Implementing the Neural Approach to Third Generation Classification of Carbon Intensity within Alternate Energy Projects

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Abstract

Atmospheric concentrations of greenhouse gases are determined by the balance between sources (emissions of the gas from human activities and natural systems) and sinks (the removal of the gas from the atmosphere by conversion to a different chemical compound). The proportion of an emission remaining in the atmosphere after a specified time is the "Airborne fraction" (AF). More precisely, the annual AF is the ratio of the atmospheric increase in a given year in that year's total emissions.

In this paper, we focus upon the solutions for alleviating the AF of CO_2. In our empirical study we use multilayer perceptron neural network. This technology is very powerful for the treatment of complexity and non-linearity.

Results prove that all renewable energy sources have weak carbon intensity. In addition, sensitivity analysis allows us to classify these sources according to an increasing intensity of carbon.

Keywords

Renewable Energy, Climate Change, Ecological Economy, Neural Networks. Environmetrics.

JEL Classification

Q42, Q54, Q57, C45.

1. Introduction : Historic Climate Change Timelines

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The modern history of climate change awareness began in 1800-1870 during the First Industrial Revolution. Coal, railroads, and land clearing speed up greenhouse gas emission, while better agriculture and sanitation speed up population growth. In 1896 Arrhenius publishes first calculation of global warming from manmade emissions of CO_2.

- **1870-1910** sees the Second Industrial Revolution. Fertilizers and other chemicals, electricity, and public health further accelerate CO_2 growth. In 1920-1925 the opening of Texas and Persian Gulf oil fields inaugurates the era of cheap energy.
- **1939-1945**, World War II. Military grand strategy is largely driven by a struggle to control oil fields.
- **In 1960**, Keeling accurately measures CO_2 in the Earth's atmosphere and detects an annual rise in CO_2. The level is 315 ppm. Mean global temperature (five-year average) is 13.9°C.
- **In 1969**, Astronauts walk on the Moon, and people perceive the Earth as a fragile whole.
- **In 1975** Warnings about environmental effects of airplanes leads to investigations of trace gases in the stratosphere and discovery of danger to the ozone layer.
- **In 1979**, Second oil "energy crisis" Strengthened environmental movement encourages renewable energy sources, inhibits nuclear energy growth
- **In December 1983**, the Secretary General of the United Nations, Javier Pérez de Cuéllar, asked the Prime Minister of Norway, Gro Harlem Brundtland, to create an organization independent of the UN to focus on environmental and developmental problems and solutions. This new organization became known as the Brundtland Commission, or more formally, the World Commission on Environment and Development (WCED). The Brundtland Commission was first headed by Gro Harlem Brundtland as Chairman and Mansour Khalid as Vice-Chairman.
- **In 1987**, the Brundtland Commission published the first volume of “Our Common Future,” the organization’s main report. The report definition of sustainability, which stated that sustainable development was, “development which meets the needs of the present without compromising the ability of future generations to meet their own needs.” The term, sustainable development, became the coverall terminology for a range of initiatives related to the ethos of environmental conservation and reduction of CO_2 projects (Weart, 2015).

The 15 years post the publication of The Brundtland Report witnessed an era of incongruent conflation of differing concepts which was also reflected in the premature rush to create codes of practice, standards, and environmental stewardship practices before adequately defining or testing the available data.

During these years, global academia devised many hundreds of differing approaches related to the measurement of Climate Change elements. The gathering of empirical evidence was severely inhibited by the plethora of subjective information emanating from the major polluting industries. As is the case today, firms are permitted to self-report their emissions. For major corporations this information is then analysed and included in various GHG reports and "Sustainability Indexes", which guide global investment into companies that are signed to a set of qualatively based principles that monitor and assess their environmental sustainability. As an example, The Dow Jones Sustainability Index is the premier Index of the largest global corporations who self-report their environmental performance and CO_2 emissions.

In 2001, Professors Cerin & Dobers of the Royal Institute of Technology and the Gothenburg Research Institute, Sweden, produced the results of their research into self-reported emissions, information which was implemented as global investment guides via Dow Jones Sustainability Indexes. Cerin and Dobers (2001) found that companies listed on the FTSE Stock Exchange selected for entry into the Dow Jones Sustainability Index emit on average 714,000 tons CO_2 while other companies listed on the same exchange but not listed on the DJSI,emit on average 114,000 tons CO_2. This proportion is similar to the one between reporting companies, 944,000 tons CO_2 emissions, and non-reporting companies, 60,000 tons, i.e. Companies listed in the DJSI based upon unverified self-reporting actually emit some 11x more CO_2 than companies who do not report at all.

