered responsible for more than 50% of the sector emissions.[41] An additional problem is represented by traffic congestions, which increasingly deteriorate the quality of air. Gasoline engines release more CO_2 than diesel, but the differences are very little. On the other hand, biodiesel and ethanol are considered a good solution, since, being plants a carbon sink[42], the emitted CO_2 is absorbed by the same plants employed for their production. However, the cultivation of some plants and deforestation to increase the output should also be evaluated. Even better are electric cars, because of reduced emissions and greater possibility of fuel generation; nevertheless, problems related to the employed batteries persist.[43]

Agriculture also affects the environment. In the past, farmers used to cultivate mixed crops, not to erode the soil, and to preserve the environment, exploiting natural wastes as fertilizers and rainwater to irrigate the fields. Nowadays industrial agriculture is more energy-dependent.[44] Farming requires more and more land, especially because of the growing population and the resulting demand for food. As a consequence, huge areas are deforested and converted to either pastures for feedstock or fields. Deforestation not only increment

[40] ENERGY4ME – SOCIETY OF PETROLEUM ENGINEERS, *Environmental Impact by Energy Source*, 2014, <www.energy4me.org/energy-facts/environmental-protection/environmental-impact-by-source/>.
[41] U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA), *Sources of Greenhouse Gas Emissions*, July 22, 2014, <www.epa.gov/climatechange/ghgemissions/sources/transportation.html>.
[42] Carbon sinks are oceans and forests. The name derives from their ability to absorb carbon dioxide.
[43] FUELECONOMY, *All-Electric Vehicles (EVs)*, December 12, 2014, <www.fueleconomy.gov/feg/evtech.shtml>.
[44] Marilyn A. BROWN and Benjamin K. SOVACOOL, *Climate Change and Global Energy Security*, pp. 35-36.

the concentration of carbon dioxide in the atmosphere, because they release the CO_2 previously absorbed and the reduction of such an important carbon sink, but it also contributes to desertification and biodiversity extinction. Nonetheless, modern agriculture is based on monocultures, which accelerates soil erosion, since the ground has no time to rest. In addition, toxic pesticides kill all microorganisms and contaminate the environment. Effects exacerbated by fertilizers and means used for the agricultural production and harvest. Finally, farming is the sector that wastes more water; in fact, more than 60% of the employed freshwater goes to waste every year.[45]

Environmental problems also spread with advancing consumerism economy. The rate at which goods are replaced has greatly accelerated the amount of wastes produced by society. The European Commission has estimated that in 2010 in the Old Continent waste production reached 2.5 billion tons, of which only a very small amount was recycled. Most waste is accumulated in landfills, with negative effects on humans, animals and plants.[46] Furthermore, a considerable amount of waste is found in the oceans, probably the most notorious is the so-called Great Pacific Garbage Patch, also referred to as the Pacific Trash Vortex, a huge accumulation of floating garbage, composed mainly of plastic, located in the Pacific Ocean between California and Japan. A similar gyre is also represent in the Atlantic Ocean, off the United States eastern coasts.[47] Trash is not simply solid, but also liquid, and can contain very dangerous toxins, such as mercury. These toxins are indirectly eaten by humans and animals, since plants and fish absorb them. Moreover, the loss of pollutants in landfills and their emissions can also contaminate groundwater and air. Furthermore, electronic waste or e-waste is estimated to be between 20 to 50 million tons per year. Components of electronic products are rich in mercury and other metals, which are typically disassembled under inhumane conditions in Asia, with dreadful consequences for workers.[48]

Other important damages to the environment can derive from armed forces both in warfare and peace times. Armed forces, as it has already been stated, are significant consumers of natural resources, not only fossil fuels, but also water. Soldiers need to train to be ready

[45] WORLD WILDLIFE FUND (WWF), *Environmental impacts of farming*, 2014, <www.wwf.panda.org/what_we_do/ footprint/agriculture/impacts/>.
[46] EUROPEAN COMMISSION, *Waste*, October 30, 2014, <www.ec.europa.eu/environment/waste/>.
[47] Lindsey HOSHAW, *Afloat in the Ocean, Expanding Islands of Trash*, November 9, 2009, The New York Times, <www.nytimes.com/2009/11/10/science/10patch.html?_r=0>.
[48] Marilyn A. BROWN and Benjamin K. SOVACOOL, *Climate Change and Global Energy Security*, p. 47.

for eventual fights; therefore, they can cause huge environmental harms even in peace-times. During wars, there is an incrementing extraction and utilization of resources to fuel combats. Moreover, bombing and the techniques of attack and defense can contribute significantly to the degradation of the ecosystem. The chemical weapons used both during the First and the Second World War, besides causing many causalities, contributed to water and soil contamination.[49] The devastating consequences of the two nuclear bombs that destroyed the cities of Hiroshima and Nagasaki, and testing of nuclear armaments contaminate large areas of the planet. Probably the most memorable examples are the tests, occurred in the Marshall Islands, which literally vaporized some islets on Bikini and Enewetak Atolls. Nevertheless, the effects of warfare on the environment became evident, especially after the Vietnam War. The American troops used an herbicide and defoliant, called Agent Orange, aimed at removing the leaves of the trees so to deprive the Viet Cong of the protection given by the vegetation cover. In addition, the persistent effects of the agent on the wood contaminated the whole food chain.[50]

4.2.3 Environmental change effects

The effects of environmental change, in particular that of climate, are becoming increasingly evident. They include a range of different phenomena, such as temperature rise, extreme weather conditions, droughts, glacier retreat and sea level rise, ocean acidification, and habitat loss. Nevertheless, it is not just a matter of physical impacts, since their consequences affect the entire social and economic system, leading to lack of food supply, health problems and even wars for the control of essential resources.

Climate change is acknowledged as the principal environmental trouble facing the globe. Climate change is mainly due to the rising global average temperature. Since the beginning of the Industrial Revolution, the concentration of greenhouse gases has been progressively climbing and, in the best case scenario, is expected to double by 2100. Consequently, according to the Intergovernmental Panel on Climate Change, temperatures may rise up to 6.4°C/11.5°F. Nonetheless, only an increase of 2°C/3.4°F is considered a limit beyond which irremediable consequences will be faced. This does not mean that such a temperature rise

[49] Jon BARNETT, *Environmental Security*, in Allan COLLINS, *Contemporary Security Studies*, pp. 200-201.
[50] Sarah DEWEERDT, *War and the Environment: War can wreck landscapes and ecosystems as well as people*, in «World Watch Magazine», January/February 2008, Volume 21. Also available at <www.worldwatch.org/node/5520>.

is acceptable. Indeed, that is enough to melt Arctic ice caps.[51]

A wide spectrum of events testifies that the globe is warming. Rising temperatures are melting glaciers in the mountains, decreasing the snow cover during the winter season, as well as shrinking the extent of the Arctic sea ice. As a result, oceans are rising at a rate of 0.062 inches/1.6 millimeters per year. This situation represents a problem for many people who live along the coasts and even for many states, such as the Maldives or the many archipelagoes in the Pacific Ocean, whose elevation is below 10 feet/3 meters. The problem becomes clear by considering, for instance, that the melting of Antarctic ice sheets would raise sea level by 186 feet/56.7 meters.[52] Moreover, the reduction of the ice and permafrost is dangerous because it enhances temperatures by widening the albedo effect and by releasing entrapped methane into the atmosphere.[53] Nonetheless, the concern is not simply about sea level, but also about the quantity of freshwater, which would pour into the salty ocean waters. The mix of fresh and salt water could even stop oceanic currents, thus exacerbating meteorological conditions.[54]

Oceans play a fundamental role as carbon sinks. Indeed, they absorb part of the carbon dioxide present in the atmosphere. Nonetheless, their relation with climate change is rather complicated. Growing concentrations of CO_2 is leading to ocean acidification, resulting in mutations of seawater pH, with adverse repercussions for ocean life.[55] Furthermore, oceans also retains a share of the heat; however, the rising surface temperature of the oceans have two important implications, it reduces their ability to work as carbon sinks and, because of thermal expansion, it rises sea level.[56]

Global warming enhances both humidity and superficial seawater temperature. These two factors contribute to changes in the frequency and intensity of precipitations around the globe. As a consequence, rainfalls are moving from subtropical regions toward the poles. While vast areas of the planet will be interested by droughts and lack of water, others will

[51] WORLD WILDLIFE FUND (WWF), *Rising temperatures*, 2014, <www.wwf.panda.org/about_our_earth/aboutcc/ problems/rising_temperatures/>.
[52] William STEWART, *Climate of Uncertainty*, pp. 41-44.
[53] Alexandre ROJEY, *Energy and Climate*, pp. 27-28.
[54] NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA), *The Global Conveyor Belt*, October 20, 2014, <www.oceanservice.noaa.gov/education/turotial_currents/05conveyor3.html>.
[55] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), *Climate Change 2007: Synthesis Report*, 3.3.4 Ocean acidification, March 2007, <www.ipcc.ch/pubblications_and_data/ar4/syr/en/mains3-4.html>.
[56] Ibid., 3.2.3 Changes beyond the 21st century, <www.ipcc.ch/publications_and_data/ar4/syr/en/mains3-2-3.html>.

experience floods. This change in the distribution of precipitations is primarily due to the increased humidity rate of the atmosphere, which transports, thanks to the support of winds and currents, increasing quantities of water vapor from the tropics to higher latitudes.[57] These changes could lead to warmer and longer summers characterized by heat waves and droughts, as well as to reduced cold waves, rapid falls in temperatures, during winter. Extreme precipitation events are very probable, since an abnormal high sea temperature could possibly nourish storms, leading to floods. Even hurricanes are expected to intensify and last longer; however, the impact of global warming on their formation is still uncertain.[58]

Climate change is also deeply affecting many species. Global warming, especially in some regions of the planet, will lead animals and plants to migrate to cooler and higher locations to survive, thus altering ecosystems. Nevertheless, some species are more at risk than others are, since their habitats will disappear. With no place to live and nothing to eat, many autochthonous animals and plants will surely extinct. In the worst scenarios, estimates indicate a loss of 56,000 plants and 3,700 animal species.[59] The polar bear has become the symbol of the effects of global warming on the planet. With shrinking Arctic ice, polar bears find limited places on Earth to live; consequently, their survival is at stake. Other animals classified in vulnerable status, because of habitat loss, are corals, marine turtles, whales, pandas, koalas, and tigers among others.[60]

Climate change will also profoundly influence human lives. According to FAO, food security is menaced by atmospheric changes. Extreme temperatures, global warming, mutations in precipitation distribution will reduce food supply. In particular, arable land will turn into an arid wasteland and fish will either die or move to higher latitudes. The supply of livestock products is also dependent on the availability of water and crop output.[61] Furthermore, human health is also at risk. Heat waves and pollutants in the air are responsible for an

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[57] GEOPHYSICAL FLUID DYNAMICS LABORATORY, *Will the wet get wetter and the dry drier?*, October 15, 2008, <www.gfdl.noaa.gov/cms-filesystem-action/user_files/kd/pdf/gfdlhighlight_vol1n5.pdf>.

[58] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), *Managing the risks of extreme events and disasters to advance climate change adaptation*, Cambridge, Cambridge University Press, 2012, pp. 9-11. Also available at <www.ipcc.ch/pdf/special-reports/srex/SREX_FD_SPM_final.pdf>.

[59] Brian HANDWERK, *Global Warming Could Cause Mass Extinctions by 2050, Study Says*, National Geographic News, April 12, 2006, <www.news.nationalgeographic.com/news/2006/04/0412_060412_global_warming.html>.

[60] WORLD WILDLIFE FUND (WWF), *Species threatened by climate change*, 2014, <www.wwf.panda.org/about_our_earth/aboutcc/problems/impacts/species/>.

[61] FOOD AND AGRICULTURE ORGANIZATION (FAO), *Climate Change and Food Security: A Framework Document*, 2008, pp. 9-12. Also available at <www.fao.org/forestry/15538-079b31d45081fe9c3dbc6ff34de4807e4.pdf>.

increasing rate of respiratory and cardiovascular diseases, eventually leading to death. Humid air and floods can expose humans to some water-borne and insect-transmitted illnesses, such as malaria, diarrhea and dengue fever.[62] Moreover, dealing with climate change will exacerbate adaptation costs, considerably cutting global GDP year after year. Extreme weather conditions will not only damage or destroy existing infrastructures, but they will also induce people to migrate, rising costs especially in the poorest countries. As a result, global growth and development will be deeply affected.[63]

[62] WORLD HEALTH ORGANIZATION (WHO), *Climate Change and health*, August 2014, <www.who.int/mediacentre/factsheets/fs266/en/>.
[63] Nicholas STERN, *The Economics of Climate Change: The Stern Review*, Cambridge, Cambridge University Press, 2007, pp. vi-vii.

Chapter Five
The Debate On Climate Change

5.1 The scientific debate on climate change

5.1.1 Supporters of the human causation

Many scientists agree that the main reason behind global warming is man. Since the Industrial Revolution, deforestation and the consumption of fossil fuels have been rising the concentration of greenhouse gases in the atmosphere, causing significant climatic variations. Supporters of the human causation advocate an immediate intervention in order to avoid irreversible consequences. According to a series of surveys, conducted to assess general belief, the majority of scientists, referred to as scientific consensus, believes in the anthropogenic causation of global warming.

The evidence of the anthropogenic role in global warming is strong and supported by many data. In pre-industrial times, the concentrations of carbon dioxide were approximatively fluctuating between 180 and 300 parts per million.[1] Such estimates are based on the analysis of Antarctic and Greenlandic ice caps, which still conserve the carbon absorbed year after year. For ages, forests and oceans have been operating as carbon sinks, removing the quantities in excess. However, nowadays, the carbon equilibrium seems to have vanished, since CO_2 levels are close to 400 ppm, considered the highest volume reached in more than millions of years. Comparing the Keeling Curve[2] is possible to notice that, since the beginning of monitoring in 1958 on Mauna Loa, Hawaii, there has been an increasing detection of atmospheric CO_2 particles, related to the growing world's population and the global economic development. Indeed, scientists claim that the greater concentrations of

[1] U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA), *Causes of Climate Change*, March 18, 2014, <www.epa.gov/climatechange/science/causes.html>.
[2] Cf. SCRIPPS INSTITUTION OF OCEANOGRAPHY, *The Keeling Curve*, 2014, <www.scripps.ucsd.edu/programs/keelingcurve/wp-content/plugins/sio-bluemoon/graphs/mlo_full_record.png>.

carbon dioxide in the atmosphere are very likely the results of the enhancing consumption of fossil fuels, especially oil and coal in both developed and developing countries, energy production, deforestation and manufacturing.[3]

Even the concentrations of methane and nitrous oxide are rising. Methane levels has experienced a dramatic multiplication in the last two centuries. Before the Industrial Revolution, CH_4 in the atmosphere fluctuated between 580 and 730 parts per billion (ppb)[4], whereas now it exceeds 1,800 ppb. Similarly, nitrous oxide has increased by 120% compared to pre-industrial times.[5] Although CH_4 and N_2O are less abundant than C_2O, their global warming potential (GWP), which expresses the contribution of GHGs to the greenhouse effect, is respectively 21[6] and 310[7] times greater than carbon dioxide over a century. Accordingly, their effects are predicted to keep growing and become manifest in future years.

A concrete evidence of the so-called human causation stems from carbon isotopes. Carbon-14 (^{14}C) is a radioactive isotope produced by the reaction between cosmic rays and the nitrogen gas, which is present in the atmosphere. Although it exists only in small traces, measurements should not demonstrate a constant decline of its presence in the air. The answer is pretty clear. Over centuries, the carbon-14 absorbed by plants decays. Fossil fuels, which are rests of dead vegetation, do not contain any residues of ^{14}C. Therefore, while burning fossil fuels increments the quantity of other carbon isotopes in the atmosphere, thus explaining the reduction in percentage of traces of carbon-14. Another proof consists in the so-called δ13C (delta carbon thirteen), which is the ratio between the isotopes ^{13}C (small quantities) and ^{12}C (around 99%). While oceans maintain the ratio in equilibrium, since they do not discriminate between the two kind of isotopes, plants, through photosynthesis, mainly absorb carbon-12, because it is lighter than carbon-13. Accordingly, the ratio should be positive. Nevertheless, stations around the world are detecting a negative ratio,

[3] Anna MCCARTNEY, *Find out where, when levels of CO2 increase*, in «Erie Times-News», January 11, 2011, p. 3D. Also available at <www.goerie.com/apps/pbcs.dll/article?AID=2011301119984>.
[4] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), *Climate Change 2007: Working Group I: The Physical Science Basis*, 2.1.1 Changes in Atmospheric Carbon Dioxide, Methane and Nitrous Oxide, 2007, <www.ipcc.ch/publications_and_dayta/ar4/wg1/en/tssts-2-1-1.html>.
[5] WORLD METEOROLOGICAL ORGANIZATION (WMO), *Greenhouse Concentrations in Atmosphere Reach New Record*, November 6, 2013, <www.wmo.int/pages/mediacentre/press_releases/pr_980_en.html>.
[6] U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA), *Overview of Greenhouse Gases: Methane Emissions*, July 2, 2014, <www.epa.gov/climatechange/ghgemissions/gases/ch4.html>.
[7] Ibid., *Overview of Greenhouse Gases: Nitrous Oxide Emissions*, April 17, 2014, <www.epa.gov/climatechange/ghgemissions/gases/n2o.html>.

indicating the presence of incremental quantities of ^{12}C in the atmosphere. Once again, the explanations are deforestation and the consumption of fossil fuels, both due to human activities.[8]

Another motivation attributable to man is the emission of GHGs that do not exist in nature. As mentioned in the previous chapter, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs,) and hydrofluorocarbons (HFCs) are human-made gases. These gases, which are considered responsible for the depletion of the ozone layer, have a global warming potential much higher than all the other natural existing GHGs. Indeed, the release of CFCs provokes chemical reactions that split ozone molecules, thus contributing to the formation of the ozone hole. The depletion of the ozone layer enables ultraviolet (UV) rays to reach the Earth's surface, which represents a risk for both plants and animals. Although global warming is something completely different, there is a connection between the two phenomena, since the atmosphere is an indivisible system. Moreover, the extended lifespan, exceeding a century, of these dangerous anthropogenic gases, implies that their contribution to global warming will persist for as many years.[9]

Other data prove the thesis of the human causation. The troposphere (the lower atmosphere) is warming, while the stratosphere (the upper atmosphere) is cooling. Stratospheric cooling is caused by both the depletion of the ozone layer and carbon dioxide emissions. The shrinking concentration of ozone reduce the stratosphere capacity to absorb UV rays, demonstrates its decreasing temperature. Conversely, greenhouse gases in the troposphere entrap infrared light, preventing it from reaching the upper layer. As a result, sun cycles and cosmic rays cannot be considered responsible for the change in global temperature.[10] The incrementing emissions of carbon dioxide due to the consumption of fossil fuels can also prove the increasing acidity levels of the oceans, resulting from an intensification of their absorption ability. Finally, other phenomena, such as the accelerating retreat of glaciers, especially since the 1980s, the rising sea level and the reduced albedo effect, coincide with a period of growing industrialization. Even the enhanced evaporation of water vapor, the most abundant and only naturally occurring greenhouse gas, is the consequence of

[8] Lauren SHOEMAKER, *The Basics: Isotopic Fingerprints*, Earth System Research Laboratory, August 2010, <www.esrl.noaa.gov/gmd/outreach/isotopes/>.
[9] EARTH SYSTEM RESEARCH LABORATORY (ESRL), *Ozone Depletion*, 2014, <www.esrl.noaa.gov/gmd/outreach/faq_cat-2.html>.
[10] K. MOHANAKUMAR, *Stratosphere Troposphere Interactions: An Introduction*, Berlin, Springer, 2008, pp. 90-91.

rising temperatures.[11]

Many organizations support the idea that human activities are to blame for global warming. Several international science academies, such as the International Council of Academics of Engineering and Technological Sciences (CAETS), the International Council of Science, the InterAcademy Council, foster this theory, endorsing the results published by the Intergovernmental Panel on Climate Change in its reports.[12] Furthermore, national science academies assent the human causation, such as the national academies of countries of the G7 and BRIC group. The list comprises the United States National Academy of Sciences, the British Royal Society, the Academié des Sciences, the Royal Society of Canada, the Accademia dei Lincei, the Russian Academy of Sciences, the Science Council of Japan, the Deutsche Akademie der Naturfoscher Leopoldina, the Chinese Academy of Sciences, the Indian National Science Academy, and the Academia Brasileira de Ciências.[13] The position of the scientific consensus is well summarized by a statement appeared in the 2008 edition report "*Understanding and responding to Climate Change*" by the National Academies[14]:

"*Most scientists agree that the warming in recent decades has been caused primarily by human activities that have increased the amount of greenhouse gases in the atmosphere. Greenhouse gases, such as carbon dioxide, have increased significantly since the Industrial Revolution, mostly from the burning of fossil fuels for energy, industrial processes, and transportation. Carbon dioxide levels are at their highest in at least 650,000 years and continue to rise.*"[15]

5.1.2 Criticism of the human causation.

A minority group of scientists dissents with the mainstream scientific consensus. They agree

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[11] GLOBAL CLIMATE CHANGE and NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA), *Climate change: How do we know?*, 2014, <www.climate.nasa.gov/evidence/>.

