EDP Business Project

European, Chinese and US Energy Systems

WORK PROJECT REPORT

The US energy system:

Current energy policy implications on the long run energy outlook

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Masters in Management #1076

Spring 2014

Nova School of Business and Economics

May 23rd 2014

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In this individual report I will cover 3 main topics. Firstly, I will start by giving a brief description of the context of EDP and the Business Project (BP). Then, I will elaborate on the US energy market and try to explore some parts that were not properly addressed in the BP. Finally, I will reflect on what I was able to take out of this project.

1. Context

1.1. Company & Market Overview

EDP is the second biggest group and the major player in the electricity and gas market in Portugal. Besides Portugal (42% of EBIDA), EDP currently distributes energy in other 12 countries being the most important ones Spain (19% of EBITDA) and Brazil (18% of EBITDA)[1]. It is important to notice the acquisition of Horizon Wind Energy that allowed the group to become the 4th largest wind operator worldwide. On top of that, the acquisition of 21.35% equity stake in EDP by China Three Gorges might open up market opportunities in new territories. Taking into consideration the revenue generation breakdown, we can see the importance of renewable energy in the total structure of the company - wind (24%) and hydro (39%) represent more than half of the earnings. The energy sector has suffered from exogenous influences ever the recent years. That is to say the macroeconomic condition that lead to a decrease in energy demand, but also the fiscal burden derived from a raise in energy related taxes.

1.2. The Business Project Challenge

On this BP the students were expected to analyze 3 energy markets: European Union (EU), the Chinese and the United States (US) market. After the analysis was made, we had to formulate different scenarios for each region based on future trends. Once the scenarios were chosen, we have selected the proper variables in EDP's 2050 simulator. The results gave us a panorama of different scenarios for 2050, according to the values chosen in energy demand and supply. Finally, we had to compare the results we had with the projections other agencies were making and draw conclusions on the findings.

1.3. Summary of Conclusions

In order to better understand how the energy outlook would be like in 2050 in the analyzed regions, we decided to base our scenarios according to a policy approach. We have found out that the 3 main factors that influence policies are (1) GHG emissions,

[1] EDP's Annual Report

(2) economic stability and (3) energy efficiency. Climate change is extremely relevant and GHG emissions are one of the priorities for governments all over the world. However, it is also important to keep/improve the economic condition. Therefore, we have to be extremely cautious with measures that would have a short-term negative effect on the economy. Lastly, and as we have seen in recent examples (e.g. Middle East or Crimea), political instability in oil or gas exporting regions will affect prices and supply.

Through the simulator, we were able to adjust the variables (please see Exhibit 1 for a list of the variables) to match our predicted scenarios according to energy intensity, electrification of the society, energy mix supplied and carbon capture and sequestration (CCS). We took the prices, GDP and population levels as constant for purposes of simplification. Consequently, there are number of conclusions that we were able to reach. Energy intensity is a key variable since it is almost impossible to achieve reduction of emissions without a decrease in energy demand. GHG Emissions will remain high as long as the percentage of dirty fossil fuels in the energy mix does not decrease. Accordingly, fuel substitution (e.g. through electrification) is also exceptionally important if we want to achieve the GHG emission goals. Despite that, policies regarding energy demand alone will not solve the world energy problems. As a result, a gradual change into a cleaner energy mix is paramount to achieve the necessary reduction in emissions. The simulator was also able to prove that the most cost efficient scenarios in the long run were those who had an investment in sustainable policies - energy efficiency, reduction in energy intensity, electrification and cleaner mixes. However, we were also able to see that the required changes will come at a significant cost for all the stakeholders. Not only a higher initial investment in renewable energy or electrification is required, but also a change in policy makers who play a major role in establishing some of the energy policies (through regulation or incentives). It is also clear that the focus should be on the long run rather than the shorter economical/political cycles we are currently facing.

2. US Energy System - Further Development of a Topic

I believe the US energy system to be the one with the most potential to pursue a deeper analysis. Regarding available information, one can more easily find it on the US than on the EU since aggregated information for the 28 countries is sometimes hard to find. While data from the Chinese authorities can somehow be unreliable. It is interesting to study the US energy market since there are a number of factors changing its dynamics. Namely an increase in customer, regulatory and political interest in demand side management technologies; government programs to incentivize selected technologies; declining price of natural gas; or a slow economic growth that leads to a cut in energy demand[2]. At the same time, we have technologies such as solar photovoltaics (PV), battery storage, geothermal energy systems, on and off-shore wind, and electric vehicles (EV) that have the potential to disruptively change the industry. As the cost curves on some of these technologies improve, they become serious threats to dirtier fossil fuels which have a negative impact on environment. Therefore, the policies adopted by the US government that encourage these alternative sources through subsidy programs such as tax incentives or renewable portfolio standards will be extremely important for the future of the US energy market.

2.1. What was the original approach to this topic?

The original approach to the US energy system was to make an assessment of the current situation, develop 4 scenarios for the future and gather the main conclusions from the market. On a global energy outlook comparison, we can see that in 2012 the US accounts for 18% of the world primary energy consumption[3] and has one of the highest energy consumptions per capita in the world[4]- 7.04 ktoe/capita against the 1.78 ktoe/capita of the world average (please see exhibit 2 and 3). Despite that, primary energy consumption has been decreasing, mainly due to the economic slowdown (see exhibit 4). Additionally, we can observe the current US energy mix where fossil fuels (like coal, oil and gas) still represent more than two thirds of primary energy consumption (exhibit 5). It is also important to be aware of the low commitment of the US government towards GHG reductions since the US remains one of the few countries that has not accepted the Kyoto protocol. Therefore, environmental concerns are not as high in the priority list as the reduction of oil imports - where the country is still highly

[2] Kind P., Disruptive Challenges
[3] BP Statistical Review of World Energy 2013
[4] idem

dependent on. As for future prospects, the exploration of shale gas can be a game changer in the energy outlook.

After the exploratory phase we used the EDP 2050 simulator to define 4 scenarios for the US energy system (1) Minimized Emissions, (2) Economic Stability (3) Energy Security and (4) Sustainable Green with all the aforementioned general conclusions. To support the conclusions, we had to analyze the US results and we were able to mainly focus on energy substitution policies and combined policy effects. Moreover, we performed a brief comparison with EIA International Outlook results on energy consumption and CO2 emissions.

2.2. What are the main limitations of the approach used?

The problem with the approach we used was that we firstly looked into 4 different scenarios 3 regions at a time. Then, we analyzed the main takeaways in each categories (demand, supply, GHG emissions) one region at a time. Finally, we compared our scenarios with the IEA scenarios. Consequently, we used specific scenarios to illustrate a general idea but since we have 12 possible scenarios we cannot present them all. Therefore, it is hard to follow the specific outcomes for the US energy outlook and I believe that a more detailed analysis could have been performed.

On top of that, there are a number of limitations of the simulator that we had no means of addressing. I do consider that even though we refer shale gas several times, the consequences of its use are not totally incorporated into the final report. In particular when it comes to sensitivity analysis on gas prices on the total cost of energy. This is especially relevant in the US where shale gas can play an important role in fuel substitution. Another major limitation is the cost function of solar photovoltaic (PV) energy. The cost function in the simulator does not fully incorporate economies of scale and does not assume an exponential reduction in costs. This is particularly important in the US where government subsidies are driving costs of solar energy down and solar PV is already positioning itself as a viable competitor of traditional fossil fuels[5].

Another limitation of the simulator that greatly affects the outcome of our results is the inability to calculate indirect costs for the economy. This is particular important for economic stability given that by imposing energy reduction policies, the government

[5] Kind P., Disruptive Challenges

requires individuals or companies to incur in costs that are not included in the simulator (see exhibit 5 for more on indirect costs).

Finally, I must explain that the cost of energy is measured by billion dollars per year or per dollar/MWh every five years. Subsequently, even if we can compare the total cost of energy for 2050 and see what is the scenario that has the lowest cost in that year, we cannot calculate the present value of all the costs from the present day until 2050 and see which is the scenario that minimizes the overall costs throughout the years (exhibit 6 explains better how the costs of energy are calculated).

2.3. What would you have done differently when developing this topic?

We could have pursued a different strategy when taking into account the US market. I believe it is important to take a deeper look into energy demand side policy effects in energy intensity and electrification. Additionally, we could have done a sensitivity analysis for the price of oil and natural gas to demonstrate how sound the business as usual scenario is to a fluctuation in prices. Besides that, we could have perceived the difference it makes in the US market to develop solar PV since there is a sharp decline in the price of PV panels from $3.80/watt in 2008 to $0.86/watt in mid-2012[6]. Finally, we must better incorporate shale gas in our analysis and all its future implications.