Clearly, information based upon self-reported is non verified data acts in opposition to the reduction of Global CO_2 emissions as is evidenced by the study "Banking on Oil – Undermining our climate". This report stated that: "Coal is the single greatest source of carbon emissions endangering our climate. Yet never before has so much coal been mined on the planet as today. Since 2000, global coal production has grown by 70% and has now reached a staggering 7.9 billion tons annually, and what's more, the industry is still expanding. Who on earth is financing the enormous production increases of the world's dirtiest fossil fuel? […] From 2005 to mid-2013, 89 commercial banks poured a total of 118 billion euro into the coal mining industry" (Schücking, 2013).

The research also shows that coal finance has increased tremendously over the past few years. Since 2005 – the year the Kyoto Protocol came into force – banks' financing for coal mining companies increased by 397%. The three banks at top of the list are Citi (€7.29 billion), Morgan Stanley (€7.23 billion) and Bank of America (€6.56 billion) (Schücking, 2013).

During the last thirty years, economists have conducted many researches in this field. Hence, several new concepts and theories have appeared and have established a good analysis framework.

2. Theoretical Framework

Renewable energy promotion is established by several approaches and theoretical thoughts.

2.1. Sustainable development

This concept was born with the publication of the report of the World Commission on Environment and Development (WCED), titled "Our common future". The concept of "sustainable development" stemming from this report is defined as: “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987, p.37). After this concept, new economic approaches were born especially the ecological economy. However, sustainable development is not a theory. On one hand, it is an analytical referential studying the interdependence of three domains or pillars: economy, society and environment. On the other hand, it is a normative referential which joins together public and private actions to guarantee intragenerational and intergenerational justice (Rumpala, 2003).

The rich literature on sustainable development came from diverse organizations (international institutions, government services, local authorities, corporates, and associations). Mainly, it focuses on the central place that natural environment needs to occupy in any decision-making. Its theoretical approach was the identification of economic activities’ impact on environment and the ways to mitigate them. So, privilege must be granted to prevention while looking for the best settlement between economic efficiency and environmental conservation.

Sustainable development and ecological economics focused on the explanation of the notions of uncertainty, irreversibility and resilience; and their effects on the decisions modes (Muradian, 2001).

2.2. Ecological economics

It is a branch of economy which theoretically deals with co-evolution in time and space of human and ecosystems. The purpose of this branch is to guide the actions of both public and private actors for the sustainability of economic development. So, it means conciliation between economic progress, social justice, and environmental protection (Organization for Economic Co-operation and Development, 2001).

The dichotomy between environmental and ecological economics has been the object of several debates. According to most famous of them, environmental economics supports the hypothesis of "weak sustainability". So, better growth is useful for reducing the environmental damage. In fact, a high growth allows a country to improve prevention and insurance policies as well as institutionalizing their management (Jemli, Chtourou and Feki, 2010; Jemli, Yahyaoui and Chtourou, 2011).

At the opposite, the ecological economics adopts rather a hypothesis of "strong sustainability" (Merino-Saum and Roman, 2012). The upholders of this current of thought consider that degrowth (the contraction of economies) can be the best solution for ecosystem protection. In that, the ecologists seek firstly the environmental gain (for example: GHG reduction comes before the economic profit).

2.3. Environment as a global public good

The "global public good" (GPG) is a notion that is appeared in 1990. According to which a GPG is: “Any resource or service that benefits all, including the operation or maintenance may warrant international collective action. The global public good can either be material such as marine, air and water; or immaterial such as scientific knowledge, justice, health and human rights” (Official Journal of the French Republic, 2008, p.16049, translated citation).

In 2001, the World Bank fixed six global public goods (environment, health, knowledge, peace, financial stability and governance). As the environment is the first GPG, its protection needs to be in the interest of all people, the current as well as future generations (Barkat, 2008).

According to the priority granted by the World Bank to this GPG, environmental issues have taken on a large importance. Moreover, "global public goods" such as: environment, water, health, biodiversity and security over time the crucial stakes in the well-being improvement (Boidin, Hiez and Rousseau, 2008). The most common environmental issues are those related to the hole in the ozone layer, global warming, and renewable energy (Thoyer, 2002; Barkat, 2008). In fact, international cooperation urges for reducing greenhouse gas emissions. In this regard, several international agreements were signed the most famous among them are: the earth summit agreements in 1992, the Kyoto protocol in 1997, and the United Nations Millennium Summit in 2000 establishing the Millennium Development Goals. In 1991 the "global environment facility" endowed 3 billion dollars. (USD) It became the first mechanism for financing the amelioration of world environmental problems (Dalode, 2006; Thoyer, 2011).

3. Achieving Third Generation Financial Solutions

Products and services that present solutions to the increasing constraints on natural resources and unmet basic human needs will be a major driving force for our global economy. While there will be numerous investment opportunities that claim both premium financial returns and social/environmental benefit, non-financial metrics will enable us to distinguish the "pretenders" from the "real deal" (Duncan and Wong, 2010).