[12] STATE OF CALIFORNIA – OFFICE OF PLANNING AND RESEARCH, *List of Worldwide Scientific Organizations: Scientific Organizations That Hold the Position That Climate Change Has Been Caused by Human Action*, 2011, <www.opr.ca.gov/s_climatechangefacts.php>.

[13] JOINT SCIENCE ACADEMIES, *Joint science academies' statement: Climate Change Adaptation and the Transition to a Low Carbon Society*, June 2008, <www.science.org.au/sites/default/files/user-content/climatechange-g85.pdf>.

[14] The National Academies work like a unique scientific national academy for the United States; nevertheless, it englobes four distinctive organizations: the National Academy of Sciences (NAS), the National Academy of Engineering (NAE), the Institute of Medicine (IOM), and the National Research Council (NRC).

[15] THE NATIONAL ACADEMIES, *Understanding and responding to Climate Change: Highlights of National Academies Reports*, Washington, D.C., The National Academies Press, 2008, p. 2.

that the planet is warming, thus leading to climate change, but deny that the guilt is to be attributed to man. The Heartland Institute, a think tank based in Chicago, which is also the fundamental advocate of the denial, asserts that anthropogenic emissions are too small, and therefore insufficient, to markedly alter the Earth's climate conditions. Moreover, they bring into question the veracity of data published by the IPCC.[16] However, it should be noted that disputes prevail in the popular media, rather than in the scientific literature, considering the almost unanimous consensus already reached. Furthermore, it seems that the debate concerns more the Anglophone world, especially the United States, followed by the United Kingdom and Australia, than the rest of the globe.[17]

One point supported by critics of the anthropogenic causation is that terrestrial temperatures depend on glaciation periods. An ice age is a geological time, characterized by a reduction in global average temperatures and advancing glaciers, which affects the Earth's climate. Glacial periods alternate with interglacial periods, which, on the other hand, are distinguished by warmer climate and a retreat of the ice cover. While glacial periods last approximately 100,000 years, the interglacial periods have a shorter duration, between 10 to 15,000 years.[18] According to anthropogenic causation deniers, temperatures during the so-called Medieval Climate Optimum, a period of warm climate during the Middle Ages, were similar to those of the 20th century. Therefore, the current warming, equal to 1.4°F/0.6°C above the century baseline, is within the 5°F/3°C range of fluctuations that global temperatures have been experiencing in the past three centuries.[19]

The ocean acidification and warming are described as a fiction. Radiocarbon dating on corals samples from the South China Sea enabled to reconstruct the level of seawater pH of the past seven centuries. Even variations in ocean acidity seems to be natural; therefore, carbon dioxide emitted by man should not be considered imputable. Further research, based on the variability in coral reef, found that ocean pH oscillated between 7.9 and 8.2.

[16] Joseph BAST and James M. TAYLOR, *Global Warming: Not a Crisis*, The Heartland Institute, 2014, <www.heartland.org/ideas/global-warming-not-crisis>.

[17] Chris MOONEY, *The Strange Relationships Between Global Warming Denial and…Speaking English*, The Guardian, July 23, 2014, <www.theguardian.com/environment/2014/jul/23/the-strange-relationship-between-global-warming-denial-and-speaking-english>.

[18] Sandy ELREDGE and Bob BIEK, *Ice Ages – What are they and what causes them?*, in «Survey Notes», September 2010, vol. 42, n. 3, pp. 7-8. Also available at: <www.geology.utah.gov/surveynotes/archives/snt42-3.pdf>.

[19] Arthur B. ROBISON, Noah E. ROBINSON, and Willie SOON, *Environmental Effects of Increased Atmospheric Carbon Dioxide*, in «Journal of American Physicians and Surgeons», Fall 2007, vol. 12, n. 3, pp. 79-80. Also available at: <www.jpands.org/vol12no3/robinson.pdf>.

Compared to pre-industrial times, oceans has acidified by 0.1 pH unit.[20] In a similar way, it has been demonstrated that ocean warming is the result of fluctuations in deep currents. Indeed, from the 1940s until the 1970s superficial seawater underwent a cooling process. The drop of oceanic temperatures by almost 0.3°F/0.2°C showed that anthropogenic carbon dioxide emissions were not the cause of global warming.[21]

Deniers of the human causation also criticize the work of the Intergovernmental Panel on Climate Change. They claim that the IPCC is made up of 2,500 people, not all being scientists. Moreover, contributing scientists do not read the entire report. In 2008, Dr. Arthur B. Robison, president of the Oregon Institute of Science and Medicine (OISM), stated that more than 31,000 signatories approved the text of the Oregon Petition, which urged the United States government to reject the IPCC reports.[22] In the same year, the Heartland Institute sponsored the International Conference on Climate Change. The main outcome of the conference was the approval of the Manhattan Declaration, a document which highlights the lack of evidence of the human causation and of existence of a scientific consensus.[23] Besides, skeptics point to the fact that uninterrupted enhancing emissions of carbon dioxide did not materialize in global warming for more than a decade, as predicted by IPCC computer-based models.[24]

Criticism regarding the way IPCC reports are released comes also from its own members. Richard S. Lindzen, member of the National Academy of Sciences and participant in the IPCC, accused the panel to encourage misinterpretation of the summaries of its reports. In particular, he affirmed that an ambiguous language is used, that both public unawareness of the matter and facts upon which scientists can agree are exploited, and that accuracy, certainty and authority are overestimated. In addition, he argued that the Policymakers Summary was drafted by a group of authors, and not by participating scientists. Talking about the report, Lindzen described the coordinators' pressure to avoid excessive criticism on the

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[20] Keith SHERWOOD and Craig IDSO, *The Ocean Acidification Fiction*, CO2 Science, June 3, 2009, vol. 12, n. 22, <www.co2science.org/articles/V12/N22/EDIT.php>.
[21] Catherine BRAHIC, *Climate myths: The cooling after 1940 shows CO_2 does not cause warming*, in «New Scientist», May 16, 2007, vol. 194, n. 2604, pp. 34-42. Also available at: <www.newscientist.com/article/dn11639-climate-myths-the-cooling-after-1940-shows-co2-does-not-cause-warming.html>.
[22] Peter C. GLOVER and Michael J. ECONOMIDES, *Energy and Climate Wars*, pp. 95-96.
[23] THE HEARTLAND INSTITUTE, *Manhattan Declaration on Climate Change*, March 4, 2008, <www.heartland.org/press-releases/2008/03/04/new-york-global-warming-conference-considers-manhattan declaration>.
[24] VV.AA., *No Need to Panic About Global Warming*, The Wall Street Journal, January 27, 2012, <www.wsj.com/articles/SB10001424052970204301404577171531838421366>.

employed models, but rather to insist on their correctness.[25]

An embarrassment for the IPCC came from three major scandals. The scandals gave reason to some of the theses advanced by the group of skeptics. The first one regards the Fourth Assessment Report published by the Intergovernmental Panel in 2007. In one paragraph, it was revealed that glaciers in the Himalaya range were receding much faster than in any other region; as a consequence, they were projected to completely disappear by 2035, if not sooner. The Himalaya is the principal source of fresh water for hundreds of millions of people, especially in India and Bangladesh. As soon as the report was published, the Indian Environment Ministry entrusted a special committee to conduct a special study. The results demonstrated that glaciers were retreating, but not as fast as declared by the IPCC, and one was even advancing. The President of the IPCC, Dr. Rajendra Pachauri, apologized asserting that that paragraph should not have been included. Later, it was claimed that the incident arose from a copy and paste from a text published by the World Wildlife Fund (WWF), which was based on an article by the New Scientist, based on review appeared on the Indian Magazine.[26] After the outbreak of the "Glaciergate", the International Centre for Integrated Mountain Development created for the first time a map of the Himalayan glaciers to be used as a baseline for future research. The organization affirmed that only 10 out of 54,000 glaciers had been examined to establish net retreat or progress.[27] Correlated to the "Graciergate" is the "Amazongate". Even in this case, the indicted paragraph, which stated that 40% of the Amazon rainforest would vanish because of climate change, appeared in the 2007 report, citing the WWF as the source. Subsequently, many other passages were signaled, all citing WWF or Greenpeace, instead of peer-reviewed scientific literature as a source.[28] The third scandal "Climategate" ignited in 2009 following a leak of e-mails and documents from the Climate Research Unit (CRU) of the University of East Anglia. Skeptics highlighted some lines of the documents in which scientists, members of the IPCC,

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[25] Richard S. Lindzen, *Testimony of Richard S. Lindzen before the Senate Environment and Public Works Committee on 2 May 2001*, May 2, 2001, <www.eaps.mit.edu/faculty/lindzen/Testimony/Senate2001.pdf>.
[26] Peter WILSON, *Glaciergate threatens a climate change*, The Australian, January 23, 2010, <www.theaustralian.com.au/opinion/glaciergate-threatens-a-climate-change/story-e6frg6zo-1225822681922?nk=50329a60c23903c995192c4d6068d6ff>.
[27] DAILY MAIL, *'Glaciergate' UN scientist repeats warnings of Himalayan melting*, December 7, 2011, <www.dailymail.co.uk/sciencetech/article-2071017/Glaciergate-UN-scientist-repeats-war-nings-Himalayan-melting.html>.
[28] Christopher BOOKER, *Amazongate: new evidence of the IPCC's failures*, The Telegraph, January 30, 2010, <www.telegraph.co.uk/comment/columnists/christopherbooker/7113582/Amazongate-new-evidence-of-the-IPCCs-failures.html>.

admitted having manipulated data to give greater weight to human activities in the current climate change. Moreover, it appeared that they were trying to conceal some information, in order to fuel the political debate on the environment.[29] The scandals were a godsend for the disbelievers of the human causation, who, consequently, were able to support their own theses and ridicule the work of the International Panel on Climate Change.

Deniers of the scientific consensus rely on scientific data to demonstrate the accuracy of their statements. In 2006, Dr. Duncan Wingham, Professor of Climate Physics at University College of London and Director for Polar Observation and Modelling, and his colleagues asserted that 72% of the Antarctic ice sheet was expanding by 5 millimeters/0.2 inches per year. In fall 2008, the Arctic icecap experienced a record in growth, increasing its extension by 28.7% compared to the previous year. During the summer, Alaskan, Norwegian, Canadian and New Zealand glaciers did not shrink. Although worldwide media focused on the collapse of a large chunk of the Wilkins Ice Shelf in Antarctica to show the effects of global warming, Dr. Ben Herman, former director of the Institute of Atmospheric Physics, claimed that only the western peninsula was warming, whereas the rest of the continent was actually cooling.[30]

According to organizations supporting the naturally occurring global warming, the scientific consensus is driven by money. The United States government is said to have invested $32 billion for climate research and $36 billion for the development of specific technologies, intended to find a solution to global warming. Accordingly, scientists have an interest in supporting anthropogenic climate change so to continue achieving substantial funds. Even though, skeptics are accused of receiving money from oil companies, especially from ExxonMobil, they defend themselves by arguing that there is no comparison between the annual government subsidies to mainstream scientists and the total fund of $23 million they received.[31] Moreover, former vice-President and Nobel Peace Prize winner, Al Gore is blamed not to have the qualifications to be the primary spokesman on global warming. Gore is also said to have an economic interest in promoting the scientific consensus and government controls, since after losing the election he reinvented himself as a businessman and made

[29] James TAYLOR, *Climategate 2.0: New E-Mails Rock The Global Warming Debate*, Forbes, November 23, 2011, <www.forbes.com/sites/jamestaylor/2011/11/23/climategate-2-0-new-e-mails-rock-the-global-warming-debate/>.
[30] Peter C. GLOVER and Michael J. ECONOMIDES, *Energy and Climate Wars*, pp. 136-140.
[31] Joanne NOVA, *Climate Money*, Haymarket, VA, Science and Public Policy Institute (SPPI), July 21, 2009, pp. 2-6. <www.scienceandpublicpolicy.org/images/stories/papers/originals/climate_money.pdf>.

investments in energy-saving and environmentally friendly technologies through the firm Generation Investment Management he co-founded with David Blood.[32]

Joseph D'Aleo, former chairman of the American Meteorological Society's Committee on Weather Analysis and Forecasting and Executive Director of the International Climate and Environmental Change Assessment Project (ICECAP), summarized in twelve points data in support of the skeptics' theory. These points are the following:

1. temperatures have been cooling since 2002;
2. carbon dioxide, which is a trace gas, produces little warming;
3. carbon dioxide has not been correlated with global warming over the last decade;
4. carbon dioxide is a naturally occurring gas;
5. carbon dioxide concentrations are almost at their lowest;
6. global warming changes the emissions of carbon dioxide;
7. water vapor is the most abundant greenhouse gas;
8. observations in the tropics show cooling at high atmosphere levels, instead of warming;
9. solar activity explains global temperatures;
10. the Pacific and Atlantic oceans are cooling since the late 1990s and 2004 respectively;
11. ocean cycles explains changes in polar icecaps;
12. Antarctic ice has been expanding.[33]

5.2 The political debate on climate change

5.2.1 International Relations theories and international cooperation

International relations can be analyzed through different theoretical perspectives. The two prevalent schools are realism and liberalism. Nevertheless, new thinking about security has emerged, including historical materialism or Marxism. It is therefore interesting to examine the different conception that these theories have about international cooperation, since it is a milestone for the achievement of agreements concerning climate change.

[32] Ed PILKINGTON, *Al Gore's green investments prompt conflict of interest row*, The Guardian, November 3, 2009, <www.theguardian.com/world/2009/nov/03/al-gore-conflict-of-interests>.

[33] Michael J. ECONOMIDES, *12 Facts about Global Climate Change That You Won't Read in the Popular Press*, Energy Tribune, August 18, 2008, <www.energytribune.com/1268/12-facts-about-global-climate-change-that-you-wont-read-in-the-popular-press#sthash.SFbvqcjl.dpbs>.

Realism is considered as the prevailing theory of international politics. The fundamental element of analysis for realists is the state, considered as a unitary and rational actor. Realists regard the international system as being anarchic. As a consequence, states are prone to compete one against the other, in order to defend their own interests. Indeed, competition and conflict are due to the uncertainty about others' intention. Nevertheless, realism is a family of partly different theories. Although defensive realism shares some assumptions with Waltz and offensive realism, it finds that competition can be risky; therefore, cooperation should be preferred.[34] Cooperation is feasible if there is a "hegemon" state. At the end of the Cold War, the United States was the only superpower, accordingly, it was expected to play the role of the hegemon. Nonetheless, it missed to exploit its resources to build an international cooperation to face climate change. Conversely, Washington, D.C. took advantage of its political and economic strength, sometimes applying a sort of veto power on the timetable of emissions reductions. Other countries that could eventually be influential actors are the European Union, Russia and China.[35]

The second dominant theory is liberalism. Compared to realism, liberalism is optimistic and sustains international cooperation, especially through several international organizations. Indeed, liberalists see states as the fundamental actors, but, unlike realists, highlight the role played by different organizations, such as IGOs and NGOs, international regimes and private entities. International organizations are very important forums for bargaining and information and resource. Moreover, they can monitor states to avoid free-riding and cheating situations. Another important element for the emergence of cooperation is the existence of international regimes. They consist of a set of principles, norms, rules and decision-marking procedures, which can be either explicit or implicit.[36]

The third approach is historical materialism. The theory focuses on economic relations within a historical and global context. Marxists affirm that the main limit to international cooperation is that only problems affecting the most powerful capitalist states are discussed. Consequently, agreements reflect the interests of the industrialized North, at the expense of other countries. According to them, the proof is represented by the existing disagreements

[34] Charles L. GLASER, *Realism*, in Allan COLLINS, *Contemporary Security Studies*, pp. 14-16.
[35] Ian H. ROWLANDS, *Major Theoretical Approaches*, in Detlef F. SPRINZ and Urs LUTERBACHER, *PIK Report N.21: International Relations and Global Climate Change*, Potsdam, Potsdam Institute for Climate Impact Research (PIK), pp. 33-34. Also available at: <www.pik-potsdam.de/research/publications/pikreports/.files/pr21.pdf>.
[36] Patrick Morgan, *Liberalism*, in Allan COLLINS, *Contemporary Security Studies*, pp. 29-34.

between industrialized and non-industrialized states during conferences on climate change. Nevertheless, this is obviously a generalization, since it does consider neither internal divisions nor the interests of different national industries. In fact, sometimes the United States have sided with oil-exporting countries and the European Union has maintained a mainly environmental position than other OECD states. Furthermore, the imposition of emission reductions involves a huge loss for coal industries, but at the same time is a great opportunity for renewable energy technologies.[37]

5.2.2 International environmental agreements

International agreements concerning the environment present some differences compared to other matters of public international law. The global environment is protected by relevant multilateral treaties; however, they impose rather generic obligations. Parties usually discuss and ratify separately additional Protocols, which produce results only if ratified and respected by every state.