In this section of this report, I will try to elaborate on the conclusions we were able to take from the usage of the simulator and relate them with the US energy market. In Exhibit 8 we can clearly distinguish the effect of policy change in the primary energy demand. This can be explained by the demand side policies like energy intensity (Exhibit 9) and electrification of the society. Without lower levels of energy intensity it becomes nearly impossible to reduce total energy demand in the US. Within energy intensity, the key variable of our study is industrial energy intensity. Taking as the base scenario Economic Stability, I have developed a sensitivity analysis showing that the US energy market is extremely sensitive to a reduction in industrial energy intensity. By going from 25 toe/M$ to 15 toe/M$ the total primary energy demand will go down from 2784Mtoe to 2376Mtoe and the energy per capita will decrease from 6959toe/capita to 5948toe/capita. What we can conclude from this is that a change in this single variable can affect the total energy demand by 15% (please see exhibit 10 and 11 for 2010 - 2050 comparison), which is actually very significant. However, it is not only the energy

[6] Kind P., Disruptive Challenges

intensity that affects the demand. As shown in Exhibit 12 and 13 the Energy Security and Sustainable Green Scenarios have the same efficiency related policies, yet they have very different demand functions. The effectiveness of electrification and fuel switching can be demonstrated since the scenario with the highest levels in those categories (Sustainable Green) displays a 15% reduction in primary energy demand.

Looking into combined policy effects on the supply side, our report notices that policies to substitute dirty fossil fuels for cleaner ones greatly affect GHG emission. More specifically to the US case, even the substitution of oil and coal for natural gas can have a deep impact on GHG emissions (exhibit 14, 15 and 16). The main reason for this to happen in the US is that the combustion process in vehicles is inefficient compared to larger-scale power plants and the US has one of the highest road transports penetration. Electrification leads to higher efficiencies even when oil is replaced by a more CO2-intensive fuel like coal.

In our report we have analyzed how the Economic Stability scenario makes countries exposed to fluctuations in energy prices. This remains true for the US scenario when it comes to oil (Exhibit 17) and its predicted raise in price. I have develop another sensitivity analysis where I change the prices on oil and gas, with all else constant (ceteris paribus). I could observe that an increase in oil prices to 200$/bbl (compared to the baseline of 130$/bbl) will lead to a 17% increase in total energy costs in 2050. However, due to the extraction of shale gas, it is predicted that prices of natural gas will decrease[7]. Globally, 32 percent of total estimated natural gas resources are in shale formations, and 10 percent of total estimated oil resources are in shale or tight formations[8]. Consequently, we can argue that an increase in gas supply will lower its prices[9]. Therefore, a decline in natural gas prices to 5$/Mbu (-55%) will reduce the total energy costs by 16% - comparing with the baseline levels used in the simulations (Exhibit 18). We must take into account that this scenario is extremely permeable to changes in prices since fossil fuels still represent the lion share of the energy mix. Despite that, we can still reach general conclusions with this analysis. As long as the US is dependent on imported oil, the risk of a change in price of the commodity will greatly affect the total cost of energy.

[7] Kind P., Disruptive Challenges
[8] IEA Report
[9] Kind P., Disruptive Challenges

In my opinion, EDP's simulator provides a valuable service in understanding the fundamentals of the energy industry. However, if we compare its results with the EIA long term scenarios we might come to the conclusion that they are over optimistic of our future (Exhibit 19 and 20). This happens specially when it comes to CO2 emissions since energy consumption levels seem to go in line with EIA predictions. It should also be taken into account that the Economic Stability and Minimized Emissions scenarios were purposely extreme so as to better illustrate our ideas and what was asked of us.

Now that I have been through the proposed changes I would like to give a new approach on the US energy market. Leveraging the deep knowledge I have on the simulator I wanted to show that by addressing the key variables in the US market, good results could be achieved with extremely low effort. What I was able to realize during the conclusion of the business project was that even though we are 35 years away from 2050, it will be tremendously difficult to experience a 30% reduction in fossil fuels as a total of primary energy demand in the US. We currently see willingness from the EU to change its energy policies into a greener mix or we see China as the number one investor in renewable energy. However, that political will to change energy policies in the US has not been as straightforward as in the other regions. The main problems are the high initial investment costs required with renewable energy, electrification and reduction of energy intensity. Additionally, there are also a series of indirect costs to the economy that are not being taken into account (like domestic or company investments). Consequently, and even though the difficulty levels are not that high for the Sustainable Green scenario, I believe it will be much harder to achieve those goals. I am not saying that some states will not be able to reach the goals (since we have states deeply committed with energy sustainability) but I am addressing the country as a whole. Since it has been so hard to impose change, the US needs ambitious but realistic goals for the future. Therefore, I think that they could focus on 5 key variables in energy demand/supply, the ones that can make a significant difference in the energy outlook. I took the business as usual scenario (Economic Stability) as a baseline and then I tried to work from there. On the demand side I have decided to focus on reducing industrial energy intensity (from 25toe/M$ to 15toe/M$), increasing electrification of road light transports (from 25% to 50% of electrification) and fuel switching of road light transports (from 10% to 50% roll-out of gas vehicles). On the supply side I chose to invest on gas power (1000GW) and solar PV (800GW). As described during the course of this project, industrial energy intensity is one of the variables with the highest impact on results - lowering energy demand which in turn will decrease the cost of energy and GHG emissions. The higher electrification of road light transports serves the purpose of decreasing the oil dependence and reducing one of the dirtiest fossil fuels in the mix. It is also important to switch fuel from oil to biofuel and gas for the same reason we increased electrification, but also because the US can take advantage of its shale gas reserves to supply the energy required in the transportation sector. Reserves that are fully being exploited since the gas power variable is at its maximum. Lastly, solar PV comes as the natural choice for a clean energy that can directly compete with fossil fuels since its subsidies have made it affordable.

As a result from this new scenario we can observe the energy per capita decreasing from 6959toe/capita to 5462toe/capita (Exhibit 21). I experienced this result due to efficiency gains on the demand side. It is of the utmost importance to notice that the renewable share in power generation goes from 27% to 42% only with the increase in solar PV (Exhibit 22). However, the most shocking result emerges in the GHG emissions since the US is able to go from 101% to 63% of GHG Emissions vs. 2005 levels (Exhibit 23). This is an incredible result particularly when bearing in mind that the difficulty level only went up from 10% to 23%. Last but not least, we can observe the impact these measures will have on the cost of energy. In 2050, the Economic Stability scenario would cost 1493B$. While with this new scenario the total cost of energy would be only of 1230B$ - allowing savings of around 18% in 2050 alone (Exhibit 24).

It is now clear for me the direction the world needs to take so as to reach the desired decrease in emissions. What policy makers need to understand is that that these changes in the energy outlook can not only decrease GHG emissions, but also be the most viable long term solution when it comes to the overall cost of energy for the society. At the same time, with an investment in national energy sources the US would also decrease its dependency on imports. The tools are at our disposal, it is now time for the policy makers to promote these changes and for the society to embrace them. Only then will we be able to leave a more sustainable future for the next generations.

3. Reflection on Learning

3.1 Previous knowledge learned from your Masters program

To begin with, I must say that the business project I did relates with the energy market. Consequently, and since I have not made any energy related course during my Masters there was no previous technical knowledge when it comes to energy. However, I did some courses over this two years that helped me in assessing the best ways to tackle problems and structure my work. Analysis of Industry and Competition gave me guidelines on how to better evaluate an industry and its key variables. Having studied Geopolitics and the Global Economy made it easier for me to understand international relations - for instance why Kyoto protocol measures are being so hard to ratify. The Consulting course helped me in finding the optimal way to structure a presentation especially in terms of flow in the story, making my message clearly understandable for the audience and the reasoning behind the structure. Additionally, Project Management was important to help me manage my time and its various phases while Negotiation allowed me to better manage the relationship between all the parties involved (team members, academic and business advisors).

