# The carbon prices making low carbon plants competitive

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The carbon value of a low emitting plant in energy sector, transformation industries [or else the carbon valueof infrastructures (transportation, building, etc)] is the value of avoided emissions by the development of this plant when it is developed instead of an emitting plant [or an « inefficient » infrastructure] ; the latter being less costly than the low carbon plant, with no carbon price at all.

In this exercise, we focus on the calculation of the carbon prices which make competitive the low carbon technologies (LTCs) comparatively to a reference emitting plant, given that these carbon prices is the reference for the calculation of the carbon value of the avoided emissions by the LCT

We choose the power sector in which the charcters of the different technologies are well documented as well for reference emitting plants, the gas-CCGT and the coal plants, as for the coal-CCS and nuclear as low carbon technologies.

The calculation of the equilibrium carbon prices is made in three situations :

- a common regime of investment with an identical capital cost of 8%,
- a differentiated regime with a government guarantee on the investment in low carbon technologies which leads to a capital cost of 5% besides the common regime for emitting plants with a capital cost of 8%. Indeed high capital costs of LCTs tend to encourage the use of fossil fuels. To achieve the same degree of decarbonization, countries rather than imposing a higher price on carbon emissions than countries with low capital costs could implement de-risking arrangements (long term guarantee on the loans by governement, long term contracts like contracts for differences) to lower the cost of capital,
- a reverse differential regime with no governemental guarantee for the LCTs which are faced to a risk aversion from the investors, which leads the latters to invest with a capital cost of 12.5% in LCT plants, while the CCGT and coal plant are invested normally with a capital cost of 8%.

In the first stage we calculate the carbon price which make low carbon technologies (LCT) competitive with fossil fuel plants with the same regime with capital cost of 8%.

- Coal plants with CCS become competitive with simple coal plants for a carbon price of 35€/tCO2 and with CCGT for a carbon price of 85 €/tCO2.
- Nuclear reaches competitiveness with coal plant for a carbon price of 30 €/tCO2 and with gas CCGT for a carbon price of 60€/tCO2.

**Table 1. The equilibrium carbon price for the competitiveness of LCT plants with fossil fuel plants**

| Ref. fossil tech. | Coal with CCS | | | Nuclear | | |
|---|---|---|---|---|---|---|
| | Case 1 | Case 2 | Case 3 | Case 1 | Case 2 | Case 3 |
| | 8% capital cost | 5% capital cost | 12.5% capital cost | 8% capital cost | 5% capital cost | 12.5% capital cost |
| **Gas CCGT 8% capital cost** | Carbon price 85€/tCO2 | Carbon price **50 €/tCO2** | Carbon price 120€/tCO2 | Carbon price 60 €/tCO2 | Carbon price **20€/tCO2** | Carbon price 132€/tCO2 |
| **Coal plant 8% capital cost** | Carbon price 35€/t | Carbon price **20€/t** | Carbon price 54€/t | Carbon price 30€/t | Carbon price **12.5 €/t** | Carbon price 60€/t |

In the second stage we calculate the effect of such a guarantee which would lower the capital cost from 8% to 5% to make the low carbon technologies competitive with the fossil fuel plants (or the emitting ones) for which the investors use a capital cost of 8%. The cost of capital has a key influence of the economic position of low carbon technologies which are generally much more capital intensive than emitting technologies as in the electricity sector. Indeed :

- the coal plants with CCS become competitive with the coal plant at a carbon price of 20.5 €/tCO2, instead of 35 €/tCO2 ; and with CCGT at the carbon price of around 50€/tCO2 instead of 85 €/tCO2.
- The nuclear becomes competitive with the gas CCGT at a carbon price of around 20€/tCO2 instead of 60€/tCO2, and with the coal plant with a carbon price of 12.5 €/tCO2, instead of 30€/tCO2.

In the third stage, we consider the opposite situation in which the low carbon investment are perceived as so risky that the lender and the investor consider a capital cost of 12.5%.