The main feature of environmental agreements is uncertainty. This characteristic arises from several sources. Climate change harms various populations and areas in different ways. Therefore, countries wonder whether other actors will cooperate and maintain their commitments. Major polluters have to change their behavior, although future advantages are not completely clear, because there is no synchrony between the moment in which actions are taken and the time of seeable effects. Moreover, the causes, as previously debated, are not always certain. Finally, even the existence of the problem and its impacts may not be manifest. For instance, when the 1985 Vienna Convention on the Protection of the Ozone Layer was signed, the causes of the depletion of the ozone layer were still unclear and there were only suspects that the source were chlorofluorocarbons. Nonetheless, waiting to see the consequences can be fatal.[38]

Fundamental in the evolution of environmental agreements is the participation of both developing countries and non-state actors. Developing states were initially ignored; nevertheless, on some particular environmental issues, it became evident that their attendance was fundamental. The reasons are essentially two. These countries may either contribute

[37] Ian H. ROWLANDS, *Major Theoretical Approaches*, p. 37.

[38] Elizabeth R. DESOMBRE, *The Evolution of International Environmental Cooperation*, in «Journal of International Law and International Relations», Winter 2004/Spring 2005, Vol. 1, n. 1-2, pp. 79-81. Also available at: <www.jilir.org/docs/issues/volume_1/JILIR_1_FULL_ISSUE.pdf>.

to or be afflicted by the problem. Cooperation between industrialized and developing countries results in a mutual gain, especially because the latter can protect the environment without sacrificing its development goals. In particular, since the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, in order to overcome the obstructionism of developing countries, a funding mechanism is provided to address the problem of incremental costs.[39] For what concerns NGOs, their role is essential. Indeed, they monitor government actions, provide useful information, and give policy recommendations. Moreover, many non-governmental organizations attend conferences as observers.[40]

The lack of a supranational government led to the development of regulatory regimes. The outcome of the negotiation process in international environmental conferences is rarely the final product, but rather produces a framework convention, based on international regimes. Rulers agree on principles, on the decision-making process and on the need of further scientific research to reduce uncertainty. Only at a later date, the parties negotiate a protocol that defines the measures to be implemented. While the principle is common among all countries, the responsibilities are different.[41] Indeed, some countries are typically requested to take more measures to address a specific problem. This is especially true in the case of the most developed countries in reference to climate change.

The positions of government are influenced by national lobbies and pressure groups. For this reason, rulers have to negotiate on two levels. The so-called double-edged diplomacy is conditioned by both domestic and international factors. National interests arise from ecological vulnerability and abatement costs. As a result, countries facing a high impact from climate change ask for substantial emission reductions, while countries with high abatement costs, but low ecological vulnerability do not obtain any benefit from emission moderation. Moreover, the position of domestic actors depends on whether they experience a welfare gain or loss from pollution. Therefore, countries with no strong polluter interests support international environmental negotiations.[42]

Participating countries maintain different positions regarding environmental protection.

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[39] Ibid., pp. 82-83.

[40] Kal RAUSTIALA, *Non-state Actors*, in Detlef SPRINZ and Urs LUTERBACHER, , *PIK Report N.21: International Relations and Global Climate Change,* pp. 57-61.

[41] Elizabeth R. DESOMBRE, *The Evolution of International Environmental Cooperation*, pp. 84-85.

[42] Detlef F. SPRINZ and Martin WEIß, *Domestic Politics and Global Climate Policy*, in Urs LUTERBACHER and Detlef F. SPRINZ, *International Relations and Global Climate Change*, Cambridge, MA, The MIT Press, 2001, pp. 67-71.

The United States is one of the major polluters in the world, but is also the country that has invested and contributed the most to environmental research. The opposition made by the White House to the reduction of emissions is due to the strong role played by the lobbies of some domestic sectors and to fears that a strong commitment would cause extensive damage to the national economy. The role of the European Union is the most complex, since three aspects should be considered: the role of the union as a whole, the relations between Brussels and the member countries, and the role of the individual states in the international context. Despite being the third largest emitter of carbon dioxide and face moderate ecological vulnerability, if considered as a unique entity, the EU is the stronger supporter of emission reduction, although with varying degrees from one member to another. Nonetheless, European countries need to import energy from abroad and, unlike the United States, have interests in investing in renewable and energy-efficiency technologies.[43] Little compactness also exists among developing countries. In fact, it is possible to discern three main groups. Small island states are strong supporters of the implementation of rapid measures to slow global warming. The economies of oil-producing countries depend mainly on petroleum exports; as a result, they generally line up with the United States and often question science about the climate. Finally, the big industrializing countries are in an intermediate position, since their economic growth, on the one hand, depends on fossil fuels, but, on the other, especially agricultural sectors, can be vulnerable to climate change. Generally, they approve the measures to combat global warming as long as the right to develop and their sovereignty are not compromised.[44]

Two methods are used in environmental agreements on climate change. The difference between the two procedures is important with regard to the application of treaties by participating states. While the top-down approach defines specific policies and actions that states must adopted, the bottom-up approach is more flexible and gives each state the freedom to determine its own commitment. The former inspired international treaties since the adoption of the 1987 Montreal Protocol. The turning point was the Kyoto Protocol, which, despite still fixing the nature of the duty, granted states the chance to choose the preferred implementation. Nevertheless, the bottom-up process was preferred for the Copenhagen and Cancún

[43] Ibid., pp. 77-82.
[44] Daniel BODANSKY, *The History of the Global Climate Change Regime*, in Urs LUTERBACHER and Detlef F. SPRINZ, *International Relations and Global Climate Change*, pp. 30-31.

Accords, in which the parties were able to fix their own target levels, base year, time limits and rules for what concerns the reduction of pollutants. It should be noted that neither system is perfect; on the contrary, both have their limitations. In the bottom-up approach, since states are free to establish their own commitment, there is the risk that states undertake limited actions to combat climate change. Moreover, the possibility that other governments do little and the uncertainty of their adequate engagement discourage action. On the other hand, the top-down approach can curb some countries from accepting impositions on emissions cutting. In addition, sub-state actors have to wait for the decisions to be taken at national or international level before developing their own environmental policies.[45]

5.2.3 The United Nations Conference on Environment and Development

The publication of the First Assessment Report by the Intergovernmental Panel on Climate Change in October 1990 established that the planet was warming. Already in the UN Conference on the Human Environment, held in 1972 in Stockholm, it was recognized the need to address the issue. Consequently, the United Nations General Assembly promoted the organization of an international conference on environment and development. The summit was held in Rio de Janeiro from June 3 to June 14, 1992.

Three important achievements were reached at the United Nations Conference on Environment and Development (UNCED), informally called Rio Earth Summit. The Rio Declaration on Environment and Development is a short document in 27 principles intended to ensure environmental protection and responsible development by governments. Agenda 21 is a plan of action to sustainable development, which, in its second section, addresses the issue of conservation of biodiversity, the protection of environment and the management of toxic and nuclear wastes. To ensure full support for its implementation, three bodies were created: the United Nations Commission on Sustainable Development (CSD), the Inter-Agency Committee on Sustainable Development, and the High-Level Advisory Board on Sustainable Development. Finally, the third achievement was the Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests, a statement for the sustainable

[45] Daniel BODANSKY, *A Tale of Two Architectures: The Once and Future U.N. Climate Change Regime*, in «Arizona State Law Journal», Fall 2011, Vol. 43, n. 3, pp. 697-712. Also available at: <www.papers.ssrn.com/sol3/papers.cfm?abstract_id=1773865>.

management of forests. All of them were adopted by consensus at the conference. Moreover, the summit established the operating rules for the Global Environment Facility (GEF), which became the financial mechanism for future international convention.[46]

The Rio Conference also achieved other important results [Table 12]. It was decided to establish an Intergovernmental Negotiating Committee to draft a convention to fight desertification in countries suffering from severe drought. On June 17, 1994, the Convention to Combat Desertification was adopted in Paris.[47] Furthermore, the Framework Convention on Climate Change (FCCC) and the Convention on Biological Diversity (CBD) were opened to signature[48], and delegates agreed on the former Soviet leader Mikhail Gorbachev's proposal to create a non-governmental environmental organization, the Green Cross International.[49]

Table 12. Results achieved at the United Nations Conference on Environment and Development (UNCED).

UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT (Rio de Janeiro, June 3-14, 1992)	
ACHIEVEMENTS	*OTHER RESULTS*
Rio Declaration on Environment and Development: *27 principles to protect environment and ensure responsible development*	**Convention on Biological Diversity**
Agenda 21: *Plan of action to sustainable development*	**United Nations Framework Convention on Climate Change** (UNFCCC)
Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests: *Statement for sustainable development of forests*	**United Nations Convention to Combat Desertification** (UNCCD)

5.2.4 The United Nations Framework Convention on Climate Change

The Framework Convention on Climate Change (FCCC), adopted at the UNCED, is a non-

[46] UNITED NATIONS (UN), *UN Conference on Environment and Development (1992)*, May 23, 1997, <www.un.org/geninfo/bp/enviro.html>.
[47] UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION (UNCDD), *History*, 2012, <www.unccd.int/en/ about-the-convention/history/Pages/default.aspx>.
[48] UNITED NATIONS, *UN Conference on Environment and Development (1992)*.
[49] GREEN CROSS, *Our History*, 2014, <www.gcint.org/our-history>.

binding treaty. The agreement per se establishes neither greenhouse gases restrictions nor enforcement mechanisms; rather it fixes the principles for negotiating specific protocols. The objective of the treaty is explicated in Article 2, which states:

"*The ultimate objective of this Convention and any related legal instruments that the Conference of Parties may adopt is to achieve, in accordance with the relevant provisions of this Convention, stabilization of greenhouse concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.*"[50]

The Convention, in accordance with Article 23, entered into force on March 21, 1994, ninety days after the date of deposit of the fiftieth instrument of ratification.[51] Subsequently, the first Conference of Parties (COP) was held in Berlin the following year, as required by Article 7 paragraph 4 of the FCCC. According to other paragraphs of the same article, it is determined that the COP is the supreme body of the Convention and that it should meet once a year in order to exchange acquired information, assess progress and coordinate measures to address the problem of climate change and its effects, among other tasks. If it is deemed necessary, given the support of at least one third of the parties, the Conference may hold extraordinary sessions.[52]

The Conferences of Parties started meeting in the mid-1990s. Since 2005, when the Kyoto Protocol entered into force, the Meetings of Parties of the Kyoto Protocol (MOPs) were held in conjunction with them. Parties of the Convention, which are not also parties of the Protocol, can participate as observes. Some COPs deserve more attention because of their achievements. They include the meetings that took place in Kyoto in 1997, in Bali in 2007, in Cancún in 2010, in Durban in 2011, and in Doha in 2012.

The third COP was held in Kyoto in December 1997. The result of the conference was the Kyoto Protocol, requiring developed countries, which were and still are the largest polluters, to reduce emissions of greenhouse gases by an amount not less than 8% of values recorded in 1990, considered as the base year, in the period 2008-2012 [Figure 7]. Its

[50] Cf. UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC), Article 2: Objective, <www. unfccc.int/essential_background/convention/background/items/1353.php>.
[51] Cf. UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC), Article 23: Entry into force, <www.unfccc.int/essential_background/convention/background/items/1407.php>.
[52] Cf. UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC), Article 7: Conference of the Parties, <www.unfccc.int/essential_background/convention/background/items/1368.php>.

implementation rules were established at COP 7 in Marrakesh in 2001. The Protocol offers three flexible market-based mechanisms, intended to help countries meeting their targets.[53] The Clean Development Mechanism (CDM) enables industrialized countries to undertake projects in developing countries that produce environmental benefits to earn certified emission reduction (CER) credits, each equivalent to one ton of carbon dioxide. The Joint Implementation (JI) gives an industrialized country the possibility to implement a joint project to reduce emissions with another state of the same group and share credits. Finally, the Emissions Trading (ET) consists in the chance given to countries that have achieved their targets to sell the excess capacity to other states that, on the contrary, have not been able to meet their commitments [Table 13].[54] The Protocol entered into force on February 16, 2005, ninety days after the date in which the fifty-fifth state, the Russian Federation, deposited its instrument of ratification, in accordance to Article 23. Among signatories, only one country, Canada, withdrew from the Protocol on December 12, 2011, because of the failure to meet the expected targets and the damages that they would have brought to national economy.[55] The only industrialized country that did not ratify the Protocol is the United States of America. The Senate had passed in July 1997, just a few months before the end of the negotiations, the Byrd-Hagel Resolution, which expressed the refusal to accept any treaty that could harm the US economy and exempted developing countries.[56]

The COP-13/MOP-3, held in December 2007, adopted the Bali Road Map. The action plan was based on five pillars: shared vision to develop a long-term cooperation, mitigation, adaptation, technology transfer, as well as financing and investment assistance from developed to developing countries. Furthermore, delegates agreed on a mechanism, named Reducing emissions from deforestation and forest degradation (REDD), to preserve forest and consequently reduce the emissions of carbon dioxide resulting from deforestation.[57]

In 2012, the 16th Conference of Parties took place in Cancún. The agreement reached at

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[53] UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC), *Kyoto Protocol*, 2014, <www. unfccc.int/kyoto_protocol/items/2830.php>.
[54] UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC), *The Mechanisms under the Kyoto Protocol: Emissions Trading, the Clean Development Mechanism and Joint Implementation*, 2014, <www.unfccc.int/kyoto_protocol/mechanisms/items/1673.php>.
[55] UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC), *Status of Ratification of the Kyoto Protocol*, 2014, <www.unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php>.
[56] THE NATIONAL CENTER FOR PUBLIC POLICY RESEARCH, *Byrd-Hagel Resolution*, 2014, <www.nationalcenter.org/KyotoSenate.html>.
[57] William STEWART, *Climate of Uncertainty*, pp. 88-89.

the end of the meeting is considered as the largest collective effort ever taken to cut the emissions of GHGs. The main objectives of the accords covered all the five pillars established in Bali. In particular, the Cancún Agreements established to avoid the increase of the global average temperature over 3.6°F/2°C, to review the progress made by 2015, to communicate the achieved progress in the field of green technology, to protect forests and assist the countries, which are most vulnerable to climate change.[58] In addition, the meeting created the Green Climate Fund (GCF), already discussed in the Copenhagen conference, to help developing countries cope with the adverse effects of climate change.[59]

The 2011 Conference in Durban was a turning point. Despite the meeting produced no treaty, all participants, including the two largest emitters, the United States and China, which have always represented the main obstacle to an effective international agreement, agreed on the need to reach a binding treaty. The protocol should comprise all countries and be drafted in 2015 at the 21th COP, which will be held in Paris, so to enter into force by 2020.[60] Moreover, delegates convened that a Transitional Committee, composed of 40 members, of whom 15 from developed and 25 from developing countries, should design the Green Climate Fund.[61]

Doha hosted the eighteenth Conference of Parties in 2012. The outcome was a package of documents known as The Doha Climate Gateway. Governments reaffirmed their intention to find a universal binding agreement by 2015, by converging the five pillars of the Bali Action Plan in one work. Moreover, delegates emphasized the urgency to act to avoid irreversible consequences. However, the greatest contribution was undoubtedly to postpone the end of the Kyoto Protocol to 2020. As a result, the Protocol's three mechanisms, the Clean Development Mechanism, Joint Implementation and Emission Trading, continue to operate [Figure 13].[62] Nevertheless, the Doha Amendment, adopted in accordance with Article 20 and 21 of the Kyoto Protocol, is not yet into force. Indeed, article 20.3 requires the ratification by

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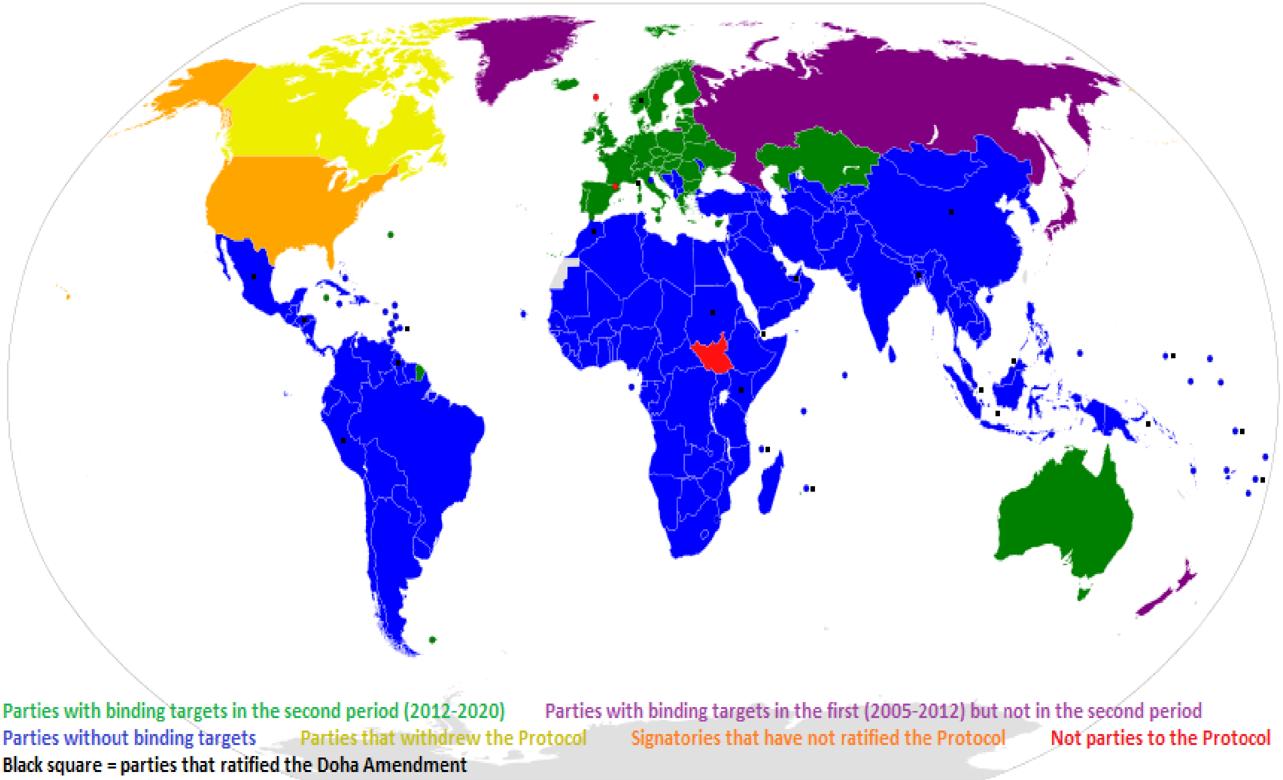
[58] UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC), *Milestones on the road to 2012: The Cancun Agreements*, 2014, <www.unfccc.it/key_steps/cancun_agreements/items/6132.php>.
[59] GREEN CLIMATE FUND, *Background*, 2014, <www.gcfund.org/about/the-fund.html>.
[60] Fiona HARVEY and John VIDAL, *Global climate change treaty in sight after Durban breakthrough*, The Guardian, December 11, 2011, <www.theguardian.com/environment/2011/dec/11/global-climate-change-treaty-durban>.
[61] GREEN CLIMATE FUND, *Mandate*, 2014, <www.gcfund.org/about/mandate.html>.
[62] UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC), *The Doha Climate Gateway*, 2014, <www.unfccc.int/key_steps/doha_climate_gateway/items/7389.php>.

three-quarters of the parties to enter into force.[63] At the end of 2014, only twenty-three out of 192 countries deposited their instruments of ratification [Figure 7].[64]

Figure 7. Kyoto Protocol and Doha Amendment.