3.2. New knowledge

As previously said, my knowledge on the energy market was indeed reduced. Therefore, and so as to be able to discuss the business project with the Business Advisor with an engineering background, I had to quickly gain knowledge on energy related matters (e.g. GHG emissions, energy demand, energy supply). On top of that, the simulator and its 32 variables also forced me to better understand what I was dealing with. Consequently, I had to research industrial energy intensity levels or future prospects for hydroelectric capacity in all the 3 regions, for instance. This allowed me to gain knowledge on the energy outlook as a whole but also on a regional level since I had to be sure on which variable to choose for each scenario. Working countless hours with the simulator was also important for me to understand which key variables have a bigger impact on the cost, emission and difficulty of the scenarios. Without that work, I would not be able to derive conclusions or accurately pinpoint the specific limitations/areas where the simulator can be improved. To conclude this section, the time I was in charge of the project allowed me to validate the initial findings from a Belbin questionnaire saying that I feel more comfortable in a leading position.

3.3. Personal experience

On a personal experience note, it was extremely important for me to have a project with one of our local Corporate Partners. I was able to grasp the fundamentals of an interesting and dynamic industry in which I could picture myself working with in the future. This project was also helpful for me to understand my key strengths and weaknesses. I was able to confirm that I am a hard-working person that is also able to work under pressure, ability you necessarily have to develop if studying at Nova SBE. Additionally, facing a multicultural team with different working methods/schedules allowed me to enhance my interpersonal and project management skills (communication and ability to work as a team). On top of that, only by being a fast learner would I be able to work on something unrelated with my previous studies. Consequently, working with the energy market was even more challenging because I was not at ease with the subjects. Finally, I consider that without the extensive work performed on the simulator, the project would not have reached its end. I had to be extremely organized and methodical so as to process the tremendous amount of data we had and be able to deliver the project on time. Regarding skills to improve, there is still a lot to be done in terms of project management and communication - within team but also with advisors. I sometimes felt that the meeting were not as productive as they could have been. The way the project was scheduled and the way we worked on it left a lot to be done in its final stage. Consequently, I think that the content was there but we could have had a better layout. I will make an effort to improve these areas but I also believe that this is something that comes with experience.

3.4. Benefit of hindsight

The biggest added value for me was the knowledge on the energy market I was able to retain from this project. Of course that the development of interpersonal skills or working with a diverse team was also a plus, but if I had to choose I would select the new knowledge acquired. However, I would consider having a more detailed breakdown of the structure, with smaller and more measurable tasks assigned to each member of the team. Finally, with the experience I now have on the simulator I believe it could have been helpful to start working on it sooner so as to provide better recommendations and improvements while we still had time to incorporate them.

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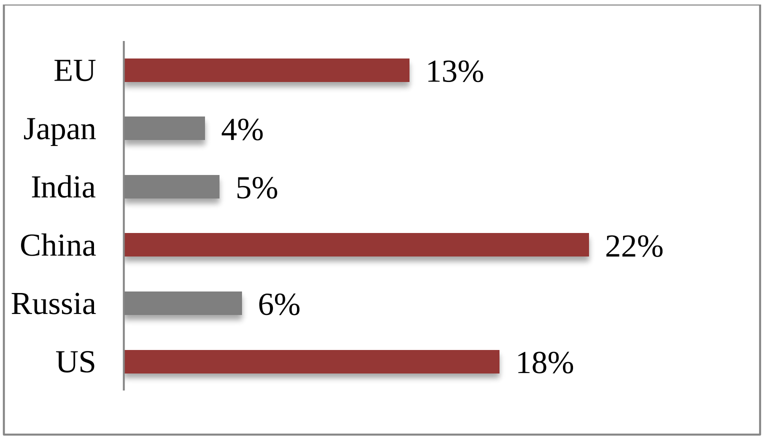
5. Appendix

Exhibit 1 - List of Variables in the Simulator

Question categories	Area	Question	Units	Answer Level 1	Answer Level 2	Answer Level 3	Answer Level 4	Question description
Prices	Fuels	Oil price	$'10/bbl	50	130	200	n.d.	Oil price by 2050[5]
	Fuels	Coal price	$'10/ton	50	110	200	n.d.	Coal price by 2050[6]
	Fuels	Natural gas price	$'10/Mbtu	5	11	20	n.d.	Natural gas prices by 2050[7]
	Other	CO_2 price	€'10/ton	20	100	200	n.d.	CO_2 price by 2050[8]
Energy demand	Residential	Residential non-power energy demand	%	2%	1%	0%	-1%	Residential current non-power energy consumption from 2010 to 2050 CAGR
	Residential	Residential energy efficiency in electricity	%	0%	25%	50%	100%	Degree of fulfillment of energy efficiency potential to reduce residential power demand by 2050
	Services	Services non-power energy demand	%	2%	1%	0%	-1%	Services current non-power energy consumption from 2010 to 2050 CAGR
	Services	Services energy efficiency in electricity	%	0%	25%	50%	100%	Degree of fulfillment of energy efficiency potential to reduce services power demand by 2050
	Industry	Industrial demand	%	2%	1%	0%	-1%	Industrial energy consumption from 2010 to 2050 CAGR
	Transport	Road transports demand	%	10%	5%	-5%	-10%	Road transportation energy consumption evolution by 2050 vs. 2010
	Residential	Electrification of residential energy demand	%	40%	60%	80%	100%	Percentage of residential energy demand electrification by 2050
	Services	Electrification of services energy demand	%	60%	70%	85%	100%	Percentage of services energy demand electrification by 2050
	Industry	Electrification of industrial energy demand	%	25%	30%	40%	50%	Percentage of industrial energy demand electrification by 2050
	Transport	Electrification of road light transports	%	10%	25%	50%	75%	Percentage of road electric transports by 2050
	Transport	Fuel switching of road transports	%	10%	25%	50%	75%	Percentage fuel switching from oil to gas/biofuel of road non-electric transports by 2050
	Transport	Electrification of non-road transports	%	10%	20%	30%	40%	Percentage of non-road electric transports by 2050
	Transport	Fuel switching of non-road transports	%	10%	25%	50%	75%	Percentage fuel switching from oil to gas/biofuel of non-road non-electric transports by 2050
Installed capacity and generation	Power	Hydroelectric generation	TWh	18	20	22	24	Gross hydro power generation (including pumping) by 2050: current 12 TWh and expected ~20 TWh by 2020 (average hydro year)
	Power	Nuclear power	MW	0	1.600	3.200	4.800	Nuclear capacity by 2050 (0, 1, 2 or 3 nuclear power plants): no current nor expected capacity by 2020
	Power	Onshore wind power	MW	5.500	10.000	14.000	18.000	Onshore wind capacity by 2050: current 4,400 MW and ~5,300 MW expected by 2020
	Power	Offshore wind power	MW	50	1.000	2.500	5.000	Offshore wind capacity by 2050: current 2 MW with no additional capacity expected by 2020
	Power	Biomass and MSW power	MW	350	1.000	2.000	3.000	Biomass and MSW capacity by 2050: current 290 MW and ~370 MW expected by 2020
	Power	Solar PV power	MW	250	2.500	5.000	10.000	Solar PV (large scale) capacity by 2050: current 130 MW and ~180 MW expected by 2020
	Power	Solar CSP power	MW	50	2.500	5.000	10.000	Solar CSP capacity by 2050: no current capacity but ~50 MW expected by 2020
	Power	Geothermal power	MW	50	500	1.000	2.000	Geothermal capacity by 2050: current 30 MW with no additional capacity expected by 2020
	Power	Ocean power	MW	50	1.000	2.000	4.000	Ocean capacity by 2050: no current capacity but ~6 MW expected by 2020
	Power	CHP power	MW	2.000	4.000	6.500	9.000	CHP capacity by 2050: current 1,800 MW and ~2,000 MW expected by 2020
	Power	Distributed generation power	MW	250	2.500	5.000	10.000	Distributed generation capacity by 2050 (Solar PV): current 60 MW and ~320 MW expected by 2020
	Power	Power imports	TWh	0	5	10	20	Power imports by 2050: historical values from last 5 years range 5 - 10 TWh
CO_2 Emissions	Power	Installed CCS capacity in the power sector	MW	0	2.800	4.000	5.200	CCS power capacity by 2050 (from 0 up to 5 power plants, starting operations from 2025)
	Industry	Industrial processes with CCS	%	0%	25%	50%	100%	Percentage of industrial processes with CCS by 2050 (starting operations from 2025)
	Geosequestration	Emissions' reduction due to geosequestration	$MtonCO_2$	0	1	2	3	CO_2 geosequestration by 2050 (reducing GHG emissions from 0 to 3 Mton/year, starting operations from 2025)