- For the coal-CCS technology, the equilibrium price with the coal plant is 54€/tCO2 instead of 35€/tCO2 in the first scenario with 8% of capital cost for every technology, and with the gas-CCGT 120€/tCO2 instead of 85€/tCO2.

- For the nuclear, the carbon price should be 132€/CO2 to challenge gas-CCGT instead of 85€/tCO2, and 60€/tCO2 instead 30 € to challenge the coal MWh.

In a last stage, we proceed in another way. We keep the same cost of capital of 8% for the different technologies, LCT ones as fossil ones. We calculate **the amount of subsidy per kW which makes the LCT projects profitable after deduction of the subsidy,** when the levels of carbon price which make the LCTs competitive when they benefit from a governemental guarantee and so from a cost of capital of 5% (see the second stage calculation). In other words, this gives a value to the governmentguarantee.

- For the CCS, with a carbon price of 20.5 €/tCO2 (instead of 35€/tCO2 if their capital cost would be 8%), this support amounts to 610 €/kW , which covers 24.4% of the investment cost of the CCS plant (2500 €/kW).
- For the nuclear, with a carbon price of 20€/tCO2 (instead of 60€/tCO2 if their captial cost would be 8%), this support amounts to 913 €/kW which covers 22.8% of the investment cost of the nuclear plant (4000 €/kW).

## 1. The equilibrium price of carbon for making low carbon technologies competitive with fossil fuel plants

For reason of simplicity, we hoose two examples in the power sector with base load and ddispatchable technologies on the opposite of variable renewables (windpower and PV) (which gerates in an erratic way (When they generate power, it is never at full power but on an interval between 5% and 60% of their nominal power and they produce without relation with the hourly value of electricity on the hourly market, on the opposite with the dispatachable plants) ;

So we consider here two low carbon technologies which are dispatchable and base-load technologies because it does not raise any poblem to be compared with fossil fuel technologies which are dispatchable and base load plants So we consider on one side a coal plant with CCS with an overall efficiency of 29.3 % and an emission of 0.11 $tCO_2$ per MWh (instead of 38% and 0.8 $tCO_2$ per MWh for the normal coal plant), and on the other side a nuclear plant with zero emission, which are in competition with performing CCGT and coal plants.

**Box**

**What about renewables plant ?**

The exercise could be complemented by adding eventually dispatchable technologies as geothermal plants or biomass plants.[1]

But it cannot include simplistic considerations and calculation about variable renewables projects, because the economic value of their variable productions is much lower than the MWh produced by dispatchable equipment. In other words a windpower which has a load factor of 25% (2200h) in fact produces in a very erratic way during all the hours on the year between 5% and 50-60% of its nominal capacity ; moreover it produces without any relation with the hourly market prices, on the opoositie of the conventional equipment. So the comparison could not be made in a simple way as below for the disptachable equipment.

The comprehensive calculation is expressed in the table of Appendix A. It is made **with the present low prices of fossil fuel (coal and gas)** which are not so lower as last years in 2015-16. For reason of commodity we proceed with a calculation with three increasing prices of the carbon : 30, 45 and 60€/$tCO_2$, in order to to identify the equilibrium price for different couples of low carbon and fossil technologies (Table 1).

After parametrisation on the carbon price, the results (table 2) show that the nuclear reaches competitiveness with coal plant for a carbon price of 30 €/$tCO_2$ and with gas CCGT for a carbon price of 60€/$tCO_2$ for the same average revenue per MWh of 66 €/MWh. But it is not competitive with the CCGT for the reference prices of 30 and 45 €/$tCO_2$.

[1] To give an indication about these types of plants, there are geothermal projects at 3400 €/kW (exemple of a project of 4x30 MW in Dominique Island) and biomass plants at 2600-3000 €/kW but with much higher fuel costs (feedstock) than the low fuel cost of current low carbon technologies (IRENA 2012, Renewable technologies : cost analysis series. Biomass for Power Generation. Issue 1/5. June 2012). Here we consider a nuclear plant at 3900-4000€/kW and a coal plant with CCS at 2450-2500 €/kW.