Map of the parties of the Kyoto Protocol and the countries that have ratified the Doha Amendment.



Source: File:UNFCCC parties.svg. Last updated: October 2, 2014.

Addition: Parties that ratified the Doha Amendment. Last updated: December 23, 2014.

There are two main problems to overcome in order to reach an international agreement. As already mentioned, the United States is not willing to accept any treaty that can put its economy in a competitive disadvantageous situation. Exceeding such a limit would be possible just if developing countries consent to cut their emissions of greenhouse gases. On the other hand, China is not prone to jeopardize its economic growth by reducing its

[63] Cf. UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC), *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, 2014, <www.unfccc.int/essential_back-groun/kyoto_protocol/items/1678.php>.

[64] UNITED NATIONS TREATY COLLECTION, *Chapter XXVII Environment: 7.c. Doha Amendment to the Kyoto Protocol*, December 22, 2014, <www.treaties.un.org/pages/ViewDetails.aspx?src:TREATY&mtdsg_no=XXVII-7-c&chapter=27&lang=en>.

consumption of fossil fuels.[65] Hope has arisen from the Asian-Pacific Economic Cooperation (APEC) forum held in Beijing on November 10-12, 2014. US President Barack Obama and Chinese President Xi Jinping reached an agreement. While the United States promised to cut their 2005 CO_2 emissions by 26-28% by 2025, China announced its intention to acquire 20% of its energy needs from renewable resources by 2030, the year in which the country is expected to reach its peak emissions.[66]

Figure 13. Flexible mechanisms of the Kyoto Protocol.

Flexible Mechanisms	**Definition**
Clean Development Mechanism (CDM)	Emission credits for developed countries that implement environmentally friendly and socio-economic development projects in developing countries
Joint Implementation (JI)	Sharing of emission credits for co-produced projects realized by developed countries in another state of the same group
Emissions Trading (ET)	Exchange of emission credits among developed countries

[65] William STEWART, *Climate of Uncertainty*, p. 93.
[66] Matt HOYE and Holly YAN, *US and China reach historic climate change deal, vow to cut emissions*, CNN, November 12, 2014, <www.edition.cnn.com/2014/11/12/world/us-china-climate-change-agreement/>.

PART 3

PERSPECTIVES FOR THE FUTURE

CHAPTER SIX
RESPONSES TO GLOBAL WARMING

6.1 Dealing with climate change

6.1.1 Mitigating and adapting to climate change

Various technologies exist to deal with the problem of climate change. Three approaches are available to reduce the risks arising from abrupt changes in climate conditions. Nevertheless, only mitigation and geoengineering try to minimize the effects of human activities, whereas adaptation, also called resilience, involves the reduction of risks resulting from occurring changes. Accordingly, it is possible to refer to them respectively as techniques and policies to avoid the unmanageable, and techniques and policies to manage the unavoidable.[1]

Mitigation policies consists of a series of different possible actions. Since the main objective is primarily fighting the dangerous repercussions of global warming, mitigation involves reducing anthropogenic emissions of greenhouse gases and increasing the ability of carbon sinks. The abatement of polluting gases discharge into the atmosphere is primarily focusing on energy use and supply. This can be achieved through a transition toward low-carbon and efficient energy sources. Moreover, some technologies are being analyzed to capture and sequester carbon dioxide.[2]

Geoengineering is the deliberate manipulation of the environment. It refers to a beneficial human intervention to prevent the dreadful effects of climate change. Two kinds of climate engineering technologies are being explored: solar radiation management and carbon-cycle

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[1] UNITED NATIONS FOUNDATION and SIGMA XI, *Confronting Climate Change: Avoiding the unmanageable and managing the unavoidable*, Washington, D.C., February 2007, pp. IX-XII. Also available at: <www.global-problems-globalsolutions-files.org/unf_websiste/PDF/climate%20_change_avoid_unmanagable_manage_unavoidable.pdf>.

[2] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), *Climate Change 2007: Synthesis Report.* 5.5 Technology flows and development, March 2007, <www.ipcc.ch/publications_and_data/ar4/syr/en/mains5-5.html>.

engineering. Geoengineering can be seen as an accompanying strategy to mitigation. Nevertheless, problems regarding the side effects that such actions could have persist. Therefore, before any human intervention takes place, all the possible consequences should be carefully considered.[3]

Adaptation seeks to diminish the vulnerabilities of humans and ecosystems. Resilience strategies are necessary to supplement mitigation, since it may not be possible to avoid climate change effects, especially in some developing countries. The adoptable policies can either prevent the damages provoked by adverse climate conditions or promote sustainable development through ecosystem management.[4] In addition to anticipatory adaptation, resilience policies can also be reactive, intended to cut costs resulting from emergency responses. While both kind of adaptation can be planned, only reactive procedures can occur spontaneously.[5]

6.1.2 Mitigation

Mitigation refers to the reduction of climate change effects by cutting the emissions of greenhouse gases. This aim can be achieved through more efficient and low-carbon sources of energy. Even though several technologies may be available, both the technical feasibility and the cost effectiveness of existing and future solutions need to be assessed before they can be effectively implemented.[6] Furthermore, the different technical options should be supported and stimulated by regulations and incentives adopted by governments.[7]

A variety of technologies can contribute to mitigation. Low-carbon sources include renewable energy, as well as nuclear power. Nevertheless, since the energy mix is still dominated by fossil fuels, a transition toward alternative sources is indispensable. The consumption of energy required to produce electricity, heat and fuels should be improved. Alternatively, carbon capture and storage (CCS) technologies are also available to guarantee development without increasing the concentration of carbon dioxide. Furthermore, reforestation and

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[3] David W. KEITH, *Geoengineering the Climate: History and Prospect*, in «Annual Review of Energy and Environment», November 2000, vol. 25, pp. 247-249.
[4] UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP), *Climate Change Adaptation: Introduction*, 2014, <www.unep.org/climatechange/adaptation/introduction/tabid/6704/Default.aspx>.
[5] GOVERNMENT OF CANADA, *What is adaptation?*, October 29, 2013, <www.nrcan.gc.ca/environment/impacts-adaptation/adaptation-101/10025>.
[6] Marilyn A. BROWN and Benjamin K. SOVACOOL, *Climate Change and Global Energy Security*, p. 66.
[7] UNITED NATIONS FOUNDATION and SIGMA XI, *Confronting Climate Change: Avoiding the unmanageable and managing the unavoidable*, p. 45.

avoiding deforestation are also recommended to enable mitigation.

The production of electricity and heat offers a wide range of solutions. In chapter 3, several already available and experimental projects concerning renewable energy sources have been discussed. Although some of them have a deep environmental impact, they emit neither carbon dioxide nor other greenhouse gases. Hydropower, solar and wind energy are especially being exploited. Renewable technologies are growing at a very fast rate, mainly due to the policies adopted by the governments of many OECD countries. Indeed, feed-in tariffs, tax incentives, and renewable portfolio standards, which are policies designed to increase investments in renewable sources, are encouraging a shift away from fossil fuels.[8]

Actions should involve all sectors. Both commercial buildings and houses should adopt new climatic systems, particularly thanks to the use of better performing thermal insulation materials. Moreover, more efficient and recently developed heating pumps and boilers can reduce the consumption of electricity. Other improvements regards lighting. New kind of lamps enable to consume less and have a longer lifespan. In the future, it is desirable to construct buildings capable of exporting the unconsumed energy. However, this will require a complete overhaul of the architecture and the structure of buildings.[9] Industrial and agricultural productions also need to undergo a change. Industry processes should avoid the waste of electricity. In addition to better insulation systems and integrated devices, this can also be achieved through the introduction of emissions trading schemes and the increase of energy prices. In agriculture, new ecology-friendly production modes must be introduced to avoid the erosion of soil. Moreover, recycling has a twofold opportunity. On one hand, it can save raw materials for future generations; on the other, wastes can be converted into fuels or used to produce energy.[10]

The transportation sector is also undergoing a revolution. As previously mentioned, transportation means do not have many alternatives to oil. Nevertheless, new propellants, such as biofuels, hydrogen and nitrogen, and new prototypes of electrically powered vehicles are already in production or in a phase of advanced study. Besides, in order to increase energy efficiency and saving, some improvements were introduced in the structure of road-vehicles and airplanes. Two types of electric vehicle are available: pure battery-operated electric

[8] Marilyn A. BROWN and Benjamin K. SOVACOOL, *Climate Change and Global Energy Security*, p. 91.
[9] Alexandre ROJEY, *Energy and climate*, pp. 54-55.
[10] Ibid., pp. 62-64.

vehicles (EV) and plug-in hybrid electric vehicles (PHEV). While the former works exclusively on electricity stored in a battery, the latter can switch from an electric to a combustion engine if the battery exhausts its recharge, especially when driving long distances.[11] It is obvious that the main problem is related to the battery. A race is underway in Asia between Japanese and South Korean car manufacturers. The competition concerns the size, the weight, the time and duration of the charging of the batteries to be inserted into the vehicles. Furthermore, the charge must be able not only to power the engine, but also to make all other devices required by the driver, such as heating, air conditioning, radio and wipers among others, work. However, it has yet to be shown that some problems, like the so-called thermal runaway or destructive overheating, cannot occur. Finally, it is necessary to restructure the whole network of charging stations. The main risk relates to the danger for cyclists and pedestrians due to the lack of noise produced by these vehicles.[12]

An alternative to electric vehicles are those powered by hydrogen. The main drawback is constituted by the considerable costs, since hydrogen does not exist as a freestanding element in nature. Consequently, it must be separated artificially by atoms of other elements. The more environmentally friendly system is electrolysis, whereby it is possible to split water molecules into oxygen and hydrogen. Thus obtained, hydrogen can be transformed into electricity or undergo internal combustion to power transportation means.[13]

Major improvements are also affecting the aviation industry. In particular, winglets and sharklets have been added to the wings and fuselages have been made smoother and painted in light colors to cut fuel consumption, by reducing friction and air-conditioning costs. Besides, carbon fibers are employed instead of aluminum in the construction of new aircrafts, such as the Boeing B787 and Airbus A350, in order to reduce the overall weight, therefore making them more fuel-efficient.[14] In addition to these construction techniques, new methods of navigation were introduced. Continuous descent arrivals (CDAs), optimum cruise altitude and cruising speed, direct air routes using satellite signals, queue management and reduced ground taxing, as well as constant climbing enable to save significant amounts of fuel. As well as having a lower environmental impact, it is obvious that these

[11] Daniel YERGIN, *The Quest*, p. 699.
[12] Ibid., p. 709-710.
[13] William STEWART, *Climate of Uncertainty*, pp. 146-147.
[14] Tim BOWLER, *Carbon fibre planes: Lighter and stronger by design*, BBC News, January 28, 2014, <www.bbc.com/news/business-25833264>.

measures contribute to lower costs for airlines.[15] The actions taken by some governments were fundamental for the realization of these improvements. For instance, despite the criticism of other countries, the European Union decided to impose a tax on carbon dioxide emitted by aircrafts flying over the airspace of its member countries. A move that even Australia has decided to implement.[16]

Rail transportation has already introduced an ecologically friendly model of train. This kind of train is called magnetic levitation train, usually indicated with the abbreviation Maglev. As the convoy does not touch the rails, the only force that opposes its motion is air friction. The Maglev is able to travel at very high speeds, up to 581 km/h or 361 mph, with a limited consumption of energy. Although the speed enables the Maglev to compete with aircraft on longer routes, the costs for the construction of infrastructure have thus far restricted its use to short sections within city limits. There are two technologies available: electromagnetic suspension (EMS) and electrodynamic suspension (EDS). The former uses conventional electromagnets, attracted to the iron in the rails. Nevertheless, this system is unstable, because it is necessary to constantly check and maintain the distance between the train and the track. This method is in operation in Shanghai where it connects the city with the international airport. The latter exploits the opposite polarities of the magnets under the train and on the track. However, EDS needs some sort of wheels, since the repulsive force develops only when the train is in motion and it is not active when the vehicle is stationary. The Superconducting Maglev Shinkansen in Japan employs this system. New projects are under construction in Beijing and Seoul. Longer routes are being developed not only in China and Japan, but also in Germany, Italy, Switzerland, the United Kingdom, the United States and Australia.[17]

Another important solution is carbon capture and sequestration (CCS). The technology involves three alternative processes for capturing carbon dioxide. Pre-combustion capture process consists in the separation of hydrogen and carbon oxide. While hydrogen can be used for other purposes, such as the production of fuel for transports or electricity, CO_2 is compressed and stored. In post-combustion systems, carbon dioxide is detached from

[15] NATS, *Ten steps to flight efficiency*, May 11, 2013, <www.nats.aero/wp-content/uploads/2013/05/11001_NATS_Swatch-book_Online_Linked_240413_HS.pdf>.
[16] Elisabeth ROSENTHAL, *Your Biggest Carbon Sin May Be Air Travel*, The New York Times, January 26, 2013, <www.nytimes.com/2013/01/27/sunday-review/the-biggest-carbon-sin-air-travel.html?_r=0>.
[17] Jon STEWART, *Maglevs: The floating future of trains?*, BBC, May 6, 2012, <www.bbc.com/future/story/20120504-the-floating-future-of-trains>.

exhaust gases, using a liquid solvent, and then buried underground. Since this process is much easier to apply that the previous one, it is preferable. Indeed, it is already widely in use in the beverage and food industry. The third method is oxyfuel combustion. The use of oxygen to burn the fuel enables to obtain carbon dioxide and water vapor from the exhaust gas. Once captured, CO_2 is transported by either pipelines or ship to the storage location. The geological formation needs to be appropriate to trap permanently the injected carbon dioxide. Ideal locations are depleted oil and gas fields, since hydrocarbons have been stored inside them for millions of years. Moreover, CO_2 can be used to facilitate extraction in exhausting fields. Other possibilities are unexploited coal seams or deep saline aquifers surrounded by low permeability rocks. Inside these formations, the gas interacts with the impermeable rocks, thus crystalizing.[18] Currently around the world, thirteen facilities are already operational and nine more are under completion. Altogether, they will be able to seize approximatively 40 million tons of carbon dioxide per year. Fourteen projects are in an advanced planning stage, while other nineteen are in the initial phase of development, respectively with an annual capture capacity of about 24 and 42 million tons.[19]

Norway wants to achieve a leadership position in the CCS technology. The first plant, Sleipner, opened in 1996 in Norwegian territorial waters of the North Sea off the town of Stavanger. The structure is able to inject more than one million tons annually. In 2008, a second plant, Snøvit, was opened in the far north of the country.[20] Norwegian ambitions aim very high. In fact, on May 8, 2012, a new plant was inaugurated in the town of Mongstad, near Bergen. Official spokesmen defined it as the largest experimental facility ever built in the world for the industrial sequestration of carbon dioxide. The plant, which was constructed next to an oil refinery, works like a laboratory, since two different methodologies of CCS patents are being exploited. The French company Alstom and the Norwegian Aker Solutions are using two different solvents, respectively amine and chilled ammonia. As a result, the infrastructure has two different systems for carbon sequestration with an estimated combined capacity of 100 thousand tons per year. Such a value is certainly impressive, but it pales when compared to the amount, ten times greater, of carbon dioxide emitted from the

[18] GLOBAL CCS INSTITUTE, *What is CCS?*, 2014, <www.globalccsinstitute.com/content/what-ccs>.
[19] GLOBAL CCS INSTITUTE, *Large Scale CCS Projects*, 2014, <www.globalccsinstitute.com/projects/large-scale-ccs-projects>.
[20] CARBON CAPTURE AND STORAGE ASSOCIATION, *Variability and timescale of developing CCS*, 2014, <www.ccsassociation.org/faqs/variability-and-timescale-of-developing-ccs/>.

nearby refinery.[21]

6.1.3 Geoengineering

Geoengineering is the second option available to minimize the catastrophic effects of continuous carbon dioxide emissions due to human activities. Unlike mitigation, climate engineering consists of a direct human intervention to reduce the catastrophic consequences of global warming. Two main methods are currently under study: solar radiation and carbon cycle-management [Table 14]. Nevertheless, the most critical problem is the unintended consequences that these actions can have, eventually exacerbating the effects of anthropogenic causes to climate change.[22]

The blanket term solar radiation management (SRM) includes all those technologies intended to reduce solar radiation. The aim is to combat global warming by mitigating the incidence and absorption of sunrays reaching the Earth's surface, thus causing a cooling effect able to equalize the impact of greenhouse gases. The reduction of insolation can be achieved by increasing the albedo, acting on the surface, atmosphere and space. Although SRM is the cheapest approach in geoengineering, the techniques, which are still under discussion, could make rainfalls scarcer because of the reduced evaporation, acidify oceans and compromise the exploitation of solar energy. Notwithstanding the risks, a few technologies have been proposed to intensify the planet's reflectivity by the Solar Radiation Management Governance Initiative.[23] Local strategies englobe the plantation of light leaf species and the utilization of white materials for buildings, pavement and roads. Indeed, the dark color of the asphalt and roofs store heat that is then released during the night, contributing, especially during the warmer months, to an incremental consumption of energy, due to the use of air condition. Marine cloud brightness or whitening can have a regional cooling effect. This technique involves either making clouds thicker or expanding their extension. Theoretically, whiter clouds can be obtained by spraying microscopic drops of seawater into

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[21] Richard BLACK, *Norway aims for carbon leadership*, BBC News, May 11, 2012, <www.bbc.com/news/science-environment-18009623>.