The first breakthrough made in the establishment of independently verified Environmental and Social metrics, came from a City of London based research group headed by, Yates-Smith, Aalders and Lillandt, who in 2002 devised an innovative quantitively based Environmental, Social and Governance, (ESG) risk algorithm[4].

This group was to develop their algorithm over the next eight years, applying the algorithm in a variety of global sustainable and alternate energy investment initiatives and to the research and development of quantitively based environmental, (environmetrics) metrics. Their years of academic research and practical deployment of solutions provided a significant database of empirical evidence related to climate change investment risk metrics.

Results of academic analysis, studies and research related to climate, predict an average of future global warming of between 1.1 and 6.4°C by 2100. The International Energy Agency (IEA) is in agreement with this forecast. A world average of global warming of 3 to 4°C at the end of the century would be potentially catastrophic (Tissot-Colle and Jouzel, 2013).

These changes have led to the intensification of natural disasters such as floods and droughts, rapid environmental transformation of ecosystems ; biodiversity losses; oceans acidification; melting of ice caps and sea levels rising; along with intensification of respiratory and cardiovascular diseases ; food insecurity and populations movement rising.

Hence, all these environmental and socioeconomic repercussions will continue in the absence of any proactive, adaptive and preventive measures (Jemli and Chtourou, 2010).

The world energy demand multiplied by a factor of 2.4 between 1970 and 2010. This demand will substantially increase in the future due to world population growth and the growing needs of developing economies'. However, until the 21st Century, fossil fuels have represented more than 80% of the total energy supply. These nonrenewable resources are,

[4] https://en.wikipedia.org/wiki/Environmental,_social_and_corporate_governance

expensive, increasingly scarce and finite in supply. This is apart from the vast irreversible damage which fossil fuel continues to wreak upon our natural environment.

Clearly, it is imperative that more effective, affordable, alternate energy sources are quickly financed, developed and deployed. Future World Climate change mitigation efforts aim to maintain the average global warming to 2°C, compared with the preindustrial level. Not exceeding this threshold means that the world GHG emissions from now (2015) to 2050 have to be reduced by half compared with late twentieth Century levels (that is almost a third of current emissions). To achieve this goal, international conventions have been ratified by numerous countries, among which the most significant is "The Climate Convention" voted at Cancun in 2010 and confirmed at Durban in 2012. According to which, emissions are planned to begin their fall in 2020 (Tissot-Colle and Jouzel, 2013).

The Intergovernmental Panel on Climate Change, (IPCC) is an international body created by the UN in 1988 to collect and synthesize the latest science on climate change and is endorsed by all UN member States. This report considered new scientific evidence, based on many independent scientific analyses from observations of the climate system, historical climate archives, theoretical studies of climate processes and simulations using climate models, to conclude that there is a 95% probability that human action is the dominant cause of climate change. This represents an increase in certainty from 90% in the previous report.

The report points out that the warming of the climate system since 1850 is unequivocal and unprecedented over a period of millennia, as confirmed by historical climate reconstructions. The 30 year period 1983-2012 is likely to have been the warmest in the past 1,400 years. Overall, global combined land and ocean surface temperatures have increased by 0.85˚C from 1850 to 2012 (Intergovernmental Panel on Climate Change, 2013).

4. Financing Climate Change Mitigation

One of the key findings of the IPCC review is that the additional investment and financial flows in 2030 to address climate change amounts to 0.3 to 0.5% of global domestic product in 2030 and 1.1 - 1.7% of global investment in 2030. This is a small amount in overall global figures, but large compared to the currently available public and private financial resources for climate change (including the ones available under the UNFCCC and its Kyoto Protocol). Current levels of funding will be insufficient to address the future financial flows estimated to be needed for adaptation and mitigation under a strengthened future climate change deal post 2012 (United Nations Framework Convention on Climate Change, 2014).

Particularly in the energy sector, huge investment flows are needed. For energy supply: USD 432 billion is projected to be invested annually into the power sector. Of this amount, USD 148 billion needs to be shifted to renewables, Carbon Dioxide Capture and Storage (CCS), nuclear and hydro. Investment into fossil fuel supply is expected to continue to grow, but at a reduced rate.

Failure to achieve changes in investment and financial flows for mitigation will lead to unsustainable development paths and "lock-in" effects for the next 20-30 years. This will lead to higher emissions, more climate change impacts, and larger investment and financial flow needs for adaptation in the long-term. Private sector investments constitute up to 86% of investment and financial flows and are thus another important means to enhance investment and financial flows to address climate change in the future (United Nations Framework Convention on Climate Change, 2014).

In May 2013, just five months prior to the publication of the IPCC report, the U.N. Office for Disaster Risk Reduction warned that economic losses from disasters since 2000 are in the range of $2.5 trillion, a figure at least 50 percent higher than previous international estimates (Yates-Smith, Aalders and Lillandt, 2003).