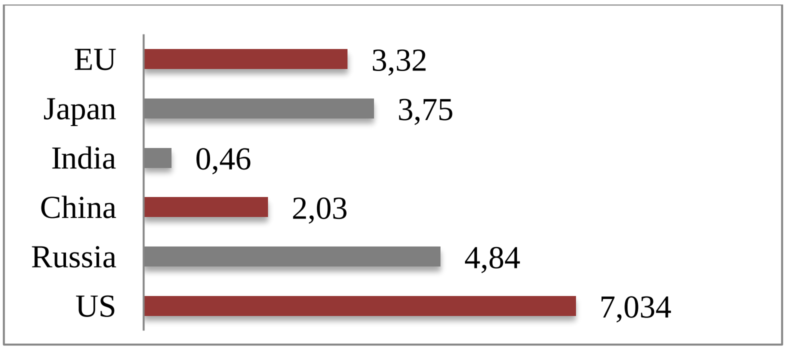
Source: EDP 2050's simulator

Exhibit 2 - Primary Energy Demand Consumption in 2012 (%)



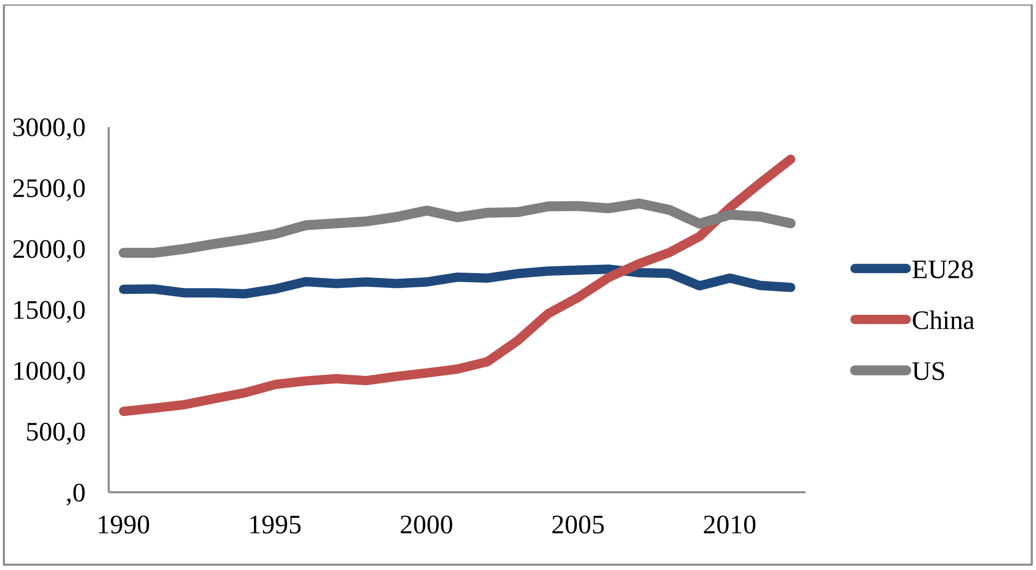
Source: BP Statistical Review of World Energy 2013

Exhibit 3 - Primary Energy Consumption in 2012 (toe/capita)



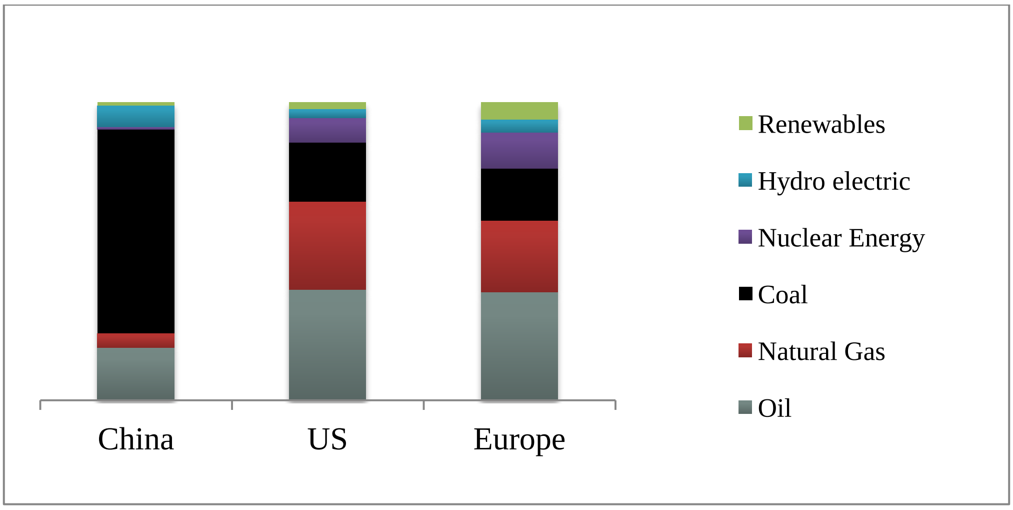
Source: BP Statistical Review of World Energy 2013

Exhibit 4 - Primary Energy Consumption 1990 - 2012 (Mtoe)



Source: BP Statistical Review of World Energy 2013

Exhibit 4 - Primary Energy Consumption by fuel type in 2012 (%)



Source: BP Statistical Review of World Energy 2013

Exhibit 5 - Simulator Costs (From EDP's User Guide)

The following items are not included in the total cost of energy:

• Domestic or company investments in energy efficiency measures

• Domestic or company investments in electrification, gasification or shift to biofuels

• Costs of power and natural gas transmission and distribution networks

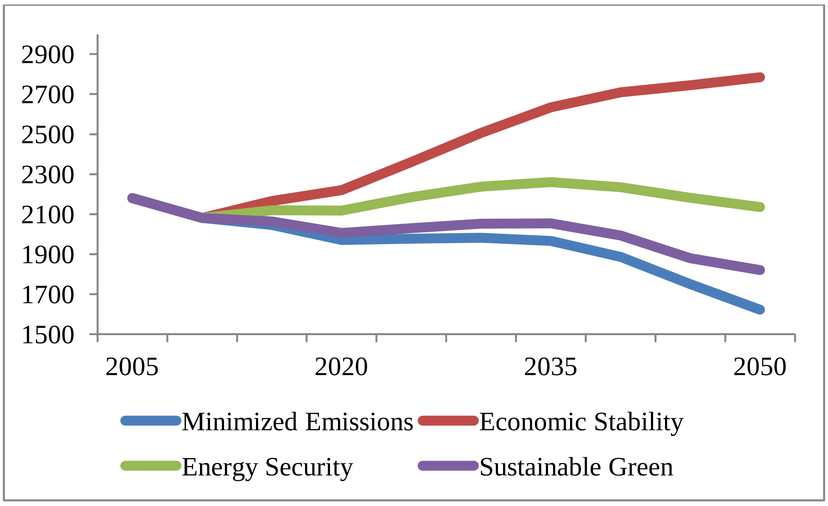
• Costs of refineries, transportation and distribution of petroleum products and biofuels

Exhibit 6 - Cost of Electricity (From EDP's User Guide)

The cost of electricity is computed by the product between the levelized costs of the various power technologies and the respective power generation. Levelized costs are computed based on the following key variables:

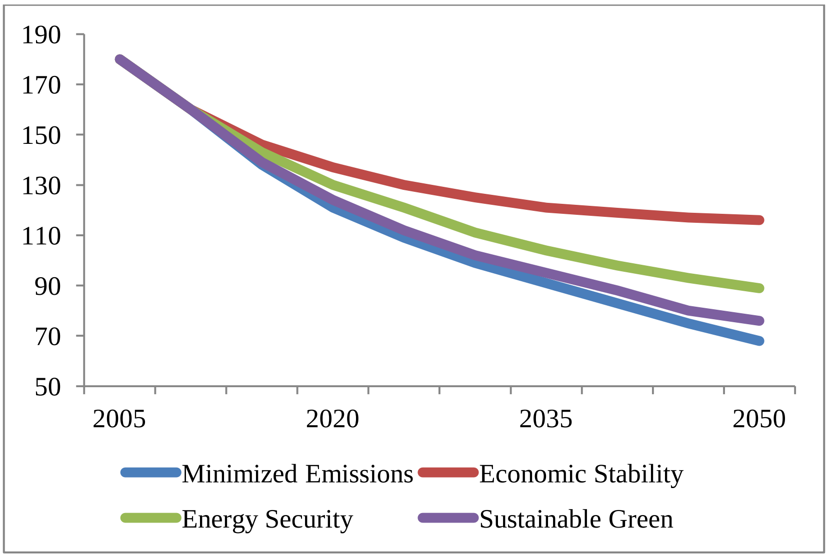
- **Economic life**: Asset lifetime
- **CAPEX25**: Investments costs
- **FOM26**: Fixed operation and maintenance costs
- **VOM27**: Variable operation and maintenance costs
- **Working regimes**: Equivalent working hours