[22] Melanie A. KENDERDINE and Ernest J. MONIZ, *Technology Development and Energy Security*, in Jan H. KALICKI and David L. GOLDWYN, *Energy and Security*, pp. 402-403.

[23] The Solar Radiation Management Governance Initiative is an international working group formed in March 2010 to study SRM techniques. Its members are: the United States of America, Canada, Barbados, Brazil, Argentina, the United Kingdom, Sweden, the Netherlands, Italy, Switzerland, Austria, China, India, Pakistan, Bangladesh, Japan, Australia, Uganda, Kenya, Ethiopia, Tanzania and Mali.

the atmosphere using boats designed for that very purpose. According to computer projections, the potential results of cloud whitening could even counterbalance rising temperatures.[24] Nevertheless, Bjørn Lomborg, a Danish environmentalist and director of the Copenhagen Consensus Center, a non-profit think tank, estimated the cost of the operation to be in the range of $9/€6.6 billion; nonetheless, the total value of benefits, approximatively $20/€14.7 trillion, far exceeds the costs.[25] On a global scale, the solution may come from the injection of stratospheric sulfate aerosols in a way similar to volcanic eruptions. The small participles, pushed by the winds, could surround the whole planet, partially blocking incoming sunlight. The eruption of Mount Tambora, in Indonesia, cooled the atmosphere, so that 1816 is remembered as the year without a summer. In 1991, the fine particles emitted by the eruption of Mount Pinatubo, in the Philippines, partially blocked the solar radiation with effects that have been felt for some years. The artificial emissions of sulfur dioxide can occur with the use of aircrafts or balloons.[26] This method could contribute to a drop by 0.5%, equal to half the reduction needed to counter global warming. The Nobel Prize in Chemistry, Paul J. Crutzen, asserted that the annual cost of stratospheric sulfur injections is estimated to be between $25 billion to $50 billion/€18.5 billion to €37 billion a year.[27] Finally, a very interesting project has been proposed by Roger Angel, astronomer at the University of Arziona. In his academic paper "*Feasibility of cooling the Earth with a cloud of small spacecraft near L1*", Angel suggests the launch of small spaceships powered by solar energy to be positioned between the Earth and the Sun, so to reduce the incoming solar radiation by more or less 2%, capable of counterbalancing a doubling of the carbon dioxide.[28]

The second approach is carbon-cycle management, also referred to as carbon dioxide removal (CDR). Despite the denomination, the strategy does not simply attempt to reduce or eliminate the excessive carbon dioxide in the atmosphere, but also other greenhouse

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[24] ENVIRONMENTAL DEFENSE FUND (EDF), *The Solar Radiation Management Governance Initiative*, 2011 <www.srmgi.org>.
[25] Bjørn LOMBORG, *Global Warming's Cheap, Effective Solution*, Project Syndicate, August 10, 2009, <www.project-syndicate.org/commentary/global-warming-s-cheap--effective-solution>.
[26] Lenny BERNSTEIN, *Scientists studying solar radiation management as a way to cool planet*, The Washington Post, September 8, 2013, <www.washingtonpost.com/national/health-science/scientists-studying-solar-radiation-management-as-a-way-to-cool-planet/2013/09/08/cfb9def8-170c-11e3-be6e-dc6ae8a5b3a8_story.htm>.
[27] Paul J. CRUTZEN, *Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?*, in «Climate Change», August 2006, Vol. 77, n. 3-4, pp. 211-220.
[28] UNIVERSITY OF ARIZONA, *Space Sunshade Might Be Feasible In Global Warming Emergency*, Science Daily, November 5, 2006, <www.sciencedaily.com/releases/2006/11/061104090409.htm>.

gases that cause global warming. When compared to SRM, the techniques of CDR are more expensive and their result are slower to materialize; nonetheless, the risks are much lower. So far, three options have been proposed. One solution is known as direct air capture (DAC), which, as the name suggests, is the extraction of carbon dioxide from the air. For the moment, there are no large-scale DAC projects. Nonetheless, such a system is already in use in submarines and spaceships. This technology involves the use of special collecting units through which air is filtered. Special plastic resins imprison the particles of carbon dioxide, creating, if mixed with water, a flow, which is then trapped under the ground. When Klaus Lackner, director of the Lenfest Center for Sustainable Energy, proposed the system in 1999, claimed that the ability of CO_2 removal of the resins is 1,000 times greater than that of a tree. The main obstacle in the realization of such structures is the exorbitant cost.[29] Another solution is to create so-called biochar. Biomass can be converted into a biofuel by pyrolysis. The same procedure can be used to produce biochar, which can be defined as a charcoal, since it is carbon in a solid form. The biochar is then buried with several positive effects. Besides trapping the carbon dioxide produced by the combustion of biomass in the absence of oxygen, biochar acts as a fertilizer, spurring the growth of plants, which therefore absorb additional amounts of CO_2. Moreover, biochar can also be produced from waste and is able to retain nitrogen, respectively reducing the emissions of methane and nitrous oxide. In 2010, it was estimated that biochar burial, without considering the effects of a transition to biofuels, could ensure an annual removal of 0.25 gigatons of carbon by 2030.[30] A third option is iron fertilization. The introduction of iron in the upper layers of the oceans accelerate the growth of phytoplankton, thus contributing to both the removal of carbon dioxide and fishery recovery in some areas. Laboratory experiments have calculated that for each ton of iron, oceans could sequester up to 110,000 tons of carbon dioxide. Moreover, the generation of dimethyl sulfides (DMS) by the phytoplankton, leading to the production of sulfate aerosols, which can stimulate the formation of clouds. However, values may be overestimated and algae blooms may kill other organisms by ether blocking sunlight or absorbing even other nutrients. Furthermore, the decomposition of the algae would reduce the amount of oxygen in the water, thus increasing the mortality of fish, or produce additional quantities of

[29] Victoria SCHLESINGER, *Can carbon dioxide removal save the planet?*, Al Jazeera America, April 12, 2014, <www.america.aljazeera.com/articles/2014/4/12/can-carbon-dioxideremovalsavetheplanet.html>.
[30] INTERNATIONAL BIOCHAR INITIATIVE (IBI), *Climate Change and Carbon Sequestration*, 2014, <www.biochar-international.org/biochar/carbon>.

methane and nitrous oxide.[31]

The discussed geoengineering solutions have divergent probabilities of success. Successful results could stem from the construction of buildings with light materials, the direct capture of carbon dioxide and the exploitation of the properties of biochar. Nonetheless, the impact of these three solutions is markedly dissimilar. Indeed, white constructions have a little impact compared to biochar burial, which is probably the best option. In general, the CDR techniques seem to offer preeminent opportunities, with the exception of iron fertilizations of the oceans, because of the high risks involved. In any case, these technologies are not meant to solve the problem of global warming, but rather as a strategy of last resort to help and facilitate mitigation.[32]

Table 14. Geoengineering methods.

GEOENGINEERING	
METHODS	***SOLUTIONS AND TECHNOLOGIES***
Solar radiation management (SRM)	• Crops of light leaf species* • White materials in construction* • Marine cloud brightness/whitening • Stratospheric sulfate aerosols° • Sun shades/mirrors
Carbon-cycle management / Carbon dioxide removal (CDR)	• Direct air capture (DAC)*° • Biochar burial*° • Ocean iron fertilization°

* supposed-to-be most successful techniques

° techniques that will have the largest impacts

Direct air capture (DAC) and biochar burial are the best solutions, since they are thought to have successful and large-scale positive effects.

6.1.4 Adaptation

Adaptation to climate change can be developed analyzing how the climate is changing due to the emissions of greenhouse gases. The negative consequences of climate change are

[31] Hugh POWELL, *Fertilizing the Ocean with Iron: Is this a viable way to help reduce carbon dioxide levels in the atmosphere?*, in «Oceanus», January 2008, Vol. 46, n. 1, pp.4-9. Also available at: <www.whoi.edu/cms/files/OceanusIron_Fertilizing_30749.pdf>.

[32] Marilyn A. BROWN and Benjamin K. SOVACOOL, *Climate Change and Global Energy Security*, pp. 136-137.

well known: sea level rise, ice melting, migration of plants and animals, droughts, desertification, floods, heat waves, alterations of the precipitations. Nevertheless, some of these effects could be an advantage for populations in some areas of the planet. For instance, the rising temperatures could expand the growing season in the northern latitudes or make minerals available because of the thawing of permafrost. Still, since the change is already underway, the international community must find adaptation measures in order to reduce the costs of insufficient mitigation efforts.[33]

Adaptation measures can be either anticipatory or reactive. Anticipatory actions are preferable since they are taken in preparation to climate variability and are less expensive. Conversely, reactive actions encompass all those measures undertaken as an emergency response to a disaster that has already occurred; as a result, costs are greater. Accordingly, anticipatory adaptation is recommended to deal with future risks. The most exposed, and therefore most vulnerable, countries are the small island nations and the tropical countries. However, this does not imply that only developing countries should implement such actions; in fact, although to a lesser extent, the effects of climate change will be felt even in developed countries, especially in alpine and coastal areas.[34]

The global climate system has been affecting ecosystems and societies for centuries. Many adaptation technologies have already been developed and are now widely in use. Consequently, they only need to be modified and improved, since future climate conditions will amplify the intensity and the duration of already known events. Furthermore, the availability of advanced and high technologies is a huge advantage both to forecast weather and to develop more efficient protection systems from natural disasters. Whatever the technology, planning adaptation to climate change consists of four phases. First, it is necessary to collect and interpret information about human vulnerability to the impacts of climate variability. Planning an appropriate response depends on existing technologies, economic feasibility, social acceptance and development objectives. Once implemented, adaptation measures should be evaluated in order to make improvements, adjustments and corrections.[35]

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[33] UNITED NATIONS FOUNDATION and SIGMA XI, *Confronting Climate Change: Avoiding the unmanageable and managing the unavoidable*, pp. 81-82.
[34] Ibid., pp. 89-90.
[35] UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC) - CLIMATE CHANGE SECRETARIAT, *Technologies for adaptation to climate change*, Bonn UNON Publishing Services Section, 2006, pp. 9-10. Also available at: <www.unfccc.int/resource/docs/publications/tech_for_adaptation_06.pdf>.

Adaptation to climate change has some important differences to mitigation [Table 15]. Adaptation and mitigation not only differ in their objective, respectively the impact and the causes of climate change, but also in terms of spatial and temporal scales, as well as in concerned economic sectors. As the main cause of climate change is considered the emission of anthropogenic greenhouse gases, whatever action should include major emitters; for this reason, mitigation decisions need to be discussed and taken at international level. On the contrary, adaptation addresses the effects of climate change at national and local levels. As a result, adaptation is driven by private actions or public local policies, whereas mitigation is the outcome of international agreements. Given their different aims, differences are found also on the economic sector of action. Policies intended to reduce emissions will concern the industrial, energy production, transportation, and waste management sectors; conversely, priorities for adaptation actions are mainly coastal areas, water and food supply, human health, ecosystem preservation, and urban planning. Finally, while mitigation has long-term effects, adaptation can have either long- or short-term effects depending on the time when the event occurs and whether anticipatory rather than reactive measures are taken.[36]

Table 15. Differences between mitigation and adaptation to climate change.

	MITIGATION	**ADAPTATION**
OBJECTIVE	Causes of climate change	Impacts of climate change
TIME SCALE	Long-term effects	Short- or long-term effects
SPATIAL SCALE	International level	Local level
PRIORITIES	Energy production Transportation Industry Waste management	Coastal areas Water and food supply Human health Ecosystem preservation Urban planning

The most exposed areas to global warming are the coasts. The risk is not simply represented by a rise in sea level due to melting alpine glaciers and polar caps, but also by the intensification of tropical storms and precipitation along the coastal zones. Besides the

[36] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), *Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability*, 5.2 Interrelationships between adaptation and mitigation, March 2007, <www.ipcc.ch/publications_and_data/ar4/wg2/en/tssts-5-2.html>.

possibility of flooding, the problem lies in soil erosion, contamination of aquifers with salt water, and sinking of the coastal cities. Three strategies appear to be the possible solutions. Protection involves the construction of barriers, such as dams, dykes or reef barriers, like those built in the Netherlands. It is extremely important to consider the available space, as well as the breadth and the height of such structures. Nevertheless, the fundamental problem is the swell of rivers.[37] Retreating is another alternative, which consists in the relocation of entire urban areas, especially the most threatened ones, and the prohibition of construction in certain zones. In this case, the worry is about the loss of historical sites, which could be submerged, if not properly safeguarded. Finally, accommodating involves the development of new construction techniques, so to make buildings much stronger, and the strengthening of forecasting and warning systems.[38]

Agriculture is the most vulnerable sector to climate change. Floods, heavy precipitations, prolonged heat waves, drought affect the availability of water and food. Some solutions have been proposed for cultivations in Southeast Asia and Africa. Diversification of the seeds grown in the fields and crop rotation have already produced good results in some West African countries. Moreover, some plants offer the advantage of growing even in hostile climates, because they are more tolerant to heat and lack of water. Examples of commercially available drought-tolerant crops are some varieties of soybean, maize, wheat, rice. Nonetheless, many new seeds are being developed in bioengineering laboratories. The marker-assisted selection (MAS), also referred to as marker-assisted breeding (MAB) is a technique, whose aim is to accelerate the process of growth of the seed and the breeding program progress, but does not involve any genetic modification of the organism. Accordingly, there is no addition, removal or modification of the genes.[39] The reduction of water consumption, the collection of wastewater and more efficient irrigation systems have been suggested to combat the problem of dryness. Alternatively, even in this case, a solution is relocation or migration toward wetter regions and more fertile lands.[40]

[37] EUROPEAN CLIMATE ADAPTATION PLATFORM, *Adapting existing dykes and dams*, 2014, <www.climate-adapt.eea.europa.eu/viewmeasure?ace_measure_id=11011>.
[38] CLIMATE CHANGE SECRETARIAT (UNFCCC), *Technologies for adaptation to climate change*, pp. 11-14.
[39] Reyes TIRADO and Janet COTTER, *Ecological farming: Drought-resistant agriculture*, Amsterdam, Greenpeace International, April 2010, pp. 9-11.
[40] Stephen N. NGIGI, *Climate Change Adaptation Strategies: Water Resources Management Options for Smallholder Farming Systems in Sub-Saharan Africa*, New York, The MDG Centre for East and Southern Africa, The Earth Institute at Columbia University, December 2009, pp. 37-44.

Climate change and water shortage will have an increasing impact on human health. The biggest challenges are primarily concentrated in the poorest countries of the world, where the few existing health facilities, located in the big cities, are already at the limit of their capacity. So far, the research has focused on the development of adequate care for the treatment of viral diseases. In particular, the higher risks come from water-borne illnesses like cholera, dysentery, leptospirosis, Escherichia coli infection and typhoid fever, and vector-born sicknesses like malaria and dengue. The World Health Organization (WHO), in collaboration with the United Nations Development Programme (UNDP), introduced in 2010 the first global program aimed at finding effective measures to reduce the vulnerability of human health to future climate change within 5 years after its implementation. The existence of various risks prompted the organization to launch a pilot project in seven countries with different ecosystems: China, Kenya, Bhutan, Uzbekistan, Jordan, Barbados and Fiji.[41]

The risk is very high for some species of plants, animals and other organisms. In biology, adaptation refers to any modification of an anatomical structure or a physiological process of an organism. In "*The Origin of Species*", Charles Darwin explains that natural selection induces adaptation to the environment in which the organism lives in order to ensure its reproduction. Evolution, however, is a process much longer than the speed to which global climate is changing, so if species are unable to adapt, they have to migrate or they become extinct. In recent years only a very few species were observed to adapt to climate change. They include larger banded snails, pink salmons, tawny owls and wild thyme.[42] Adaptation and migration of the strongest species can be guaranteed by human intervention. Indeed, man can block the migration of those species that are more resilient to environmental changes, while favoring the move of the weaker plants and animals. Furthermore, it is possible to preserve certain habitats by eliminating additional hazards to their existence.[43]

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[41] WORLD HEALTH ORGANIZATION (WHO), *Climate Change Adaptation to Protect Human Health*, 2014, <www.who.int/globalchange/projects/adaptation/en/index.html>.

[42] Emma MARRIS, *How a Few Species Are Hacking Climate Change*, National Geographic, May 6, 2014, <www.news.nationalgeographic.com/news/2014/05/140506-climate-change-adaptation-evolution-coral-science-butterflies/>.

[43] NATIONAL PARK SERVICE (NPS), *Adaptation*, January 1, 2015, <www.nps.gov/subjects/climatechange/adaptation.htm>.

6.2 Barriers and solutions to policy implementation

6.2.1 Barriers to the effective implementation of climate and energy policies

The implementation of the different climate and energy policies is not always easy. The existence of barriers of various types is an obstacle to their effectiveness. However, knowledge and analysis of these impediments is useful to politicians to reach their ultimate goal: ensuring energy security without further damaging the climate. These barriers can be classified into five broad groups corresponding to the political, economic and financial, social and cultural, technical, and legal spheres.