U.N. Secretary-General Ban Ki-moon launched the report saying the review of disaster losses in 56 countries clearly demonstrates that "economic losses from disasters are out of control" and can only be reduced in partnership with the private sector, he commented that, "Our startling finding is that direct losses from floods, earthquakes and drought have been underestimated by at least 50 percent".

Ban said. "So far this century, direct losses from disasters are in the range of $2.5 trillion. This is unacceptable when we have the knowledge to reduce the losses and benefit from the gains."For too many years, the secretary-general said, financial markets have placed greater value on short-term returns than on sustainability and resilience, which in the long-term are far more attractive and can save millions of dollars. "In the years ahead, trillions of dollars will be invested in hazard-exposed regions," Ban said. "If that money fails to account for natural hazards and vulnerabilities, risk will increase. Where such spending does address underlying risk factors, risk will go down." (United Nations International Strategy for Disaster Reduction, 2013)

Previously, renewable energy commercialization has involved the deployment of two generations of renewable energy technologies dating back more than 100 years. First-generation technologies have matured and become economically uncompetitive. Generation two has been the transition period to generation three, which includes biomass, hydroelectricity, geothermal power and heat. Third-generation technologies currently being developed require significant long term investment, both from the public and private sector in order to make the required contributions on a global scale.

Total investment in renewable energy reached $257 billion in 2011, up from $211 billion in 2010. The top countries for investment in 2011 were China, Germany, Spain, the United States, Italy, and Brazil. As of 2012, renewable energy accounts for almost half of new electricity capacity installed and costs are continuing to fall. Public policy and political leadership helps to "level the playing field" and drive the wider acceptance of renewable energy technologies. As of 2011, 118 countries have targets for their own renewable energy futures, and have enacted wide-ranging public policies to promote renewables. Globally, there are an estimated 3 million direct jobs in renewable energy industries, with about half of them in the biofuels industry. (United Nations Environment Programme, 2012)

Promoting the energy which has the lower carbon intensity will alleviate CO_2 emissions. Thereby, sensitivity analysis is useful for classifying the seven leading renewable energy methodologies. Current research focuses on the importance of renewable energy promotion. By this research, we can classify renewable sources according to an increasing order of carbon intensity.

5. Multilayer Perceptron Neural Network Technology

A multilayer perceptron (MLP) is a feed forward artificial neural network model that maps sets of input data onto a set of appropriate outputs. An MLP consists of multiple layers of nodes in a directed graph, with each layer fully connected to the next one. Except for the input nodes, each node is a neuron (or processing element) with a nonlinear activation function. MLP utilizes a supervised learning technique called back propagation for training the network.MLP is a modification of the standard linear perceptron and can distinguish data that is not linearly separable.

This paper focuses upon and analyzes the effect of seven sources of renewable energy. The seven renewable sources are: biomass, geothermal, hydraulic, solar photovoltaic, solar thermal, marine, and wind energy, measured in terms of their positioning upon the world carbon intensity supply indexes.

The basis of, this empirical study, is the use of Multilayer Perceptron which is an artificial neural network technology. This methodology facilitated the accurate testing of the sensitivity of the seven studied renewable energy sources. The increasing concentration of carbon dioxide in the atmosphere is admitted as the main factor of the global warming intensification. This large atmospheric CO_2 concentration is mainly connected to human activities and so to a country's energy model.

The present research focuses on the importance of renewable energy promotion. In effect, renewables are lesser CO_2 emitters. This work wishes to help decision-makers to choose renewable sources which have the weakest carbon intensity. We begin by presenting the research's methodology. Then, we proceed to the results interpretation.

5.1. Methodology's assets: non-linearity treatment and sensitivity analysis

Within the framework of this research, we make recourse to the neural approach which is capable of extrapolation, to deliver improved definitions of complex problems. There are many types of networks, but the most commonly used is the multilayer perceptron (MLP), which is a completely connected network (Rosenblatt, 1962).

The MLP is settled by many layers: an entrance layer (input layer) that receives exogenous data; an exit layer (output layer) which provides results; and one or several middle layers (hidden layers). The latter are responsible for the network's compilation; they can capture all the non-linearity relationships between explanatory variables. The basic components of each layer are neurons which are connected to multifarious other neurons in the next layer. The information passes forward of the entrance layer to the exit without regression. Due to that non regressive behavior, the MLP is called a "feed forward" neural network.

As is confirmed by Minsky and Papert (1969), the MLP is powerful in training and generalization. It constitutes a useful technique for sensitivity analysis of explanatory variables. In fact, when we disrupt one of the network's entrances, the training performance measured by the mean square error (MSE) varies. This variation is the biggest if the disrupted variable has more influence on the endogenous (Jemli et al., 2012).

The standard formula of the MSE is as follows:

$$MSE=\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i-y_i)^2 \quad (1)$$

With: n the number of observations in the data set; $\hat{y}_i$: the output simulated by the network; and y_i : the observed output or target.