Exhibit 8 - US Total Primary Energy Demand by Scenarios (Mtoe)



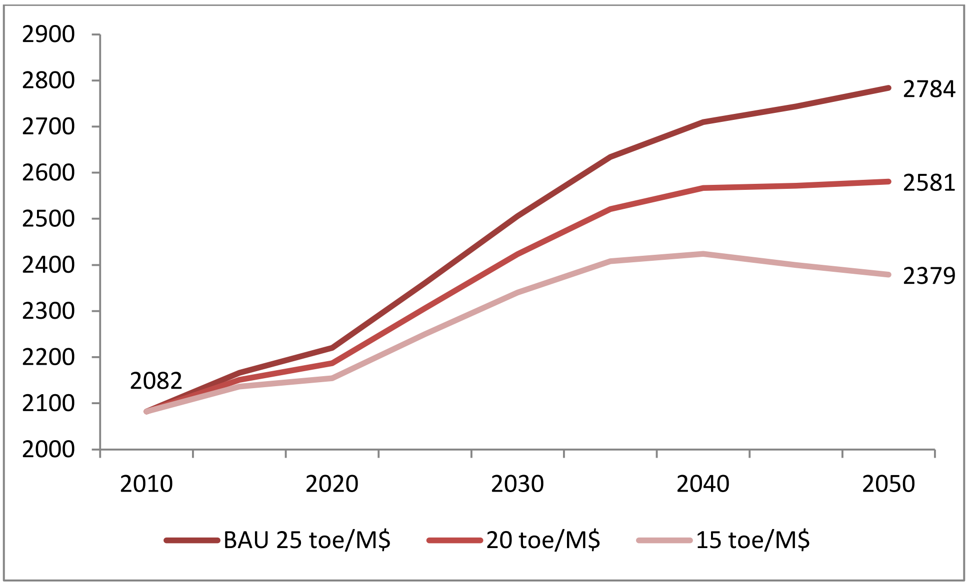
Source: EDP 2050's simulator

Exhibit 9 - US Energy Intensity by Scenario (toe/M$)



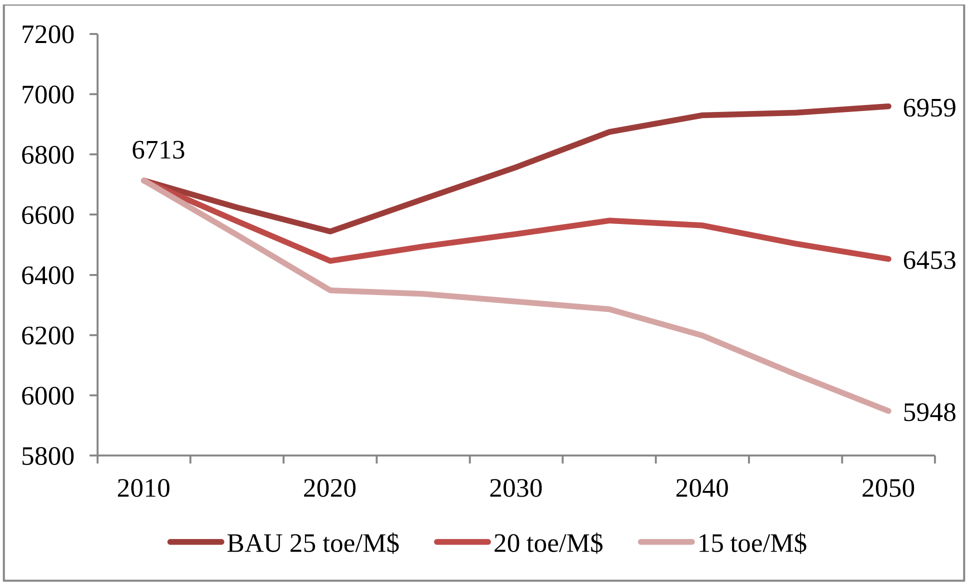
Source: EDP 2050's simulator

Exhibit 10 - Industrial Energy Intensity - Sensitivity Analysis for the Economic Stability Scenario - Total Primary Energy Demand (Mtoe)



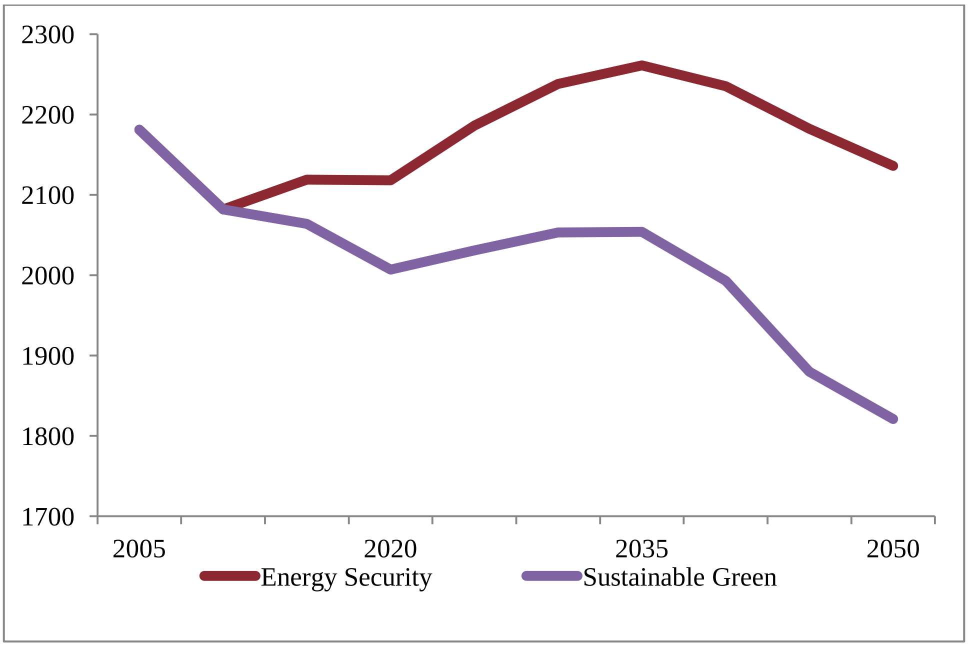
Source: EDP 2050's simulator

Exhibit 11 - Industrial Energy Intensity - Sensitivity Analysis for the Economic Stability Scenario - Energy per capita (toe/capita)



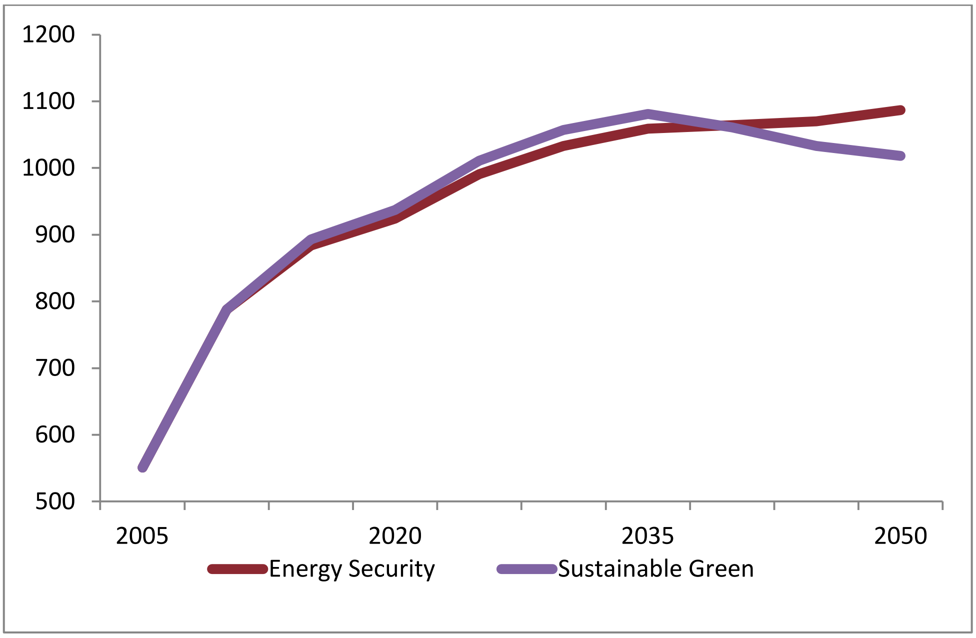
Source: EDP 2050's simulator

Exhibit 12 - US Total Primary Energy Demand for Energy Security and Sustainable Green (Mtoe)