Concerning the coal plants with CCS, they become competitive with normal coal plants for a carbon price of 35€/tCO2 and with CCGT for a carbon price of 85 €/tCO2. In the first case the average revenue par MWh is 69.5 €/MWh, in the second case it is bit higher with 74.6 €/MWh

**Table 2. Levels of carbon price to make competitive LCTs with fossil fuel technologies**

| | **Coal with CCS** | **Nuclear** |
|---|---|---|
| **Gas CCGT** | Carbon price at 85 €/tCO2<br><br>Equilibrium at 74.6 €/MWh | Carbon price at 60 €/tCO2<br><br>Equilibrium at 66 €/MWh |
| **Coal plant** | Carbon price at 35€/tCO2<br><br>Equilibrium at 69.5 €/MWh | Carbon price at 30€/tCO2<br><br>Equilibrium at: 66 €/MWh |

N.B. Carbon emission factor is supposed to be 0.35 t $CO_2$/MWh for CCGT, 0.8 t $CO_2$/MWh for coal and 0.11 t CO2 for coal with CCS

## 2. The effects of a governmental guarantee on the financing of low carbon technologies

At this stage we could compare the effects of a financial guarantee on the investment in low carbon technologies, with the carbon value of a low carbon technologies. The guarantee allows to lower the cost of capital for investment in coal-CCS plant and nuclear plant from 8% to 5%, while the guarantee does not cover CCGT and coal plant investment which remain with a capital cost of 8%.

It appears that the nuclear could become competitive in this new condition with the gas CCGT with a carbon price of around 20€/tCO2 (19.4 more precisely) instead of 60€/tCO2, and with the coal plant with only a carbon price of 12.5 €/tCO2, instead of 30€/tCO2.

On its side the coal plants with CCS become competitive with the coal plant at a carbon price of 20.5 €/tCO2, instead of 35 €/tCO2 ; and also with CCGT at the carbon price of around 50€/tCO2 instead of 85 €/tCO2. So the government guarantee means in much lower carbon price to trigger investment in low carbon technologies and, at the end, a lower price of decarbonised electricity (51.8 €/MWh instead of 66€/MWh in the nuclear case competitiveness and 59 €/MWh instead of 69.5 €/MWh in the CCS case competitiveness with coal plant).

**Table 3. New levels of carbon price to make competitive LCTs with fossil fuel technologies**

| | Coal with CCS | | Nuclear | |
|---|---|---|---|---|
| | **8% capital cost** | **5% capital cost** | **8% capital cost** | **5% capital cost** |
| **Gas CCGT** | Carbon price at 85 €/tCO2<br><br>Equilibrium at 74.6 €/MWh | Carbon price at 50 €/tCO2<br><br>62.5€/MWh | Carbon price at 60 €/tCO2<br><br>Equilibrium at 66 €/MWh | Carbon price at 20 €/tCO2<br><br>51.8€/MWh |
| **Coal plant** | Carbon price at 35€/tCO2<br><br>Equilibrium at 69.5 €/MWh | Carbon price at 20.5€/tCO2<br><br>59 €/MWh | Carbon price at 30€/tCO2<br><br>Equilibrium at 66 €/MWh | Carbon price at 12.5 €/tCO2<br><br>51.8€/MWh |

N.B. Carbon emission factor is supposed to be 0.35 t $CO_2$/MWh for CCGT, 0.8 t $CO_2$/MWh for coal and 0.11 t CO2 for coal with CCS

3. **The effect of risk aversion on the low carbon investment: which carbon tax to make LCT competitive if the capital cost is 12.5% ?**

In a 2015 NEA / OECD report on the new nuclear build 2015, nuclear merchant plants (without public guanrantee o developed by a regulated monopoly) are considered as a risky investmentFor this reason, a Weighted average captial cost (WACC) of 12.5% is considered, with a share equity/debt of 40/60, a borrowing rate of 7.5% and a return on equity of 14.5% (before tax).