The MLP neural network is useful for undertaking the sensitivity analysis of the network's entrances. This analysis allows us to test the influence of exogenous or explanatory variables (inputs) on endogenous or dependent ones (outputs). This influence depends on the relative variation of the training MSE after any entrance disruption. This variation is generally known as "the delta's error". It allows us to classify all the exogenous variables according to their relevance to the network's output (Pastor-Bárcenas et al., 2004).

In effect, sensitivity analysis is: "the study of how the uncertainty in the output of a mathematical model or system (numerical or otherwise) can be apportioned to different sources of uncertainty in its inputs" (Saltelli et al., 2008, p.1). The main purpose of sensitivity analysis is to estimate the weights of entrances' disturbances on the model's exit. So, significance of relationship between entrances and exits, presence of non-linearity's and variables' interactions can be only detected by sensitivity analysis.

Several academic works have successfully applied the analysis of sensitivity by MLP. Among them: Hewitson and Crane (1994) used the sensitivity analysis to approximate the main components of local precipitation conditions for the south of Mexico; Tangang et al. (1998) applied it to temperature anomalies' prediction for the sea surface of Equatorial Pacific Ocean; and more recently Jemli, Chtourou and Feki (2010) used the sensitivity analysis for natural disaster losses prediction.

In more general terms and according to Pannell (1997), the sensitivity analysis examines the study's robustness when it includes a certain shape of mathematical modeling. It is thus an analysis suited to answer a complex question such as: what is the weakest CO_2 emitter source?

Therefore this study is important, and will help decision-makers in matters of identifying the most effective and least carbon rich emitting solutions related to the development of Alternate Energy. Further, it may form the predictive investment risk metrics required to drive the required private and institutional development funding of Alternate Energy solutions.

5.2. Sample and Choice of the Model

The sample that is presented here is formed by 21 observations covering the extensive period between 1990 & 2014. The input data is based upon a temporal series (annual world values) of renewable energy supply indexes for seven key sources. The output data is the value of reported annual world carbon intensity (Table 1).

Table 1: Model's variables: Inputs and output of the MLP network

Data	Symbol in the model	Name in the database	Sources
Inputs	X1	Renewable Energy Supply Index - Biofuels: biogasoline and Biodiesel	Geodata Portal UNEP (2013)
	X2	Renewable Energy Supply Index - Geothermal	Geodata Portal UNEP (2013)
	X3	Renewable Energy Supply Index - Hydro	Geodata Portal UNEP (2013)
	X4	Renewable Energy Supply Index - Solar Photovoltaic	Geodata Portal (2013)
	X5	Renewable Energy Supply Index - Solar Thermal	Geodata Portal UNEP (2013)
	X6	Renewable Energy Supply Index - Tide, Wave, Ocean	Geodata Portal UNEP (2013)
	X7	Renewable Energy Supply Index - Wind	Geodata Portal UNEP (2013)
Output	Y1	CO2 Intensity (kg per kg of oil equivalent energy use)	WDI (2013)

Source: World Bank, World Development Indicators - WDI- (2013). & United Nations Environment Programme UNEP Geodetic Portal - (2013).

The first stage of the model's construction consists of decomposing the available data into three samples: namely, training, test and validation.

The training sample covers 60% of the total dataset which is equal to 13 observations. The test sample represents 20% of the total observations (equivalent to 4 observations). Additionally, the sample of validation is formed by 4 observations which represent 20% of the dataset.

The second stage consists of running the model and testing various architectures. This step plays upon the number of hidden layers as well as on that of their neurons. These architectural modifications include the variation of the mean square errors for the three samples as described above.

The selection rule of the MLP assumes the retention of the model that has simultaneously the weakest testing MSE and a significant reduction of its training MSE (compared with its initial value). Therefore, this study retains the network R20 which is a MLP with two hidden layers and has as architecture: [7 14 5 1] (Table 2).