Political barriers relate to the ineptitude of the state to introduce effective policies. Politicians tend to address critical problems based on the necessity of an immediate response. Since the impact of climate change has not yet produced noticeable effects in all areas of the planet, there are discrepancies between different states about the urgent need to act immediately. In many cases, the ministers or local authorities in charge completely ignore scientific data or are not able to choose the most appropriate measures to deal with the problem. Despite the commitments made at international meetings, the absence of a strong leader or the establishment of illegitimate governments poses a risk. Moreover, the situation is complicated by competing values and different ideologies among the various political parties, leading to a lack of cooperation. Furthermore, in some situations concrete results cannot be achieved, despite the approval by the competent bodies. In particular, some countries do not own the technical, financial or human resources necessary to implement certain projects. Another problem is related to the uncertainty about the positive effects that the policies adopted may have. Besides, governments must make decisions and bear on additional costs in the present, even though the benefits will be visible only in the medium to long term.[44]

The economic and financial barriers depend on costs and market conditions. The production of a new technology involves costs, which are usually high due to technical and market risks. While the former refers to the inability of a new technology to perform as expected,

[44] Christoph CLAR, Andrea PUTSCH and Reinhard STEURER, *Barriers and guidelines in adaptation policy making: Taking stock, analysing congruence and providing guidance*, The Governance of Adaptation, March 2012, pp. 5-11, <www.adaptgov.com/wp-content/uploads/2012/03/Clar-Barriers-guidelinesinadaptation-policy-A86-Tscience.pdf>.

the latter covers the risk of long-run demand, the emergence of competition and the possibility of rising production costs. Private investments may not be sufficient to support a new project, especially if the capital costs are very high. Capital costs are generally low for fossil fuel power stations and high for alternative resources power plants; therefore, the former alternative is preferred. Proper cost analysis, however, should consider also future costs, such as those involve in maintenance, operation and decommissioning, as well as externalities, the costs that society bear. Furthermore, investments in renewable energies are inversely proportional to the price of oil. Renewable energy projects also tend to be more expensive because of the existence of transaction costs. They arise from the need to search for information to evaluate the different plans. Economies of scale lead to reductions in the average cost as production expands. Production of electricity and fuels from alternative sources is still limited; consequently, market prices are high, reducing demand and thus production itself. Finally, another problem is related to subsidies and tariffs. Many countries provide large subsidies to fossil fuels, thus lowering final sales price. Governments may also impose tariffs on certain components of clean-energy goods to protect domestic firms from international competition. These measures entail a competitive disadvantage for renewable resources.[45]

Social barriers encompasses all the obstacles related to social processes and the organization of social institutions. Different individuals and groups may have a diverse perception of the risks inherent in climate change and consider differently the various mitigation and adaptation measures. Such differences depend on the beliefs, norms and values that govern a specific society. Indeed, theorists of social constructivism claim that preferences and interests depend on identity. Culture, in particular, has an impact on how individual actors and the entire society constructs their scale of values.[46] The governments of the most vulnerable countries to climate change argue the need to take immediate measures, whereas less exposed nations do not feel the same urgency. It is obvious that there is a different perception of risk. Discrepancies can also be found within a state. Indeed, beliefs and values influence the thinking of individuals and groups too. The interests of the various parties determine the speed at which the necessary actions to address a problem are adopted. Moreover, some

[45] Fredric BECK and Eric MARTINOT, *Renewable Energy Policies and Barriers*, Encyclopedia of Energy, Vol. 5, 2004, pp. 366-370.
[46] Christine AGIUS, *Social Constructivism*, in Allan COLLINS, *Contemporary Security Studies*, p. 91-92.

ethnic groups may be more flexible in adapting to climate change. Although very important, social and cultural barriers have not yet been thoroughly investigated.[47]

Technological limits can have two meanings. The term includes the limited availability and knowledge of new technologies, as well as the inadequacy of the training programs for technical staff. New projects may be problematic, especially in the early phase of research and development. In addition, the construction of both new energy facilities and infrastructures to protect man from climate change may take several years. Once a prototype has been created, it must be tested before it can move to the industrial development stage. Although some projects are technically feasible, they may not be replicated on a large scale due to the lack of funds. Alternatively, it may find difficulties penetrating the market because of the industry structure or the lack of supporting facilities and systems. Finally, special courses to train skilled workers should be created. Training is necessary not only to evaluate the prototype, but also to install, maintain and repair the new technologies.

Legal barriers fundamentally consists of intellectual-property laws. On the on hand, these kind of rules can promote technological innovation and production; on the other, certain anti-competitive practices can be exploited to impose an impediment to innovation itself, such as patent warehousing, trolling, blocking, and suppression. Warehousing consists in the deposit of a patent so that nobody else can develop the same technology. In case of violation, the offender is forced to pay a substantial fine. Submarine or trolling involves the registration of a broad or incomplete patent without really intending to manufacture a specific technology, waiting for someone to infringe it. In both cases, the goal is just to obtain royalties or a monetary compensation. Patent blocking prohibits other firms to file and exploit a new patent because the technology is covered by another patent. Finally, suppression is the refuse to deposit a patent so that a new product or process does not cut profits in the market.[48] An additional problem is the lack of an adequate patent protection system in developing countries and a framework law that protect their firms from disadvantageous relations when collaborating with companies based in developed countries.

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[47] INTERNGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), *Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability*, 17.4.2.5 Social and cultural barriers, March 2007, <www.ipcc.ch/publications_and_data/ar4/wg2/en/ch17s17-4-2-5.html>.

[48] Benjamin K. SOVACOOL and Michael H. DWORKIN, *Global Energy Justice: Problems, Principles, and Practices*, Cambridge, Cambridge University Press, 2014, pp. 235-236.

6.2.2 Overcoming the barriers to policy implementation

Barriers to climate and energy policies can be overcome. Policy-makers should identify and evaluate carefully the different obstacles, eventually ranking them, before preparing an effective plan of measures. It is also fundamental to distinguish between barriers that represent real problems and those that are simply symptoms. Subsequently, a list of potential solutions should be created. Each of them should be assessed in order to check its economic feasibility and social acceptance. For this reason, it is suggested to prepare alternative and complementary measures.[49]

The evaluation of the different options can be done through economic analyzes. The main methodologies used to assess the social and economic impact of the various policy mechanisms are cost-benefit and cost-effectiveness analyzes.[50] The cost-benefit analysis consists in monetizing the total costs and benefits. A specific measure should be implemented only if the benefits exceed the costs. Furthermore, it is possible to use it to choose one policy over another by comparing their total benefits and selecting the one that offer the greatest net profits. The main drawbacks that may arise from using this system are the need to convert benefits in monetary terms and the prediction of future benefits and costs. The cost-effectiveness analysis is preferable to avoid this problem. Only costs are calculated in monetary terms, while effectiveness is measured in units of services and goods. In this case, the alternative that offers the highest ratio should be preferred.[51] Benefits or effects and costs or efforts can also be employed to check whether a specific policy is equally distributed. A fair distribution should guarantee that those in need receive adequate services and that costs or benefits are not disproportionally borne by a single group. The ultimate goal is to achieve Pareto efficiency, which is a state of allocation of resources in which it is impossible to make one individual better off without making another individual worse off.[52] The problem is the existence of numerous tradeoffs.

There are different actions that governments can take. One of the easiest action is the creation of a market for greenhouse gas emissions, which can be achieved by introducing

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[49] Jørgen BOLDT, Ivan NYGAARD, Ulrich E. HANSEN, Sara TRÆRUP, *Overcoming Barriers to the Transfer and Diffusion of Climate Technologies*, Roskilde, Denmark, UNEP Risø Centre, January 2012, pp. 67-68.
[50] Ibid., p. 31.
[51] WORLD BANK, *Monitoring and evaluation: Some Tools, Methods and Approaches*, Washington, D.C., The World Bank, 2004, pp. 20-21.
[52] Michael L. KATZ, Harvey S. ROSEN, Carlo Andrea BOLLINO, *Microeconomics*, New York, McGraw-Hill, 2003, pp. 373-375.

a carbon tax or a cap-and-trade system. The carbon tax is a duty on energy sources that emit carbon dioxide into the atmosphere. Each government fixes a rate for each ton of carbon emitted from fossil fuels, but there is no limit to the emissions. For instance, Finland, which was the first country in the world to adopt such a duty in 1990, fixed it in 2013 at €35 per ton of CO_2 equivalent. Since then, only fourteen states and the Canadian province of British Columbia have implemented a carbon tax.[53] The other mechanism is cap-and-trade, as required by the Kyoto Protocol. Cap-and-trade or emission trading consists in setting a limit (cap) on the emissions of pollutants and the possibility to sell (trade) to another state, jurisdiction or company the unused portion. Overall, 39 states, including members of the European Union, Australia and New Zealand, and 23 sub-national administrations introduced this system, each of them fixing a different limit. These policies are also supported by the United Nations and the World Bank.[54]

These taxation systems are insufficient. Consequently, complementary options, such as renewable portfolio standards (RPS) or feed-in tariffs must be implemented. RPS require an increasing production of energy from renewable sources to be achieved by a specific date. These standards are more effective when accompanied by tax credits or reduction of fossil fuel subsidies.[55] With this purpose, the European Union launched the 20-20-20 Initiative in March 2007. The aim is to cut greenhouse gases emissions from 1990 levels, raise the production of energy from renewable sources and improve energy efficiency, all by 20% by 2020.[56] Similarly, the feed-in tariff (FIT) is a policy that promotes active investments in and production of renewable energy technologies. The aim is to compensate producers by guaranteeing grid access and offering long-term contracts.[57] Although, other typologies of tax credits, grants, loans and subsidies to producers of renewable energy exist, their mechanisms do not vary. Furthermore, standards and regulations can be introduced for the transportation, construction, industrial production, agriculture, water and waste management.

[53] WORLD BANK, *Putting a Price on Carbon with a Tax*, 2014, <www.worldbank.org/content/dam/World-Bank/document/SDN/background-note_carbon-tax.pdf>.
[54] WORLD BANK, *State and Trends Report Charts Global Growth of Carbon Pricing*, May 28, 2014, <www.worldbank.org/en/news/feature/2014/05/28/state-trends-report-tracks-global-growth-carbon-pricing>.
[55] NATIONAL RENEWABLE ENERGY LABORATORY (NREL), *Renewable Portfolio Standards*, September 8, 2014, <www.nrel.gov/tech_deployment/state_local_governments/basics_portfolio_standards.html>.
[56] EUROPEAN COMMISSION, *The 2020 climate and energy package*, December 11, 2014, <www.ec.europa.eu/clima/policies/package/index_en.htm>.
[57] NATIONAL RENEWABLE ENERGY LABORATORY (NREL), *Feed-In Tariffs*, September 8, 2014, <www.nrel.gov/tech_deployment/state_local_governments/basics_tariffs.html>.

Nonetheless, these rules not only vary from state to state, but also from an administrative entity to another, making impossible to generalize.

CHAPTER SEVEN
A SUSTAINABLE FUTURE?

7.1 Sustainability

7.1.1 Definition and brief history of sustainability

The concept of sustainability began to take shape in the early 1970s. In 1972, some scholars of the Massachusetts Institute of Technology (MIT) published a report, "*The Limits to Growth*", commissioned by the Club of Roma. The MIT researchers examined the interaction between the world's population, industrialization, pollution, food production and consumption of resources, predicting that exponentially increasing trends would led to growing physical impacts on nature, with consequences for economic stability and human growth within the next one hundred years.[1] In the same year, Stockholm hosted the United Nations Conference of the Human Environment. Participants claimed that the gap between developed and developing countries needed to be attenuated, whilst contemplating the mistakes made by the former, the repercussions on the environment, should not be repeated. For the first time, the existence of a link between economic development and environmental protection was discussed at international level. Moreover, several representatives of various countries stated that since the problems that plagued the world were universal, they should be solved collectively.[2]

The United Nations charged a special commission to propound strategies for improving human development without compromising the environment. After four years of hard study and debate, the World Commission on Environment and Development (WCED), also known as Brundtland Commission, named after the Prime Minister of Norway, Gro Harlem

[1] THE CLUB OF ROME, *The "Limits to Growth"*, 2014, <www.clubofrome.org/flash/limits_to_growth.html>.
[2] UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP), *Brief Summary of the General Debate*, 2014, <www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97&ArticleID=1497&l=en>.

Brundtland, who presided it, published in 1987 a report entitled "*Our Common Future*". The Commission proposed the concept of sustainable development as a way to join economy and ecology so for the international community to assume responsibility for environmental damage.[3] Sustainable development was defined in the report as follows:

"*Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:*

-the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and

-the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."[4]

Such definition depicts the world as a unique system connected over time and space. Over time, since the decisions made today will have an impact tomorrow. Over space, because actions taken in one place can have repercussions in another part of the planet.[5] Following the publication of the report, in 1989, the Swedish doctor Karl-Henrik Robèrt founded a consulting non-profit organization, The Natural Step (TNS), constituted by scientists and researchers, in order to extend the studies on sustainability. In the 1990s, collaborating with physicist John Holmberg, he suggested the idea of a sustainable society in relation to the laws of thermodynamics and natural cycles, developing and disseminating a Framework for Strategic Sustainable Development (FSSD). Robèrt's definition of sustainability was based on four basic principles: reducing the dependence on fossil fuels and heavy metals, cutting the reliance on chemicals, minimizing environmental degradation, and shrinking the conditions that globally undermine people's ability to meet their needs.[6]

Three important international conferences confronted the issue of sustainable development. The Earth Summit, held in Rio de Janeiro in 1992, produced two key documents: the

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[3] Ibon GALARRAGA, Mikel GONZÁLEZ-EGUINO and Anil MARKANDYA, *Handbook of Sustainable Energy*, Cheltenham, UK, Edward Elgar Publishing, 2013, pp. 24-25.
[4] WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT (WCED), *Our Common Future*, Oxford, Oxford University Press, 1987, p. 43.
[5] INTERNATIONAL INSTITUTE FOR SUSTAINABLE DEVELOPMENT (IISD), *What is Sustainable Development?: Environmental, economic and social well-being for today and tomorrow*, 2013, <www.iisd.org/sd/>.
[6] THE NATURAL STEP, *The Framework for Strategic Sustainable Development*, 2014, <www.naturalstep.org/en/our-approach>.

Rio Declaration on Environment and Development, and Agenda 21. Both documents constituted a wide and varied program of action and guideline for sustainable development of the planet for the twenty-first century. Ten years later, the World Summit on Sustainable Development (WSSD) took place in Johannesburg to discuss the status of implementation of decisions taken in Rio and to take note of new experiences and knowledge developed in the meantime. The main outcomes of the conference were the Johannesburg Declaration and the Plan of Implementation. Albeit long, complex and very articulate, the action plan represented a fundamental tool for many countries and organizations committed to sustainable development.[7] In 2012, the United Nations chose again Rio de Janeiro as the venue for the Conference on Sustainable Development, generally referred to as Rio 2012 or Rio+20. The central topics debated at the summit were green economy to eradicate poverty and respect the principles of sustainable development, and the creation of an institutional framework. The aims of the meeting were the renewal of the commitment to sustainable development, the evaluation of the existing gaps, and the recognition of new challenges.[8]

The conferences held in Johannesburg and Rio had their roots in the Millennium Development Goals (MDGs). The Millennium Declaration, adopted by the United Nations in 2000, set eight objectives to be achieved by 2015. These goals were the eradication of extreme poverty and hunger, the expansion of primary education, the promotion of gender equality, the reduction of child mortality, the improvement of maternal health, the fight against HIV/AIDS, malaria and other diseases, the attainment of environmental sustainability, and the creation of a global partnership for sustainable development.[9] Some critics argued the lack of analysis and measures for the achievement of these highly ambitious objectives. Moreover, progress was not uniform. While some countries attained many of these goals, others are not on track to achieve even any. Some goals were met ahead of schedule; nonetheless, an acceleration in their accomplishment is required to satisfy them by 2015.[10] The latest report, published by the United Nations on July 7, 2014, praised the results in the

[7] Hilary FRENCH, *From Rio to Johannesburg and Beyond: Assessing the Summit*, Worldwatch Institute, October 15, 2002, <www.worldwatch.org/rio-johannesburg-and-beyond-assessing-summit>.
[8] UNITED NATIONS, *United Nations Conference on Sustainable Development: Objective and Themes*, 2011, <www.uncsd2012.org/objectiveandthemes.html>.
[9] UNITED NATIONS, *Millennium Development Goals: Background*, 2014, <www.un.org/millenniumgoals/bkgd.shtml>.
[10] Rich HARRIS and Claire PROVOST, *The Millennium Development Goals: Big ideas, broken promises?*, The Guardian, September 24, 2013, <www.theguardian.com/global-development/interactive/2013/sep/24/millennium-development-goals-data-interactive>.

fight against hunger and diseases such as HIV/AIDS, malaria and tuberculosis, affirming that their respective targets will be largely satisfied. Good results were also recorded in access to drinking water and electricity, as well as in poverty reduction. Nevertheless, further results are requested in the promotion of gender equality, the improvement newborns' and pregnant women's health, and humanitarian aid to the poorest countries.[11]

7.1.2 The three pillars of sustainable development and the green economy

Sustainable development is a form of economic development that is compatible with environmental protection and needs of future generations. This process binds, in a relationship of interdependence, the protection and enhancement of natural resources to the economic, social and institutional dimensions, in order to meet the needs of current generations without compromising the ability of future generations to meet their needs. As a result, sustainable development is inconsistent with the degradation of the natural heritage and resources, the lack of recognition of the rights and equal opportunities, poverty and economic decline. For these reasons, sustainability revolves around three basic components: economy, society and environment.[12]

The three-pillar model is one way to think about sustainable development. The deep interdependence among the economy, society and the environment is the backbone of the entire system, which would collapse like a house of cards if even just one of these three elements shows a sign of weakness. Environmental sustainability is the ability to maintain the quality and reproducibility of natural resources over time. Therefore, it requires mitigation of the climate change, preservation of biodiversity, conservation of natural resources, and protection of the natural capital. Social sustainability refers to the capacity to guarantee equally distributed conditions of human well-being. Finally, since businesses and industries try to maximize welfare, the main objective of economic sustainability is to generate employment and income for population's sustenance, thus reducing poverty.

There are several ways to represent graphically sustainability [Figure 8]. Among all possible models is possible to identify three representations of which all others are just variants: the three-legged stool, the overlapping-circles and the nested circles. The first model is

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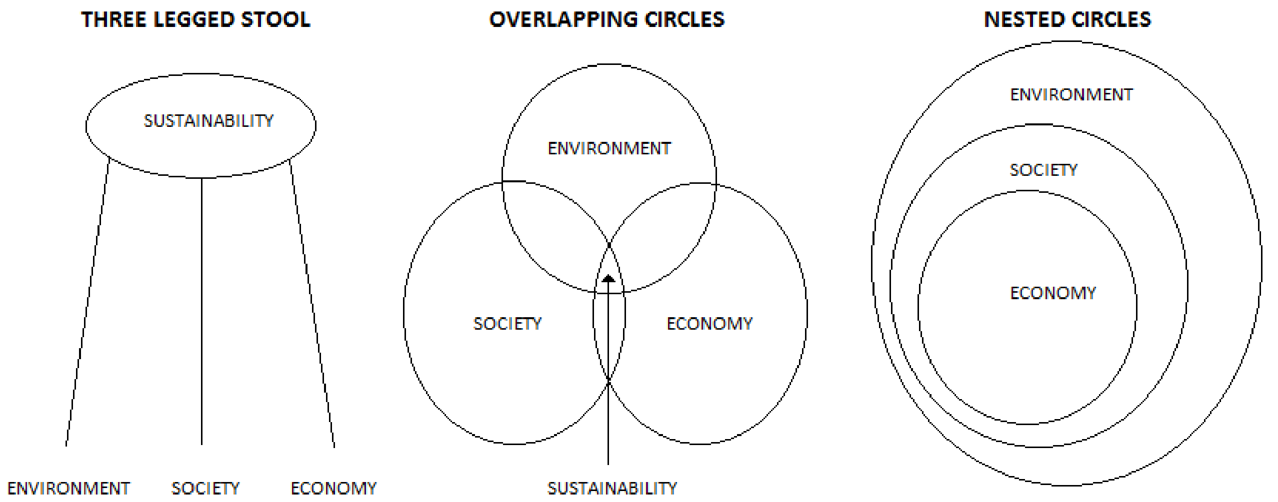
[11] UNITED NATIONS, *The Millennium Development Goals Report 2014*, July 7, 2014, <www.un.org/millenniumgoals/pdf/MDGReport2014_PR_Global_English.pdf>.