So along the results of the calculation in appendix C, we could show that the carbon price to marke LCT reaches competitiveness with coal plant or gas CCGT is much higher:

**Table 4**

| | Coal with CCS | | Nuclear | |
|---|---|---|---|---|
| | **8% capital cost** | **12.5% capital cost** | **8% capital cost** | **12.5% capital cost** |
| **Gas CCGT** | Carbon price at 85 €/tCO2<br><br>Equilibrium at 74.6 €/MWh | Carbon price at 120 €/tCO2<br><br>87.6 €/MWh | Carbon price at 60 €/tCO2<br><br>Equilibrium at 66 €/MWh | Carbon price at 132 €/tCO2<br><br>91.1 €/MWh |
| **Coal plant** | Carbon price at 35€/tCO2<br><br>Equilibrium at 69.5 €/MWh | Carbon price at 54 €/tCO2<br><br>87.5 €/MWh | Carbon price at 30€/tCO2<br><br>Equilibrium at 66 €/MWh | Carbon price at 60 €/tCO2<br><br>91.1 €/MWh |

For the nuclear, the carbon price should be 132€/CO2 to challenge gas- MWh instead of 85€ in a scenario with 8% of capital cost for every technology, and 60€/tCO2 instead 30 € to challenge the coal MWh.

Concerning the Coal-CCS technology, the equilibrium price with the coal plant is 54€/tCO2 instead of 35€, and with the gas-CCGT 120€/tCO2 instead of 85€/CO2

### 4. In the same regime of 8%-capital cost, which share of LCT investment to subsidize to make it competitive with fossil fuel technologies at the same carbon price as in the 5% capital cost case ?

We estimate the carbon value of LCTs to be subsidized in order to make LCTs competitive with the fossil fuel technologies in the 8%- capital cost regime with the same carbon price which makes LCTs competive when they benefits from the public investment guarantee

**a.1. The nuclear case compared to a coal plant**

When the nuclear is built with a capital cost of 5%, the plant is competitive with the coal plant build at 8% capital cost if the carbon price is 12.5€/tCO2 instead of 30 €/tCO2 (with an electricity cost-price of 51.8€/MWh instead of 66€/MWh ).

However, when we build the nuclear at 8% capital cost, the policy maker wants the nuclear competitive with the coal plant at this carbon price of 12.5 €/tCO2. In this case the subsidy to support the nuclear plant under the form of a shadow carbon value per avoided tCO2 will be 17.5€/tCO2.

Calculated per nuclear MWh produced, the subsidy per MWh would be 14.2 €/MWh (66-51.8 €/MWh). Thisis equivalement to a subsidy of 18.5 per avoided t/CO2. During the lifetime of the plant (40 years), this support amounts to 913 €/kW (with a discount rate of 8%), this corresponds to 22.8% of the investment cost of the nuclear plant (4000€/kW).

**a.2. .The nuclear case compared to a gas-CCGT plant**

The results per MWh and per kW are the same with a CCGT plants : 14.2 €/MWh of subsidization and 913 €/kW . The major differences stays in fact at the level of the omplicit subsidy per avoided t of CO2 because a kWh of gas CCGT emits much less than a kWh of coal plant : 0.35 versus 0.8 tCO2/MWh. That means that the implicit subsidy to the LCT technology per avoided t of CO2 is much more important if we compared to the gas CCGT and the reference emitting plant (40€/tCO2 against 18.5 €/tCO2)