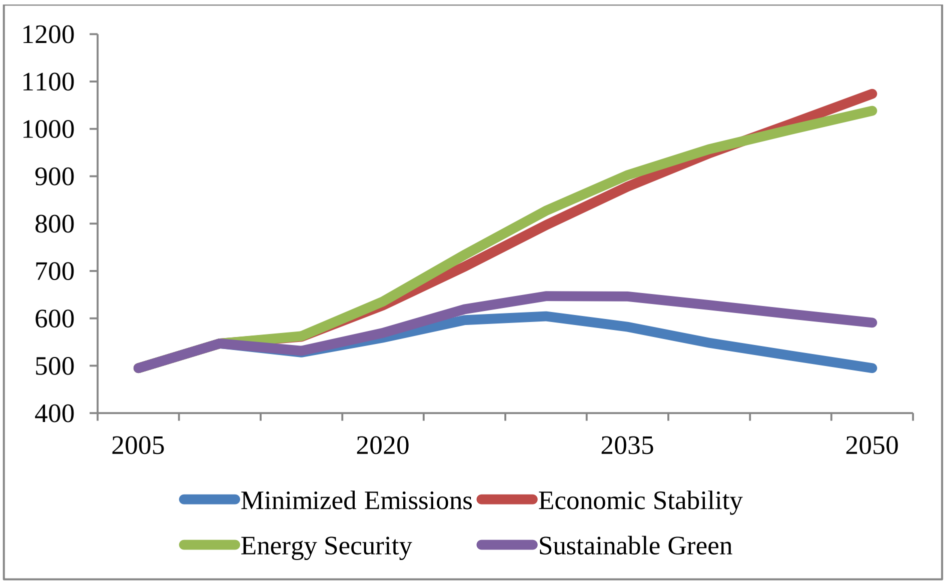
Source: EDP 2050's simulator

Exhibit 13 - US Energy Cost for Energy Security and Sustainable Green (B$/year)



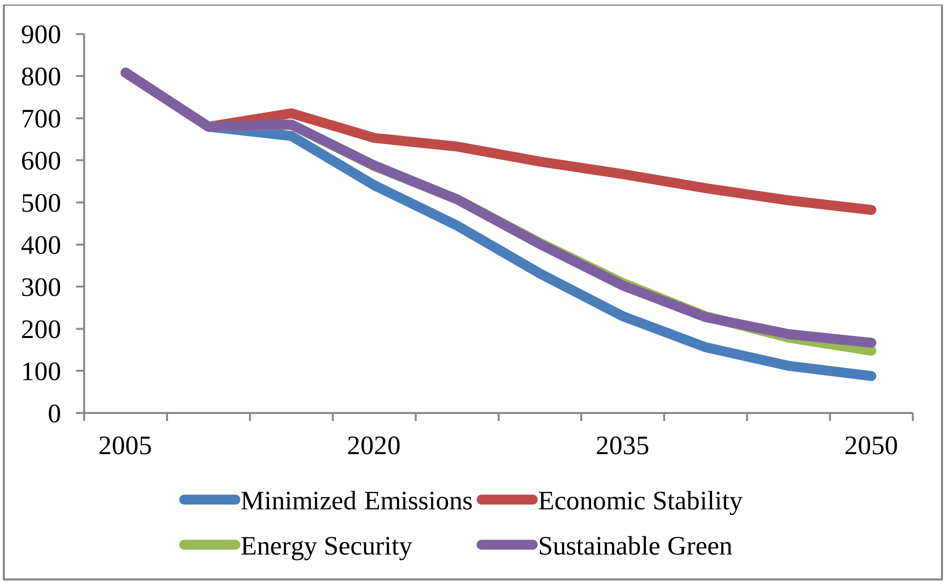
Source: EDP 2050's simulator

Exhibit 14 - Combined Policy Effects - US Natural Gas (Mtoe)



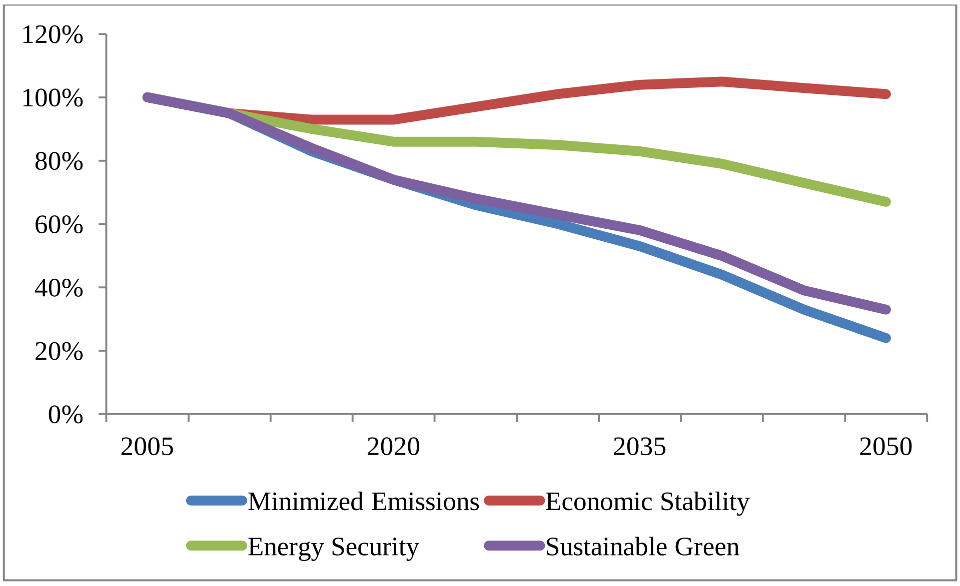
Source: EDP 2050's simulator

Exhibit 15 - Combined Policy Effects - US Oil (Mtoe)



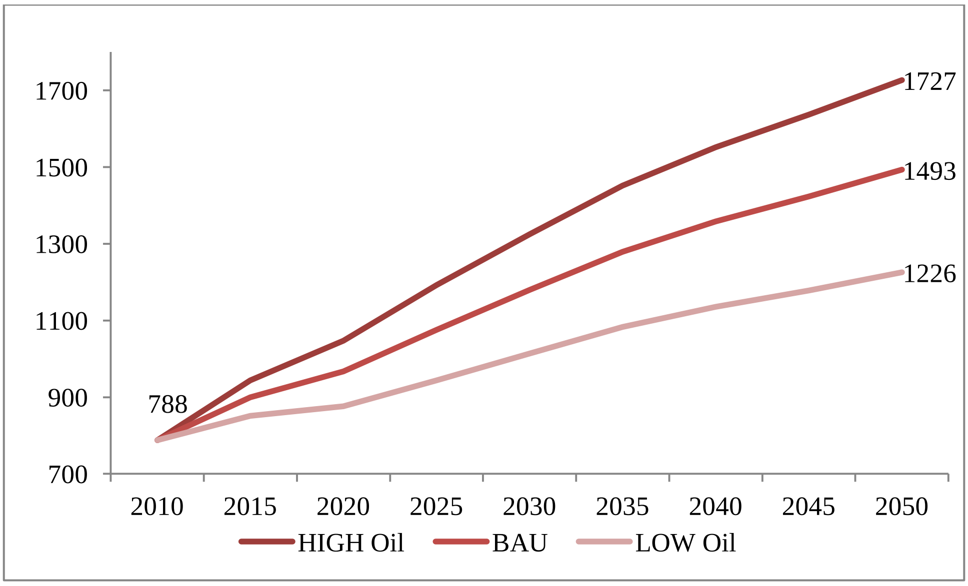
Source: EDP 2050's simulator

Exhibit 16 - Combined Policy Effects - US GHG Emissions vs. 2005 (%)