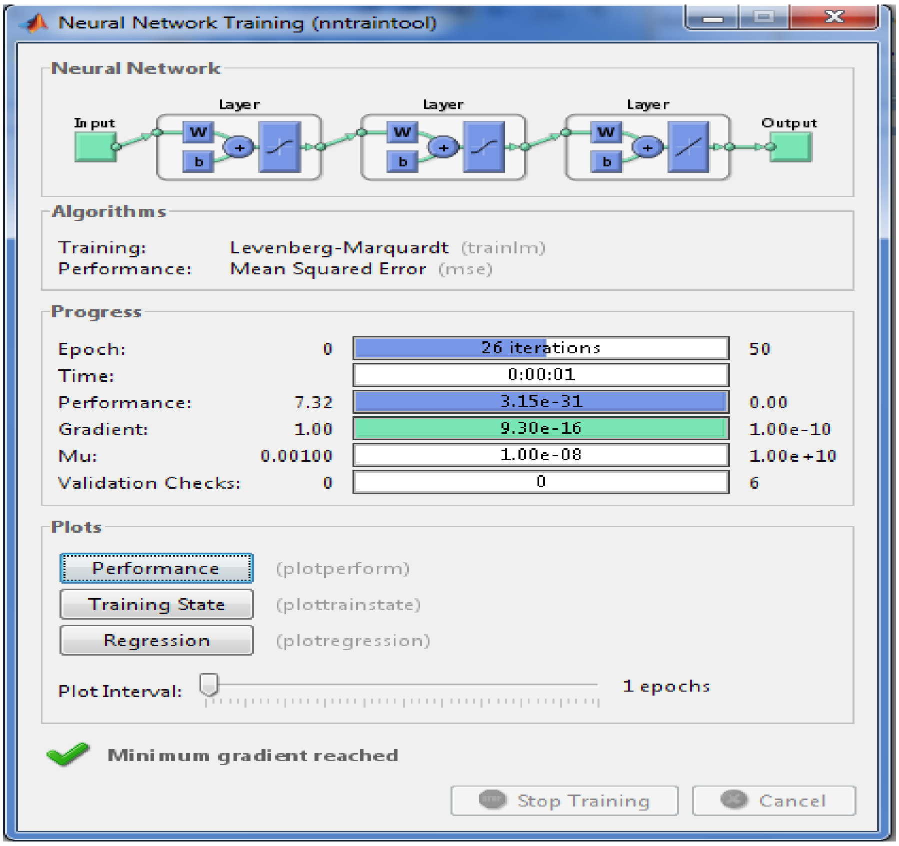
Table 2: The different MLP architectures tested and the chosen model

	MLP's Name	Architecture	Initial Training MSE	Training MSE	Testing MSE	Validation MSE	speed of training (number of iterations)
1 Hidden Layer	R1	[7 3 1]	0.972	9.22E -23	1.2549	0	15
	R2	[7 4 1]	3.56	3.58E -28	1.1542	0	11
	R3	[7 5 1]	2.46	1.95E -21	1.7116	0	19
	R4	[7 7 1]	4.59	1.02E -26	0.0878	0	11
	R5	[7 10 1]	0.939	4.47E -27	0.2685	0	10
	R6	[7 12 1]	3.76	1.02E -22	0.3103	0	9
	R7	[7 15 1]	2.04	5.72E -31	0.4917	0	9
2 Hidden Layers	R8	[7 3 2 1]	1.71	6.56E -21	1.2859	0	49
	R9	[7 3 3 1]	1.83	7.73E -24	1.0907	0	105
	R10	[7 4 2 1]	0.823	1.21E -28	0.2423	0	17
	R11	[7 4 3 1]	1.79	1.93E -26	0.5436	0	15
	R12	[7 5 2 1]	0.95	2.54E -23	0.1679	0	23
	R13	[7 5 3 1]	0.851	1.09E -28	0.874	0	16
	R14	[7 7 5 1]	1.84	1.22E -23	0.1486	0	11
	R15	[7 7 10 1]	3.41	4.57E -31	0.1645	0	10
	R16	[7 10 5 1]	4.09	6.93E -28	0.3111	0	19
	R17	[7 10 10 1]	2.18	4.09E -31	0.1914	0	10
	R18	[7 12 5 1]	1.46	9.39E -30	0.5223	0	12
	R19	[7 12 10 1]	2.13	3.39E -27	0.1205	0	12
	R20	[7 14 5 1]	7.32	3.15E -31	0.1779	0	26
	R21	[7 14, 10 1]	3.14	1.13E -27	0.2376	0	13
	R22	[7 15 5 1]	1.26	5.13E -28	0.5906	0	15
	R23	[7 15, 10 1]	1.92	6.13E -31	0.3214	0	11

Source: Authors Estimations (2013).

The testing MSE is about 0.1779 and its training one decreased considerably from 7.32 (which is excessive) to 3.15E-31. This network reaches the minimum gradient after 26 iterations. Thus, it manages the training of a complex phenomenon after a reasonable number of iterations. It is not reproved by overtraining. Indeed, the same network applied to another sample (test set) always maintains good performance (which means a low testing MSE). Furthermore, the activation function for both hidden layers is the sigmoidal. While for the output layer, the activation function is linear (Figure 1).