**Table 5. How to align the LCT plant profitability with a capital cost of 8%, with the profitability under the government investment guarantee ?**

| | Nuclear built at 8% capital cost | | Nuclear built at 5% capital cost | |
|---|---|---|---|---|
| | Nuclear compared to coal plant built at 8% | Nuclear compared to a gas CCGT built at 8% | Nuclear compared to coal plant built à 8% | Nuclear compared to a gas CCGT built at 8% |
| Equilibrium carbon price Nuclear/coal (€/tCO2) | 30€/tCO2 | 60 €/tCO2 | 12.5 €/tCO2 | 20 €/tCO2 |
| Electricity price equilibrium Nuclear/coal (€/MWh) | 66 €/MWh | | 51.8 €/MWh | |
| Subsidy on nuclear at 8% capital cost per MWh to reach the same equilibrium cost-price between fossil and nuclear price with 5% capital cost for nuclear (€/MWh) | | | 14.2€/MWh | |
| Total subsidy on the lifetime of nuclear* (€/kW) | | | 913 €/KW | |
| Implicit subsidy in € per t of avoided emissions | | | 18.5 €/t | 40 €/t |

* 7000h/y during 40 years lifetime and a discount rate of 8%

### b. The CCS case compared to a coal plants

We procee in the same way than above for the nuclear case. If CCS is built with a capital cost of 5%, the plant is competitive with the coal plant build at 8% capital cost if the carbon price is 20.5€/tCO2 instead of 35 €/tCO2 (with an electricity cost-price of 59 €/MWh instead of 69.5 €/MWh ).

However, when we build the CCS at 8% capital cost, the policy maker wants the CCS competitive with the coal plant at this carbon price of 20.5 €/tCO2. In this case the subsidy to support the nuclear plant under the form of a shadow carbon value per avoided tCO2 will be 14.5€/tCO2.

Calculated per CCS MWh produced, the subsidy per MWh would be 10.5 €/MWh (66-51.8 €/MWh) and an implicit subsidy of 14.4 €/tCO2 avoided. During the lifetime of the plant (40 years), this support amounts to 610 €/kW (with a discount rate of 8%), this corresponds to 24.4% of the investment cost of the CCS plant (2500 €/kW).

**Table 6. To align the CCS plant profitability with a capital cost of 8%, with the profitability under the government investment guarantee ?**

| | Coal with CCS compared to coal plant | |
|---|---|---|
| | **CCS built at 8% capital cost** | **CCS built at 5% capital cost** |
| Equilibrium carbon price (€/tCO2) | 35€/tCO2 | 20.5€/tCO2 |
| Electricity price equilibrium CCS /coal (€/MWh) | 69.5 €/MWh | 59 €/MWh |
| Subsidy on CCS MWh at 8% capital cost to reach the equilibrium CCS/Coal when CCS at 5% capital cost (€/MWh) | | 10.5€/MWh |
| Total subsidy on the lifetime of plants (€/kW)* | | 610 €/kW |
| Implicit subsidy in € per t of avoided emissions | | 14.5 |

N.B. Emission Rate of 0.11 tCO2/MWh for CCS versus 0.8 tCO2/MWh for coal plan.

* 7000h/y during 40 years lifetime and a discount rate fo 8%

## Appendix A

## Calculation of equilibrium prices of carbon and electricity between nuclear and CCS with cCCGT and coal plant at the same capital costs of 8%