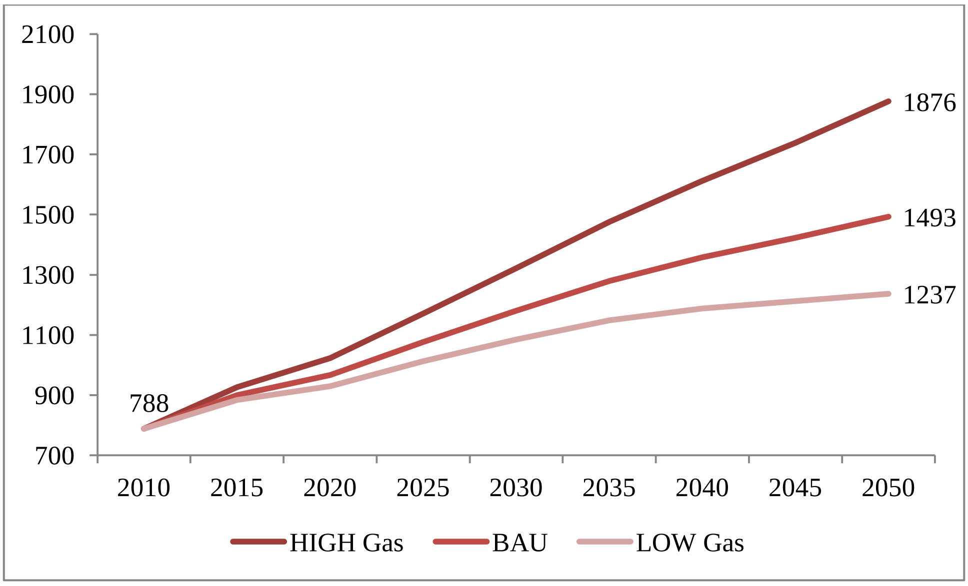
Source: EDP 2050's simulator

Exhibit 17 - Sensitivity analysis for oil - Cost of Energy (B$/year)



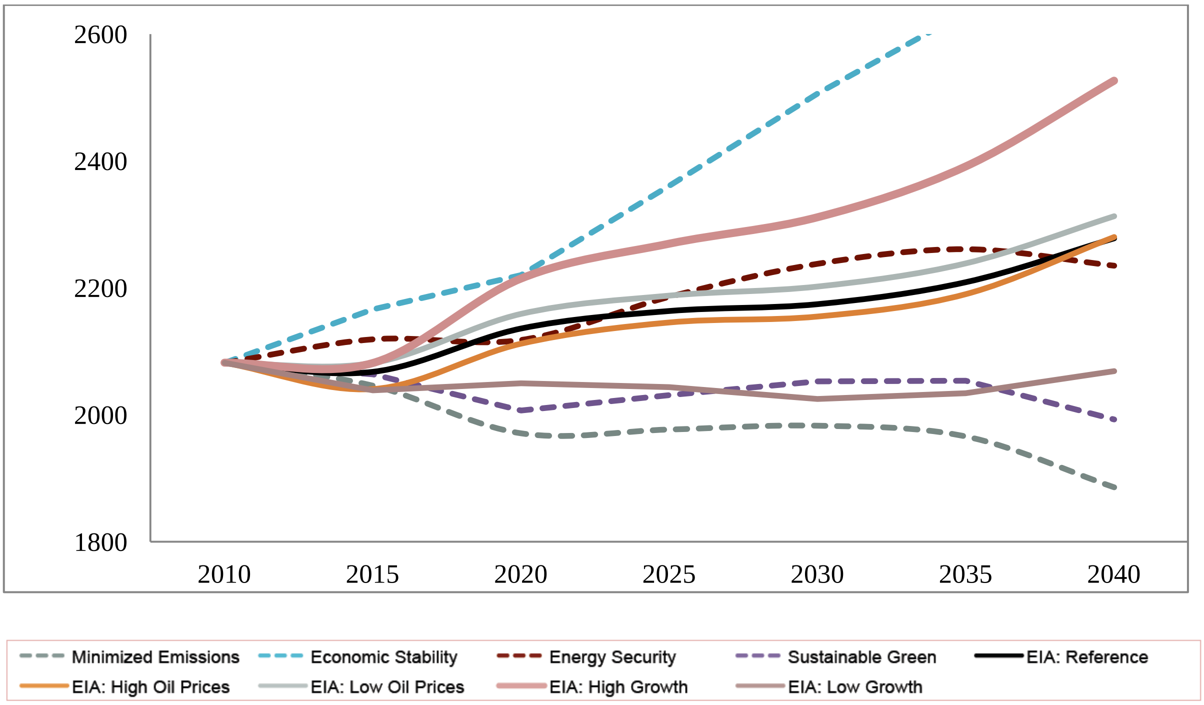
Source: EDP 2050's simulator

Exhibit 18 - Sensitivity analysis natural gas prices - Cost of Energy (B$/year)



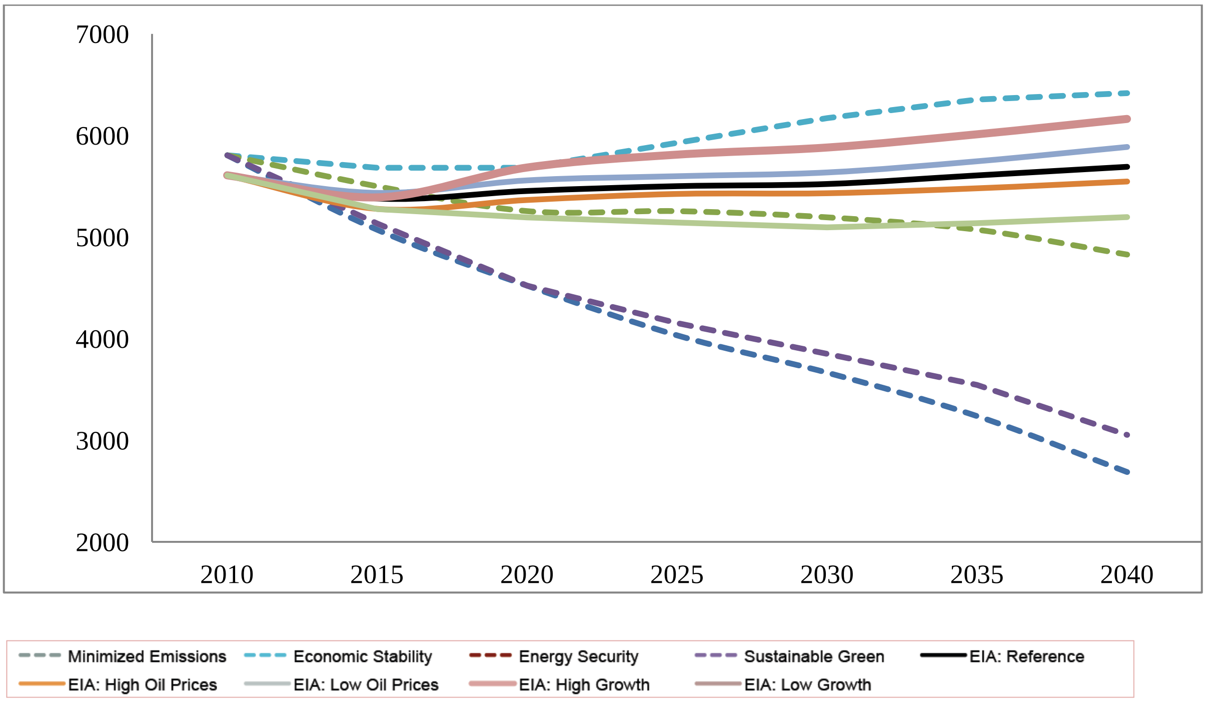
Source: EDP 2050's simulator

Exhibit 19 - Comparison with EIA International Energy Outlook regarding energy comsumption (Mtoe)



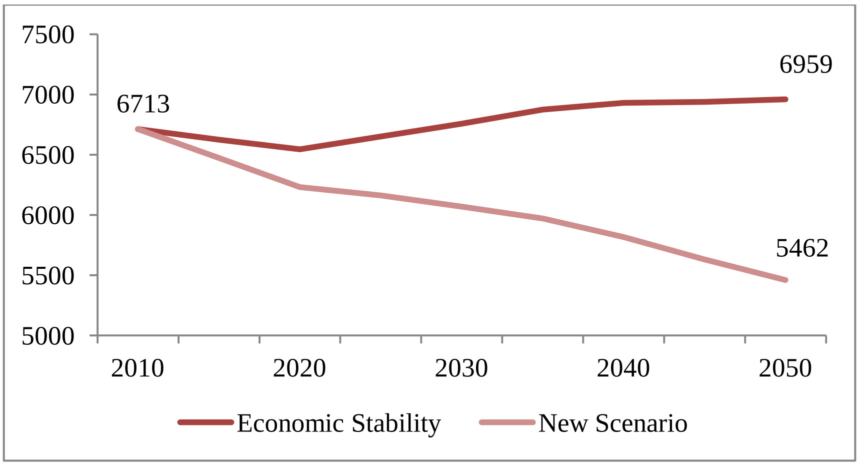
Source: EDP 2050's simulator and EIA International Energy Outlook

Exhibit 20 - Comparison with EIA International Energy Outlook regarding energy and CO2 Emissions (Mt)