Figure 1: Architecture and Training of the retained MLP

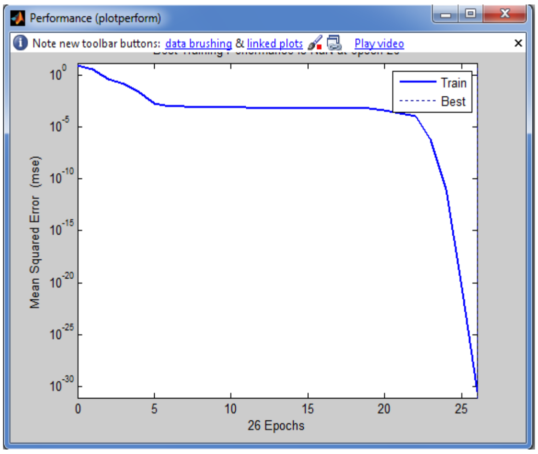


Source: Authors' Estimations (2013).

5.3. Results Interpretations

The resultant MLP ("R20") is endowed with good training capacity. During this phase, the MSE of the training dataset diminishes significantly and then converges to its minimum gradient: 3.15E-31 (Figure 2). So, this neural network has a high-quality convergence during its training process.

Figure 2: The training MSE's evolution



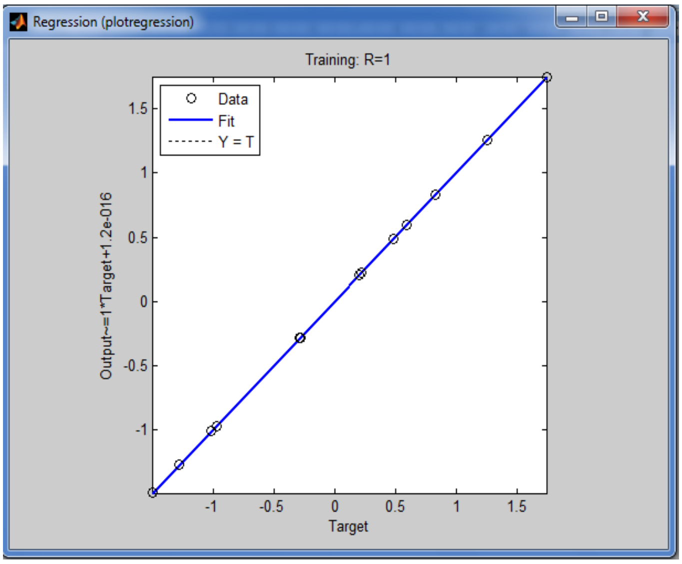
Source: Authors' Estimations (2013).

Moreover, this network is marked by its robustness (the capacity of learning from new inputs-output couples). In fact, this indicates low values for the test and validation MSE which are respectively 0.1779 and 0.

Additionally, this MLP is characterized by a high-quality linear adjustment between its real output "Target" (the observed value of carbon intensity) and its simulated one (the network's output) (Figure3). Indeed, the R-value is equal to 1. And, its linear adjustment regression is given as follows:

$\text{Output} = 1 * \text{Target} + 1.2^{-0.16} (2)$

Figure 3: MLP's quality of linear adjustment



Source: Authors' Estimations (2013).

According to the sensitivity analysis' results, each one of the seven renewable sources has a significant effect on the carbon intensity. The relative variation of the training MSE is very high. It includes a variation between minimum values of 7.77E+28 and a maximum of 2.04E+30 (Table 3). Thereby, deleting any leads to a sharp increase in the training MSE. Hence, each one of these renewable sources has a significant effect on carbon intensity mitigation.

Table 3: Sensitivity analysis and energy sources classification according to their weak carbon intensity

	Relative variation of the training MSE	Sensitivity Order	Classification of renewable sources by an increasing carbon intensity
Training MSE (X2 = 0)	2.04E +30	1	Geothermic
Training MSE (X6 = 0)	1.11E +30	2	Marine
Training MSE (X3 = 0)	1.05E +30	3	Hydraulic
Training MSE (X4 = 0)	7.88E +29	4	Solar Photovoltaic
Training MSE (X7 = 0)	6.37E +29	5	Wind
Training MSE (X5 = 0)	1.34E +29	6	Solar Thermal
Training MSE (X1 = 0)	7.77E +28	7	Biomass

Source: Authors Estimations (2013).

This effect, while being significant for all the sources studied, displays certain superiority to the effect in other results found. Thus, this sensitivity permits renewable source classification according to that source's weak carbon intensity. In that, the source's elimination leads to a sharp increase in the training MSE is inevitably the weakest emitter of carbon and vice versa. Indeed, according to the equation (1), a sharp increase in the training MSE necessarily results from an increase in the simulated MLP's output (since the observed output or "Target" has a fixed value). So, the deleted EnR source which caused the sharpest increase of carbonic intensity is without fail the weakest emitter of carbon. Hence, it will be attributed the first order of sensitivity. In contrast, deleting the biggest carbon emitter source engenders the smallest variation of the training MSE. So, to it will be attributed the last sensitivity order (Table 3).

In this frame, promoting the energy which has the lower carbon intensity will alleviate CO_2 emissions. Thereby, the sensitivity analysis proved extremely useful for classifying the seven renewable energy sources, according to an increasing order of carbon intensity.