[12] Alternatively, the three components of sustainability may be summarized in the three E's (economy, equity and ecology) or the three P's (profit, people and planet).

certainly the one that best enables to understand how each component is essential to support the entire system. The main drawback is the lack of a link between the three dimensions. To overcome this limit, it has been proposed a Venn diagram consisting of three intersecting circles. The three circles are typically of equal size; however, there is the possibility to adjust their size according to the importance given to each element. In this model, there are two problems. Each component can exist separately from the other two or can interact with just one of them excluding the other. The concentric circles or Russian dolls model offers significant advantages. It enables to conceive how the three dimensions are interconnected. In such a scheme, the environment surrounds society and the economy, since both are constrained by environmental limits. Besides, the social dimension encloses the economic one because the economy depends on the choices regarding goods and services made by people.[13]

Figure 8. Main representation models of sustainability.



Own source based on descriptions.

The last model permits to associate the concept of green economy to all components of sustainable development. The green economy is generally understood simply as a kind of economy that reduces environmental risks; nonetheless, this definition is restrictive, since it does not include the social sphere of sustainability, focusing only on the interaction between economy and ecology. A more appropriate definition is that offered by the United Nations

[13] Bob WILLARD, *3 Sustainability Models*, Sustainability Advantage, July 20, 2010, <www.sustainabilityadvantage.com/2010/07/20/3-sustainability-models/>.

Environmental Programme (UNEP), which describes "*a green economy as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities*."[14] Indeed, the green economy offers much more than just growth and employment, while protecting the ecosystem. Various organizations and scholars have demonstrated that it also promotes the eradication of poverty, provides better job opportunity, creates the conditions for good governance, and ensures social equity not only between countries, but also between generations. For these reasons, many governments now consider the green economy as a means to reach sustainable development.[15]

A key component of the green economy is the transition toward renewable energy. Green energy is considered able to create green jobs, ensure real economic growth, and prevent environmental problems, such as pollution, global warming, ecological degradation and depletion of natural resources. The dependency on energy imports and the catastrophic consequences of climate change have encouraged a transition to alternative sources. Such a transition, already underway in many countries, would help achieve global access to electricity, which is a necessary requirement for improving the living conditions of many people around the world, especially in sub-Saharan Africa and in Asia, as well as enhancing economic growth, without harming the planet.[16] The universal energy access, the transition to renewable energies and the increased energy efficiency are the milestones for the future of the world. Indeed, an important initiative, Sustainable Energy for All, a partnership between governments, the private sector, and civil society, launched in 2011 by the United Nations Secretary General, Ban Ki-Moon, has listed them as goals to be achieved by 2030.[17] Following the creation of this ambitious initiative, the United Nations General Assembly declared the period 2014-2024 as the Decade of Sustainable Energy for All with the aim of meeting the objectives of sustainable development, listed in the Millennium Declaration, and creating a post-2015 development agenda.[18]

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[14] UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP), *Green Economy: What is the "Green Economy"?*, 2015, <www.unep.org/greeneconomy/AboutGEI/WhatisGEI/tabid/29784/Default.aspx>.
[15] UNITED NATIONS DIVISION FOR SUSTAINABLE DEVELOPMENT (UNDESA), *A Guidebook to the Green Economy – Issue 2: exploring green economy principles*, New York, UNDESA, November 2012, pp. 13-14. Also available at: <www.sustainabledevelopment.un.org/content/documents/743GE%20Guidebook%202&20-%Principles_final.pdf>.
[16] WORLDWATCH INSTITUTE, *Energy Poverty Remains a Global Challenge for the Future*, January 31, 2012, <www.worldwatch.org/energy-poverty-remains-global-challenge-future-1>.
[17] SUSTAINABLE ENERGY FOR ALL (SE4ALL), *Our Vision*, 2013, <www.se4all.org/our-vision/>.
[18] UNITED NATIONS, *United Nations General Assembly Declares 2014-2024 Decade of Sustainable Energy for All*, December 21, 2012, <www.un.org/press/en/2012/ga11333.doc.html>.

7.2 Clean energy projects

7.2.1 The Grand Inga Project

Hydropower is the electricity produced by the force of flowing or falling water. Already exploited in ancient times, hydropower is nowadays the most wide spread source of renewable energy. The International Energy Agency (IEA) estimated that approximatively 17% of the global electricity production is generated by water. Despite the persistence of high costs in the construction of dams, the low maintenance required, low operating costs, the great availability of water in some regions of the planet and the possibility to rely on proven technology make hydropower reliable and competitive.[19] Currently the largest hydroelectric power stations are the Three Gorges Dam on the Yangtze River in China and the Itaipu Dam on the Paraná River on the border between Brazil and Paraguay with a respective installed capacity of 22,500 MW and 14,000 MW.[20] For two advanced economies like Brazil and China, such a power generation is certainly a significant amount, but it is little when compared to the 39,000 MW that the fourth dam on the Inga Rapids will ensure to one of the least developed countries in the world, the Democratic Republic of Congo.[21]

The Grand Inga Project consists of four dams along the rapids of the Congo River. The first two dams, Inga I and Inga II, were respectively built in 1972 and 1982 with a total generation capacity of 1,775 MW. The civil war that has been plaguing the country since 1997 has led to poor maintenance of the infrastructure, which are currently able to produce only 30% of their capacity.[22] Nonetheless, a mega project is under construction. The whole plan includes the renovation and rehabilitation of the existing dams, already underway, the construction of a third dam, with a generation capacity of 4,000 MW, commissioned in 2012, and finally, the Grand Inga or Inga 4. The whole project, consisting of seven phases, is estimated to provide a total capacity of over 40,000 MW.[23]

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[19] INTERNATIONAL ENERGY AGENCY (IEA), *Hydropower*, 2014, <www.iea.org/techinitiatives/reneableenergy/hydropower/>.

[20] POWER-TECHNOLOGY.COM, *The 10 biggest hydroelectric power plants in the world*, October 28, 2013, <www.power-technology.com/features/feature-the-10-biggest-hydroelectric-power-plants-in-the-world/>.

[21] Terri HATHAWAY, *Is the Grand Inga project going to "light up Africa," or is it merely a grand illusion?*, in «World Rivers Review», April 2005, Vol. 20, n. 2, pp. 6-7.

[22] Ibidem.

[23] SOUTH AFRICAN GOVERNMENT - NEWS AGENCY, *Grand Inga project treaty to be tabled in Parliament*, August 21, 2014, <www.sanews.gov.za/south-africa/grand-inga-project-treaty-be-tabled-parliament>.

The future of the whole project will depend on the first phases of construction. The rehabilitation project is expected to cost $500 million/€370 million, made available by the World Bank, the European Investment Bank and the African Development Bank. The repair or replacement of the turbines should be completed during 2015.[24] As regards Inga 3, according to the plan, it is envisaged the construction of a low dam, called Inga 3 Basse Chute (lower falls), and a power plant, which will be built at the end of a canal, which should divert water from the existing dams. The height of Inga 3 will progressively be raised, leading to the flooding of approximatively 22,000 hectares of land, including the diversion canal. Only then a more majestic and high dam, containing 52 turbines, will be built in another area of the Congo River.[25] The beginning of works is scheduled for October 2015; however, a choice on the developer of the project has not yet been made, despite pressure from South Africa, which should import 2,500 MW of energy from the Democratic Republic of Congo.[26]

Congo has been estimated to be the third largest potential producer of hydropower, behind only China and Russia. Nonetheless, the difficulty of doing business, corruption and the civil war that shook the country have led to underinvestment in the country. The financing of the project will be very complex requiring both public and private investments. Recently the World Bank has approved a package of $73 million/€54 million, in addition to the $30 million/€22 million provided by the African Development Bank, to pursue a study on the expansion of the system of dams and on its social and environmental impacts. However, the Washington-based organization has not yet made a decision whether to support the construction of Inga 3, whose total costs are calculated to be about $12 billion/€8.8 billion.[27] The will of the South African government of buying a large part of the energy produced on the infrastructures along the Congo River is an incentive to finance. Nevertheless, doubts remain about the potential benefits. Half of the generated electricity will be transferred to South Africa by a series of pipelines, not yet built, and the remaining quantity will be destined to the Congolese mining industry and the capital city, as a result, nothing will remain for the

[24] INTERNATIONAL RIVERS, *Inga 1 and Inga 2 Dams*, 2014, <www.internationalrivers.org/resources/inga-1-and-inga-2-dams-3616>.
[25] INTERNATIONAL RIVERS, *The Inga 3 Hydropower Project*, 2014, <www.internationalrivers.org/ campaigns /the-inga-3-hydropower-project>.
[26] Michael HARRIS, *South Africa urges decision on Grand Inga hydropower plant*, Hydroworld.com, June 11, 2014,<www.hydroworld.com/articles/2014/11/south-africa-urges-decision-on-grand-inga-hydropower-plant.h-tml>.
[27] Anna YUKHANANOV, *World Bank approves funds to study Congo's Inga dam*, Reuters, March 20, 2014, <www.reuters.com/article/2014/03/20/us-congodemocratic-worldbank-idUSBREA2J1Y220140320>.

rural communities.[28]

The possible completion of the entire project involves huge environmental challenges. All dams in the world represent a barrier to the natural flow of water, so their construction is necessarily detrimental to the ecosystem. First, large areas will be submerged by water, forcing local population to migrate and increasing mosquito-borne diseases, such as malaria. The Inga rapids are located about 150 km/93 miles from the mouth of the Congo River. The damming of the river will affect the Mangrove National Park, as well as on the coasts of the Atlantic Ocean, leading to a massive die-off of fish because of the lack of sediment feeds. Nonetheless, this problem may be overcome by constructing a bypass facility. The construction of the Grand Inga Dam may seem a bad idea. However, if some of the energy produced is to be destined to the local communities, the expectable socio-economic effects will be great. Besides, it provides a better alternative to the edification of many oil- and gas-fired power plants that would imply a worst environmental damage by contributing to the emissions of greenhouse gases.[29]

7.2.2 The Noor Solar Project

The sun is the main source of energy in the planet. Not only its energy is widespread, but also it is available to everybody in huge quantities. Due to the Earth's rotation, the regions that receive the higher irradiation in hours per year are the tropical desert areas, particularly North Africa, the Arabian Peninsula, the Namib Desert, and Australia. For this reason, many national and international projects have been developed in those regions to exploit solar energy. Despite some projects are suffering impediments, such as the ambitious Desertec[30], or require huge investments, such as the Sahara Solar Breeder (SSB) Project[31], others are under completion and soon will begin to produce an amount of energy that in all likelihood will be exported to neighboring countries.

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[28] Teo KERMELIOTIS, *Will 'world's biggest' hydro power project light up Africa?*, CNN, June 28, 2013, <www. edition.cnn.com/2013/06/28/business/biggest-hydropower-grand-inga-congo/>.

[29] UNITED NATIONS ENVIRONMENT PROGRAMMA (UNEP), *The Inga hydroelectric projects*, 2014, <post-conflict.unep.ch/congo/en/content/inga-hydroelectric-projects>.

[30] Desertec was a German project of exploitation of renewable energy in North Africa, the Middle East and Europe. The idea was to build wind farms along the Atlantic Ocean coasts and to develop a set of solar power plants in the Sahara desert.

[31] The Sahara Solar Breeder (SSB) or Apollo Project is an Algerian-Japanese plan, whose goal is to create a group of solar power plants in the Sahara desert using its sand for obtaining the silicon necessary for the construction of solar panels.

Morocco is estimated to receive up to 3,600 hours of sunshine in the desert regions. This peculiarity makes it the ideal place for the exploitation of solar energy. Casablanca approved the construction of five solar power plants, the first of which is the Noor power plant[32], for a total cost of $9/€6.6 billion. The aim is to generate 2,000 MW by 2020 with the possibility to export electricity to Europe.[33] The first phase of the project, which consists in the construction of the concentrated solar power plant Noor I, near the town of Ouarzazate, is almost completed and production is currently scheduled to be active by the second half of 2015. The building works were inaugurated at a ceremony held in May 2013 in the presence of King Mohammed VI. The entire complex is being built by the Saudi Arabia-based company ACWA Power International, which will also own and operate it, while maintenance will be entrusted to a consortium led by one of its subsidiary, NOMAC. The generated electricity will then be sold to the Moroccan Agency for Solar Energy, MASEN, under a 25-year agreement worth $1 billion, approximatively €740 million.[34]

The realization of the five power stations has a high cost. The obtained loans for the construction of the first phase give reason to believe that the whole project will be realized. During the 17th Conference of Parties (COP-17), held in 2011 in Durban, an agreement was signed for the construction of the Ouarzazate power plant. The memorandum of understanding involves a loan of $297 million, of which $200 million from the World Bank and $97 million from the WB Clean Technology Fund.[35] Due to the good results obtained in the construction of the 160MW power plant, the World Bank has recently approved a new loan of $519 million for the realization of phase 2 and 3 of the project, which should begin in 2015. These phases include the construction of a second concentrated solar power station and of a tower, respectively able to generate 200 MW and 100 MW.[36]

The whole complex promises several benefits. The production of electricity from the sun,

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[32] The five power plants projects are: the 500 MW each Noor-Ouarzazate, Foum Al Ouad and Boujdour solar plants, the 400 MW Ain Beni Mathar solar plant, and the 100 MW Sebkhat Tah solar plant.

[33] Zlatica HOKE, *Morocco's First Solar Power Plant to Start Operating in 2015*, Voice of America, October 21, 2014, <www.voanews.com/content/morocco-first-solar-power-plant-to-start-operating-in-2015/2490557.html>

[34] Julia CHAN, *Work begins on 160MW Noor 1 CSP project in Morocco*, PV-Tech, May 13, 2013, <www.pv-tech.org/news/work_begins_on_160mw_noor_1_csp_project_in_morocco>.

[35] MOROCCO WORLD NEWS, *Morocco, WB Sign Agreements on 297 Million Dollar Loan for Ouarzazate Solar Power Plant*, December 8, 2011, <www.moroccoworldnews.com/2011/12/18423/morocco-wb-sign-agreements-on-297-million-dollar-loan-for-ouarzazate-solar-power-plant/>.

[36] CSP WORLD, *World Bank approves $519 million to support phase 2 and 3 of Noor Ouarzazate CSP solar complex*, October 1, 2014, <www.csp-world.com/news/20141001/001387/world-bank-approves-519-million-support-phase-2-and-3-noor-ouarzazate-csp-solar>.

which is one of the most promising renewable energy sources, would ensure a non-indifferent reduction of carbon emissions. Indeed, it has been estimated that the Noor power plant could contribute to a total reduction of 700,000 tons per year.[37] For a country poor in fossil fuels like Morocco, the facilities will ensure a reliable source of energy, which will benefit both businesses and consumers. Furthermore, the project is expected to exploit the local population's talent in both the construction and maintenance phases, thus creating a large number of job opportunities. Various local universities and research centers are also conducting specific studies to improve renewable technologies. It is therefore logical to think that training and graduation courses will be introduced in order to create highly qualified and skilled workers. Moreover, it has been suggested the possibility to exploit the generated power from the solar power plants to desalinize water, which would represent a significant advantage for a mostly desert country.[38]

The project is not without risks. The African Development Bank, which is also one the investors in the project, has prepared a comprehensive report in which the benefits and the risks of the phase 2 of the construction of the solar power plant in Ouarzazate are evaluated. The main problems highlighted in the report concern the use of polluting substances, the high consumption of water, the risk of fire, and the ecological impact. During construction, the traffic in the area will increase significantly, causing a rise in the emissions of carbon dioxide. Furthermore, the solar panels contain synthetic oils, used as heat-conveying fluid, which are highly polluting if released into the environment. Besides, they represent a major risk of fire, due to the high temperatures, about 400°C/752°F, produced from the plant. Despite these risks can be controlled or mitigated, water consumption cannot be reduced. In addition to the moderate consumption during the construction phase, water will be continuously exploited to clean the solar mirrors; therefore, as the number of panels increases, a larger quantity of water will be needed. Finally, the disturbance to local wildlife, especially birds, will materialize only during the construction phase; nonetheless, it may be reduced avoiding works in the nesting period, which extends from March to May. Moreover, the risk of blindness is unlikely and the site is not located on a major migration corridor.[39]

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[37] Ibidem.
[38] WORLD FINANCE, *Power to the people*, 2014, <www.worldfinance.com/project-finance-deals-of-the-year-2014/moatize-ipp-noor-1-csp>.
[39] AFRICAN DEVELOPMENT BANK (AfDB), *Morocco – Ouarzazate Solar Power Station Project II – ESIA Summary*, August 5, 2014, pp. 15-19, <www.afdb.org/fileadmin/uploads/afdb/Documents/Environmental-and-Social-Assessments/Morocco_-_Ouarzazate_Solar_Power_Station_Project_II_-_ESIA_Summary.pdf>.

7.2.3 Masdar City

In the future, renewable energy sources could feed entire cities. The creation of a completely self-sustainable city has already been planned and now under construction in the United Arab Emirates. Masdar, a renewable energy company founded in 2006 as a subsidiary of the Mubadala Development Company, a real estate investment and development company wholly owned by the emirate of Abu Dhabi, heads the project. Masdar City, which is approximately 17 km south-east from downtown Abu Dhabi, wants to become a vision for future cities and a model of sustainable technologies, aiming to be a zero waste, zero carbon, and fossil fuel free city.