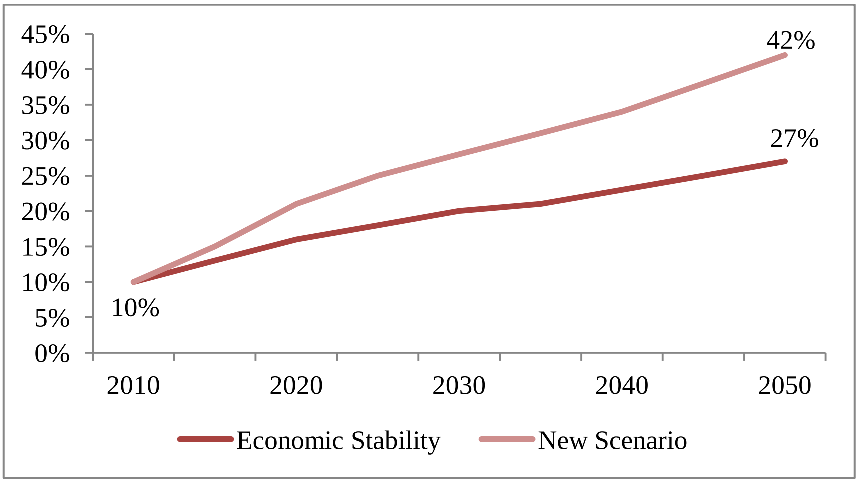
Source: EDP 2050's simulator and EIA International Energy Outlook

Exhibit 21 - New Scenario vs. Economic Stability - Energy per Capita (toe/kcapita)



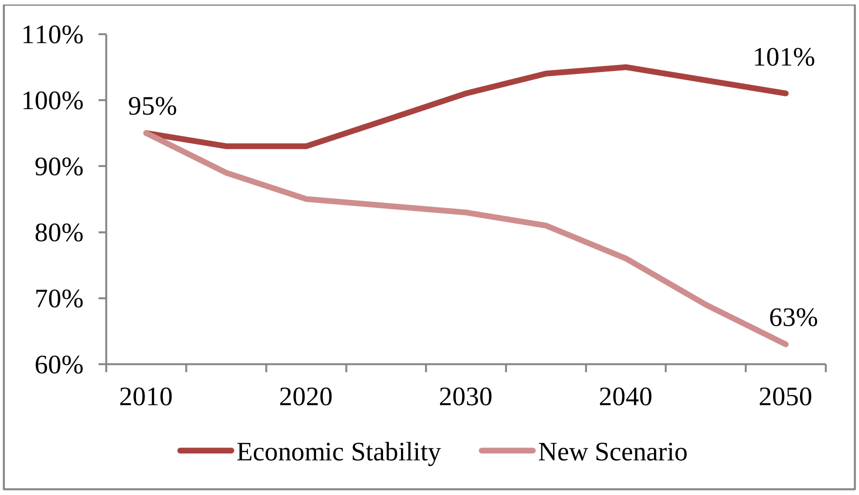
Source: EDP 2050's simulator

Exhibit 22 - New Scenario vs. Economic Stability - Renewables / Power Generation (%)



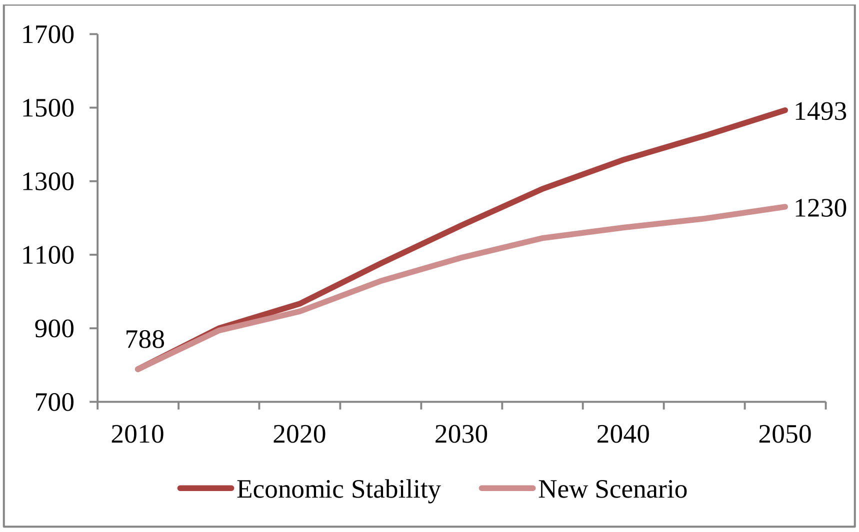
Source: EDP 2050's simulator

Exhibit 23 - New Scenario vs. Economic Stability - GHG Emissions vs. 2005 (%)



Source: EDP 2050's simulator

Exhibit 24 - New Scenario vs. Economic Stability - Cost of Energy (B$/year)



Source: EDP 2050's simulator

Exhibit 25 - List of Variables Selected for the Main Scenarios

US	Minimized Emissions	Unit	Minimized Emissions				Economic Stability				Energy Security				Sustainable Green			
Energy Demand	Population	Million	450	400	300	250	450	400	300	250	450	400	300	250	450	400	300	250
	GDP/Capita	k$/capita	110	90	60	40	110	90	60	40	110	90	60	40	110	90	60	40
	Residential energy intensity demand	toe/kcapita	850	700	550	450	850	700	550	450	850	700	550	450	850	700	550	450
	Services & agriculture energy intensity demand	toe/M$	17,45	15	12,5	10	17,45	15	12,5	10	17,45	15	12,5	10	17,45	15	12,5	10
	Industrial energy intensity demand	toe/M$	25	20	15	10	25	20	15	10	25	20	15	10	25	20	15	10
	Road transports penetration	Vehicles/cap	850	700	500	200	850	700	500	200	850	700	500	200	850	700	500	200
	Electrification of residential energy demand	%	45	55	65	75	45	55	65	75	45	55	65	75	45	55	65	75
	Electrification of services energy demand	%	55	65	75	90	55	65	75	90	55	65	75	90	55	65	75	90
	Electrification of industrial energy demand	%	30	40	50	60	30	40	50	60	30	40	50	60	30	40	50	60
	Electrification of road light transports	%	10	25	50	75	10	25	50	75	10	25	50	75	10	25	50	75
	Fuel switching of road transports	%	10	25	50	75	10	25	50	75	10	25	50	75	10	25	50	75
	Electrification of non-road transports	%	5	10	20	30	5	10	20	30	5	10	20	30	5	10	20	30
	Fuel switching of non-road transports	%	5	10	20	40	5	10	20	40	5	10	20	40	5	10	20	40
Generation or Capacity	Coal power	GW	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Gas power	GW	400	600	800	1000	400	600	800	1000	400	600	800	1000	400	600	800	1000
	Hydroelectric generation	GW	100	125	150	200	100	125	150	200	100	125	150	200	100	125	150	200
	Nuclear power	GW	100	150	200	500	100	150	200	500	100	150	200	500	100	150	200	500
	Onshore wind power	GW	100	200	400	600	100	200	400	600	100	200	400	600	100	200	400	600
	Offshore wind power	GW	10	50	100	200	10	50	100	200	10	50	100	200	10	50	100	200
	Solar PV power	GW	50	200	500	800	50	200	500	800	50	200	500	800	50	200	500	800
	Solar CSP power	GW	50	150	300	500	50	150	300	500	50	150	300	500	50	150	300	500
	CHP power	GW	50	100	150	200	50	100	150	200	50	100	150	200	50	100	150	200
	Biomass and MSW power	GW	25	50	100	200	25	50	100	200	25	50	100	200	25	50	100	200
	Geothermal power	GW	10	25	50	100	10	25	50	100	10	25	50	100	10	25	50	100
	Ocean power	GW	10	25	50	100	10	25	50	100	10	25	50	100	10	25	50	100
	Energy Imports	GW	0	10	25	50	0	10	25	50	0	10	25	50	0	10	25	50
CO_2 Emissions	Thermal power plants with CCS	%	0	25	50	100	0	25	50	100	0	25	50	100	0	25	50	100
	Industrial plants with CCS	%	0	25	50	100	0	25	50	100	0	25	50	100	0	25	50	100
	Emissions' reduction due to geosequestration	Mton	0	50	100	250	0	50	100	250	0	50	100	250	0	50	100	250
Results	GHG emissions vs. 2005	%	24				101				67				33			
	Cost of Energy	B$/year	869				1493				1087				1018			
	Difficulty Level	%	72				10				36				48			

Source: EDP 2050's simulator