In this classification, the study proceeds from the source having the weakest carbon intensity (Sensitivity order n° 1) to the strongest emitter one (Sensitivity order n° 7). According to these sensitivity orders, renewable energy sources are ranked as follows:

Geothermic, marine, hydroelectric, solar photovoltaic, wind, solar thermal, and finally biomass (Table 3)

In reality, renewable energy sources are clean energies in terms that they emit less greenhouse gas than traditional fossil fuels. However, it is a fallacy that they don't produce any pollution or emissions. Even renewable energy has certain carbon emissions, (renewable sources have some environmental disadvantages (Table 4)). But, these remain comparatively minimal compared with the emissions of unmitigated fossil fuels.

Table 4: Environmental disadvantages of renewable energy

Source of Energy	**Environnemental disadvantages**
Geothermal	The intensive exploitation of a geothermal field leads to the fall of the ground temperature. Moreover, a geothermic field is not perpetual and it will be gradually exhausted by exploitation[5].
Marine	There is of strong variability and a difficulty in the forecast of the levels of production. Marine energy is restricted to coastal zone (Edenhoferet al., 2011).
Hydraulic	Among its disadvantages, there is the threat of dams for certain botanical species and for the biodiversity. There are often risks of dam's breaking which can entail big material and human losses[8].
Solar Photovoltaic	The quantity of produced energy is strongly impacted by weather conditions and geographical locale[8].
Wind	It depends on the frequency and strength of the wind. Furthermore, wind turbines are unsightly and can spoil the landscape[8].
Solar Thermal	The cost of the investment is too high while its return is at long-term (approximately 10 years). However, the life expectancy of panels does not exceed 20/25 years[8].
Biomass	Its overexploitation can intensify the deforestation risks (wood-energy), grounds erosions, soil and waters pollutions (in case of intensive Biofuels production)[8]. Furthermore, collection, transport, and raw materials treatment make biomass exploitation the biggest CO2 emitter[6].

Source: Authors' Survey (2013)

As has been proven within the original research work conducted in 2002 by Yates-Smith, Aalders and Lillandt within the Financial Markets of The City of London.

Generally, the first weakness of any renewable source remains its consequent initial investment.

Worse still, the project's effectiveness is often fluctuating and is widely affected by the locale, season, and even the weather conditions. Nevertheless, it will be difficult to take a decision on a complex subject such as the choice of the weakest CO_2 emitter renewable source. In spite of their weakest carbon emissions, the investment in one or other of them depends on several factors: geographical, financial, political and technical. To optimize this choice, serious and hollow studies that make conciliation between benefits and disadvantages must be carefully worn. Indeed, this subject is very important and requires follow-up through a multidisciplinary and multidimensional study (ecological, economic, financial, political and technical).

[5] http://www.energies-renouvelables.fr/avantage_inconvenient_energies_renouvelables.php
[6] http://www.planete-energies.com/fr/les-sources-d-energie/la-biomasse-91.html

6. Conclusion

Several economic studies have highlighted the utility of renewable energy in the fight against global warming. This viewpoint is theoretically justified by sustainable development and ecological economics, as well by the admission of the environment as a global public good. In fact, climate change is a big challenge for countries development. So, without effective solutions (as renewable energy promotion), the consequences will be catastrophic.

For testing the weak carbon intensity of renewable energy we analyze the sensitivity, by a MLP neural network, of seven renewable sources. The results of the sensitivity analysis consolidate the strong link between each of renewable sources (measured by its supply index) and carbon emissions reduction. This analysis allows us to classify these sources according to their weakest carbon intensity. So, the geothermal energy is the weakest source of carbon emission. Indeed, its deleting entailed the biggest increase of the carbon intensity estimation error. In fact, its relative variation of the training MSE is about 2.04E+30. Nevertheless, it has certain disadvantages such as its scarce geographical availability as well as its serious consequences on the under-terrain temperature if it is over-exploited.

Biomass is classified as the biggest carbon emitter renewable energy. The deleting of this source leads to the lowest increase of the training MSE among all the studied renewable sources. The relative variation of its training MSE is around 7.77E+28. In effect, its exploitation requires the transport and raw materials treatment, which are already activities of high CO_2 emitting. In its turn, this source if over-exploited, will have big threats on biodiversity, forests and grounds.

However, a country's commitment in one or other of renewable energy sources is pre-conditioned by multiple criteria such as: availability, technical feasibility, investment costs, financial profitability, and environmental repercussions. As a consequence, it would be interesting to combine the exploitation of several renewable sources. This combination could be useful for moderating their carbon emissions as well as their environmental disadvantages. In that, it is interesting to compensate between renewable sources that are relatively less CO_2 emitter and those having small environmental disadvantages. Indeed, the diversity of renewable sources may be useful for alleviating the environmental threats resulting from the overuse of a single source.

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