Designed by the British architectural firm Foster and Partners, Masdar City, which in Arabic means the source, will rely exclusively on renewable energies. Construction works officially began in 2008 and already in October 2010, the first buildings were occupied; however, the completion of the first phase, 1 square kilometer/0.39 square miles, of the whole project (6 square kilometer/2.3 square miles) should be completed in 2015. The plan estimates works to be concluded between 2020 and 2025 for a total cost of just under $20/€14.7 billion.[40] The city is expected to accommodate up to 50,000 people and 60,000 workers per day in the different businesses that it will host.[41]

Masdar will be a completely sustainable city. During the design, architects have carefully studied the arabesque style of several buildings in surrounding areas, in order to reduce the impact of the hot desert temperatures and to respect the traditional construction techniques. Furthermore, every aspect of the city is designed to cut energy demand. For instance, the buildings are being oriented to the northeast to reduce direct sun exposure, and as a consequence the consumption of air condition. In addition, the blocks are interspersed with green oases and water creeks so that evaporation produces a cooling effect. The absence of vehicles powered by fossil fuels permits roads to be narrow and suitable for both pedestrians and cyclists, shrinking the overall space occupied by the city. Considering the high temperatures of the surrounding desert, even above 40°C/104°F, experts have estimated that this peculiar and innovative design will ensure an almost constant temperature of

[40] Haseeb HAIDER, *Completion of Masdar City pushed back*, Khaleej Times, October 10, 2010, <www.khaleejtimes.com/DisplayArticle09.asp?xfile=data/theuae/2010/October/theuae_October256.xml&section=theuae>.
[41] Dianna DILWORTH, *Zero Carbon; Zero Waste in Abu Dhabi*, Bloomberg Businessweek, August 1, 2007, <www.businessweek.com/stories/2007-08-01/zero-carbon-zero-waste-in-abu-dhabibusinessweek-business-news-stock-market-and-financial-advice>.

20°C/68°F.[42]

The transport service is based on a zero emission system. A four-passenger vehicle, called podcar or personal rapid transit (PRT), was initially thought as a means of transportation. The autonomous and clean podcars were expected to move along guide ways fitted with magnets and drive passengers to their destination thanks to a computer installed onboard. Moreover, special sensors placed on the car were to avoid collisions with other vehicles.[43] However, high costs made all prototypes to be parked and in their place, a mix of electric and clean-energy vehicles is currently in used. This change is likely to require a change in urban design, since the roads may be too narrow for electric cars. Furthermore, existing underground metro and light rail train (LRT) lines will be extended, connecting Masdar with Abu Dhabi and the other cities of the United Arab Emirates.[44]

Water and waste management was crucial in the design of the city. The aim is to reduce electricity consumption as much as possible. Up to 80% of the wasted water will be recycled to feed plants in the various oases scattered throughout the city. Energy will be produced from renewable sources, such as solar, geothermal and even waste, and the surplus will be exported. Masdar City is powered by 87,777 solar mirrors, located in the Shams 1 solar plant, the largest one in the Middle East. The power station is huge, ten times larger than the entire surface the city will cover when completed. The solar energy system will allow reducing the emissions of carbon dioxide approximatively by 175,000 tons per year. Moreover, every building in Masdar will be equipped with solar panels on the roof, potentially making it a self-sustainable city.[45]

Masdar City is expected to become a major research center. The first tenant of the city was the Masdar Institute of Science and Technology itself, a non-profit research-oriented university, which focuses on sustainable development and alternative energy. In September 2010, the campus and the headquarters of the institute relocated inside the city. In addition to research activities conducted in collaboration with the prestigious Massachusetts Institute

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[42] Patrick KINGSLEY, *Masdar: the shifting goalposts of Abu Dhabi's ambitious eco-city*, Wired Magazine, December 17, 2013, <www.wired.co.uk/magazine/archive/2013/12/features/reality-hits-masdar>.

[43] Bryan WALSH, *Masdar City: The World's Greenest City?*, Time, January 25, 2011, <www.content.time.com/time/health/article/0,8599,2043934,00.html>.

[44] Jared ANDERSON, *Masdar City: New Urban Energy Future and Climate Change Solution?*, Breaking Energy, March 20, 2013, <www.breakingenergy.com/2013/03/20/masdar-city-new-urban-energy-future-and-climate-change-solution/>.

[45] Patrick KINGSLEY, *Masdar: the shifting goalposts of Abu Dhabi's ambitious eco-city*.

of Technology (MIT), Masdar is offering courses and postgraduate degrees in English for both men and women.[46] Many cleantech companies have signed agreements to initiate research projects or have decided to transfer their offices and headquarters in Masdar City, among which the International Renewable Energy Agency (IRENA) and Siemens. The United Arab Emirates projects to experience an increasing flow of workers, researchers and students from all parts of the world.[47]

Masdar City is the largest ever-proposed sustainable project. The completion of the city is planned for 2020 or at the latest in 2025, so it is not known yet whether the final project will be successful and respect all the ambitious purposes that have been set. However, unlike many other projects that have been proposed, but never developed, the progress of construction works is auspicious. The first phase of the project is almost completed, and many workers, students and even tourists already commute the city every day. The director of Masdar City, Anthony Mallows, affirmed that the city would have a population of 4,000 by the end of 2014, compared to the 1,000 in 2013, and up to 10,000 in the next three to five years.[48] Regardless the achievable results, the project will remain an important experiment for the eventual creation of sustainable cities and the study of renewable energy technologies.

7.2.4 The Geysers

Around the world, there are many environmentally friendly projects. Some of them are just hypothetical, such as the Grand Inga Dam on the Congo River. The construction of a giant dam will depend on how the Congolese government, considered one of the most corrupt in the world, will manage financing received by the international organizations for the rehabilitation of the two existing dams and the construction of Inga 3. Other projects are under construction, but they may not be completed. The solar power plant in Ouarzazate is almost operational, but it is only one of the five stations planned by the Moroccan government. The sustainable city of Masdar could become either an oasis or a mirage in the desert, depending on whether works will continue or not. The wealth generated by oil has led the United

[46] MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT) - NEWS, *MIT, Abu Dhabi Future Energy Company sign cooperative agreement*, February 26, 2007, <www.newsoffice.mit.edu/2007/abu-dhabi>.
[47] Nick LEECH, *Masdar City: Role model for a sustainable future*, The National, November 5, 2013, <www.thenational.ae/uae/masdar-city-role-model-for-a-sustainable-future#full>.
[48] Ibidem.

Arab Emirates to start many pharaonic projects, nevertheless, not all of them have been completed, just think of The World Islands and Al Maktoum International Airport[49], both in Dubai. Finally, there are renewable energy facilities that are already a reality and have achieved excellent results, such as The Geysers.

The Geysers is the largest geothermal field in the world. Located in the Mayacamas Mountains, in northern California, the Geysers consists of 21 power stations, 19 of which operated by Calpine Corporation, with a generation capacity of 725 MW, enough to power the city of San Francisco. The complex provides 60% of electricity needs to many counties between the Bay Area and the border with Oregon.[50] The first plant opened in 1921 and since then production has increased considerably. The peak of production in 1987 and the subsequent decline in the generation of the superheated steam obtained from a greywacke sandstone reservoir threatened the sustainability of the Geysers. Consequently, the California Energy Commission devised a plan. The solution of the problem was made possible thanks to the construction of a 29-mile (46.6 km) pipeline, the Southeast Geysers Effluent Pipeline (SEGEP). In October 1997, the SEGP began to transport wastewater from the Lake County. Following an extension, the pipeline started delivering approximatively 9 million gallons of water.[51] The successful solution prompted the city of Santa Rosa to sign an agreement for the construction of a pipeline in collaboration with Calpine Corporation. Works for the 40-mile (64.4km) long Santa Rosa Geysers Recharge Project (SRGRP) started in 2003 and the pipeline became operational the following year. Besides bringing another 11 million gallons of water to the reservoir of the Geysers, the project enabled the city of Santa Rosa to save almost $200/€147.7 million on wastewater management and to protect the habitat of the Russian River.[52]

The Geysers offers many advantages. Geothermal energy is a renewable energy source. It is especially abundant along terrestrial faults, such as the San Andreas Fault that crosses California for roughly 810 miles/1,300 kilometers, separating the Pacific Plate and the North

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[49] The World Islands is an artificial archipelago began in 2003, but never concluded. The islands, which were to host homes and offices, are just mere mounds of sand. Al Maktoum International Airport is destined to become the new airport of Dubai. Although it is already in operation since 2014, construction works, which should be completed in 2024, do not appear to advance rapidly.
[50] CALPINE CORPORATION, *About Geothermal Energy*, 2012, <www.geysers.com/geothermal.aspx>.
[51] CALPINE CORPORATION, *The water story*, 2012, <www.geysers.com/water.aspx>.
[52] CALPINE CORPORATION, *The Geysers Geothermal Operation*, National Association of Regulatory Utility Commissioners, 2012, <www.naruc.org/International/Documents/The%20Geysers%20-%20Miscellaneous%20Information.pdf>.

American Plate. Moreover, it is a reliable source of energy, since it is not intermittent like the sun and the wind. As a result, the energy originated from the Earth's internal heat can used constantly. It is also affordable, because it can produce power at stable prices. Furthermore, like all the other renewable sources, geothermal energy is clean. It has been estimated that the Geysers prevents the release of 2.4 million tons of CO_2 every year. Consequently, the field may enable California, the most environmentally friendly state of the United States, to achieve the ambitious goal of generating 33% of its energy needs from renewable sources by 2020. Another advantage lies in the lower land impact that geothermal energy has compared to the other clean energy sources, even contributing to the management of effluent water. Finally, the Geysers offers more than 450 green jobs.[53]

Despite these advantages, like all renewable sources, geothermal energy also has its own disadvantages. Various studies have reported an increase in seismic activity in the counties of Santa Rosa and Sonoma. However, it has been excluded that the Geysers can generate strong and highly destructive earthquakes, which so far have never reached magnitude 3 on the Richter scale.[54] Another disadvantage is the possible depletion of the source if used faster than it can autogenerate. Nevertheless, as mentioned, the Geysers was able to manage and solve this problem.

[53] Mike THOMPSON, *Thompson: It's our responsibility to protect geothermal energy, a clean energy source*, Lake County News, June 11, 2014, <www.lakeconews.com/index.php?option=com_content&view=article&id=37178:thompson-its-our-responsibility-to-protect-geothermal-energy-a-clean-energy-resource&catid=29:opinion>.

[54] Katherine HARMON, *How Does Geothermal Drilling Trigger Earthquakes?*, Scientific American, June 29, 2009, <www.scientificamerican.com/article/geothermal-drilling-earthquakes/>.

CONCLUSIONS

Energy is essential for development. In ancient times, various renewable sources were used to grow crops, grind flour, and build houses and other infrastructures. During the 19^{th} century, the excessive deforestation forced the inhabitants of the British Isles to exploit the abundant coal, also available on the surface along the slopes of the hills, as a source for heating. The discovery of the higher energy content of carbon led some countries to exploit fossil fuels as a source for their industrial development. Consequently, the availability of coal and oil became a key component of the economy, transforming energy products in the most traded commodities in the world. Higher consumption rates and the exhaustion of the known deposits raised the risk of depletion of fossil fuels, thus contributing to the emergence of the concept of energy security.

Energy security has now become a prerogative of many governments. Various definitions have been proposed; nonetheless, all seem to share three main characteristics: availability, reliability, and affordability. By availability, it is not only meant the readiness of energy goods and services, but also their accessibility. Therefore, the existence of markets, where these commodities can be traded, is of paramount importance. The reliability of supplies refers to the fact that the energy flows and the activities of energy production are stable over time. In order to ensure this requirement, governments should diversify sources, suppliers, and transportation routes. Moreover, a gradual reduction of energy demand and the creation of emergency stocks are recommended to address potential energy crises. Since energy products are traded on national and international markets, affordability is crucial. The reasonableness of prices is particularly relevant for energy-importing countries. Prices do not simply affect the ability to import an energy commodity and its consumption, but also investments in research and in new and more efficient infrastructures. For this reason, it is desirable that prices are neither too high nor too low, but rather stable over time.[1]

[1] Jonathan ELKIND, *Energy Security: Call for a Broader Agenda*, in Carlos PASCUAL and Jonathan ELKIND, *Energy Security: Economics, Politics, Strategies, and Implications*, pp. 121-128.

In recent years, a new feature has been highlighted in the definition of energy security. The limited nature of fossil fuels and the need of energy for the development of the poorest countries has raised the issue of sustainability. The term refers to the ability to handle and store energy products in such a way as to meet the needs of both present and future generations.[2] The planet Earth is a single and indivisible system, whose longevity is threatened by human activities. Since the Earth Summit, held in Rio de Janeiro in 1992, various international conferences advocated the need to reduce dependence on fossil fuels and other heavy metals, because of their scarcity and of their effect on the environment, thus ensuring the requirement of sustainability.[3]

The United Nations Framework on Climate Change is one of the main outcome of the Rio Conference. The treaty establishes the basic principles for negotiating the subsequent protocols to be adopted by the parties that the convention itself expects to meet at least once a year.[4] The aim of the Conferences of the Parties (COP) is to exchange useful data and information in order to combat rising global average temperatures and the resulting climate change. Furthermore, the meetings are a forum where the participants can discuss the potential solutions to face the inevitability of the impacts that such changes imply. Three approaches are available to address the problem: mitigation, geoengineering, and adaptation. While the former two methods try to minimize the causes of global warming, the latter attempts to offer options to reduce the risk, in the event that it is too late and impossible to find a solution to climate change.[5]

The increasing of the average global temperature is almost certainly due to the soaring consumption of fossil fuels. Although there is still a limited dissent, climate change is mainly the result of growing carbon dioxide and other greenhouse gases particles released daily into the atmosphere by human activities. Comparing analyses of the ice extracted in Greenland and Antarctica and the Keeling Curve, a graphical representation of carbon dioxide

[2] INTERNATIONAL INSTITUTE FOR SUSTAINABLE DEVELOPMENT (IISD), *What is Sustainable Development?: Environmental, economic and social well-being for today and tomorrow*, 2013, <www.iisd.org/sd/>.

[3] UNITED NATIONS, *UN Conference on Environment and Development (1992)*, May 23, 1997, <www.un.org/geninfo/bp/enviro.html>.

[4] Cf. UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC), Article 7: Conference of the Parties, <www.unfccc.int/essential_background/convention/background/items/1368.php>.

[5] UNITED NATIONS FOUNDATION and SIGMA XI, *Confronting Climate Change: Avoiding the unmanageable and managing the unavoidable*, Washington, D.C., February 2007, pp. IX-XII. Also available at: <www.globalproblems-globalsolutions-files.org/unf_websiste/PDF/climate%20_change_avoid_unmanagable_manage_unavoidable.pdf>.

concentrations detected since 1958 on the summit of the volcano Mauna Loa, in Hawaii[6], it is possible to verify the existence of a direct proportionality between the consumption of fossil fuels and the rising in global temperatures.[7] Global warming is also attributed to natural phenomena; nevertheless, their impact is very small and there is nothing man can do to avoid them. Therefore, the political debate has focused on the need to transit toward alternative energy sources.

Alternative sources include both renewable and nuclear energies. The exploitation of such sources is not devoid of problems. The Chernobyl and Fukushima nuclear disasters, respectively in 1986 and 2011, generated a wave of protests around the world against the exploitation of uranium and plutonium as a source of power, leading many countries to pass laws that put a ban on nuclear energy.[8] Furthermore, the issue of the management of nuclear wastes, in particular the highly radioactive ones, and the risk of nuclear proliferation persist.[9] On the contrary, renewable sources do not produce wastes and are clean, still there present some limits. The lack of competition and efficiency are the main drawback when compared with fossil fuels. Moreover, clean technologies do not seem to be reliable yet, thus increasing the risks and therefore the costs. Their spread can make them more competitive, generating economies of scale. To this end, governments should encourage the deployment of clean energies, for instance by introducing some peculiar taxation systems and incentives, such as cap-and-trade and feed-in tariffs.[10]

Combining energy and environmental security is possible. The strong growth that clean energies have had in the last decade is expected to continue. However, this progress was possible mainly due to the high prices of oil, which prompted many countries to find an alternative source, investing in research and green technologies. The recent decline in the price of crude oil is a good omen for the economic recovery, but it could result in a renewed disinterest for renewable energies. Nevertheless, many national and regional governments have demonstrated a strong and firm will to increase the share of clean energy, at least if

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[6] Rob MONROE, *The History of the Keeling Curve*, Scripps Institution of Oceanography, April 3, 2013, <www.scripps/ucsd.edu/programs/keelingcurve/2013/04/03/the-history-of-the-keeling-curve/>.
[7] Anna MCCARTNEY, *Find out where, when levels of CO2 increase*, in «Erie Times-News», January 11, 2011, p. 3D. Also available at <www.goerie.com/apps/pbcs.dll/article?AID=2011301119984>.
[8] Charles D. FERGUSON, *A Nuclear Renaissance?*, in Gal LUFT and Anne KORIN, *Energy Security Challenges for the 21st Century*, p. 302.
[9] Gawdat BAHGAT, *Energy Security*, p. 9.
[10] NATIONAL RENEWABLE ENERGY LABORATORY (NREL), *Clean Energy Policy Basics*, November 26, 2014, <www.nrel.gov/tech_deployment/state_local_governments/policy_basics.html>.

not more than 20% by 2020. The European Union, in particular, is the main supporter of this policy; nonetheless, it must be said that the Old Continent has an incentive to reduce progressively its consumption of fossil fuels due both to the scarcity of these resources in its territory and to the dependence, especially for what concerns natural gas, from Russia.

The fight against climate change must be fought together. Past international agreements have resulted just in partial victories. The main problem has been the clash between developing countries, led by China, and the United States. Both sides have taken valid positions in their defense. Developing countries do not want to relinquish the possibility of growth they are experiencing by reducing or eliminating the consumption of fossil fuels, which as debated, are less expensive and generate a greater amount of energy per unit. Conversely, Washington does not want to jeopardize its national economy, giving to other countries a competitive advantage. The recent agreement between the President of the United States, Barack Obama, and the President of the People's Republic of China, Xi Jinping, is a good hope for the achievement of a binding treaty, which should be reached at the next Conference of the Parties to be held in Paris in December.

All countries must commit to environmental protection. Developed countries should be the first to implement reforms for the diffusion of green technologies and invest more in research, so that even developing countries can do their part by reducing the emissions of greenhouse gases without compromising their own development. Cooperation between all parties is necessary to achieve the desired result. However, if serious and concrete commitments will not be taken at the conference of Paris, any future action will frustrate what has been done so far, making, in all probability, irreversible the consequences of global warming and climate change on development.

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