### Table A 1. Cost of low carbon and fossil fuel technologies with different carbon prices

| | Gas CCGT | | | Coal plant | | | Nuclear plant | | | Coal with CCS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Investment cost (k€/MW) | 800 | | | 1,400 | | | 4,000 | | | 2500 | | |
| Annual O&M cost (k€/MW.year) | 20 | | | 30 | | | 75 | | | 60 | | |
| Annaul amortization k€/MW/y | 71 | | | 117 | | | 316 | | | 204 | | |
| Total annualised fixed cost (k€/MW.year)* | 91 | | | 147 | | | 391 | | | 264 | | |
| | | | | | | | | | | | | |
| Fixed cost per MWh (€/MWh)** | 13 | | | 21 | | | 55.8 | | | 37.7 | | |
| Fuel cost (€/MWh)*** | 32 | | | 21 | | | 10 | | | 27.5 | | |
| Total cost w/o carbon (€/MWh) | 45 | | | 42 | | | 65.8 | | | 65.2 | | |
| | | | | | | | | | | | | |
| Hypothesis carbon price in €/tCO2 | 30 | 45 | 60 | 30 | 45 | 60 | 30 | 45 | 60 | 30 | 45 | 60 |
| Carbon costs (€/MWh)**** | 10.5 | 15.7 | 21.0 | 24 | 36 | 48 | 0 | 0 | 0 | 3.3 | 5.0 | 6.6 |
| | | | | | | | | | | | | |
| Total costs for each carbon prices €/MWh) | 55.5 | 60.7 | 66 | 66 | 78 | 86 | 66 | 66 | 66 | 68.5 | 70.2 | 71.8 |

Sources for the costs: IEA-NEA. 2012. Generating costs
* With a discount factor of 8%. and a lifetime of 30 y for CCGT, 40 y for nuclear and coal plants
** load factor of 80% (7000h)
***Hypothesis on fossil fuel price € 5.1 per MMBtu (Feb 2017) and coal price is € 75 per ton (Feb 2017) and respective thermal efficiency: CCGT: 55% ; coal plants:38.5% ; coal with CCS: 29.3%.
****Carbon emission factor is supposed to be 0.35 t $CO_2$/MWh for CCGT, 0.8 t $CO_2$/MWh for coal and 0.11 t CO2 for coal with CCS

## Appendix B .

## Calculation of equilibrium prices of carbon and electricity between nuclear and CCS wiht a capital cost of 5% with CCCGT and coal plant with a capital cost of 8%

### Table B1. Cost of low carbon and fossil fuel technologies with different carbon prices

| | Gas CCGT Capital cost 8% | | | Coal plant Capital cost 8% | | | Nuclear plant Capital cost 5% | | | Coal with CCS Capital cost 5% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emission factor (tCO2/MWh) | 0.35 | | | 0.8 | | | - | | | 0.11 | | |
| | | | | | | | | | | | | |
| Investment cost (k€/MW) | 800 | | | 1,400 | | | 4,000 | | | 2500 | | |
| Annual O&M cost (k€/MW.year) | 20 | | | 30 | | | 75 | | | 60 | | |
| Annual amortization (k€/MW.year) | 71 (at 8%) | | | 117 (at 8%) | | | 218.2 (at 5%) | | | 140.8 (at 5%) | | |
| Total fixed cost (k€/MW.year) | 91 | | | 147 | | | 293.2 | | | 200.8 | | |
| | | | | | | | | | | | | |
| Fixed cost / MWh (€/MWh) on 7000h/y** | 13 | | | 21 | | | 41.8 | | | 28.6 | | |
| Fuel cost (€/MWh)*** | 32 | | | 21 | | | 10 | | | 27.5 | | |
| Total cost w/o carbon (€/MWh) | 45 | | | 42 | | | 51.8 | | | 56.1 | | |
| | | | | | | | | | | | | |
| Hypothesis carbon price in €/tCO2 | 20 | 30 | 45 | 12 | 20 | 30 | 20 | 30 | 45 | 20 | 30 | 45 |
| Carbon cost (€/MWh) | 7 | 10.5 | 15.7 | 9.6 | 18 | 24 | 0 | 0 | 0 | 2.2 | 3.3 | 5.0 |
| | | | | | | | | | | | | |
| Total costs for each carbon price (€/MWh) | 52 | 55.5 | 60.7 | 51.6 | 60 | 66 | 51.8 | 51.8 | 51.8 | 58.3 | 59.4 | 61.1 |

Source for the costs: IEA-NEA. 2012. Projected Costs of Generating Electricity: 2012 Edition. OECD/IEA.

* With a discount factor of 8%. for CCGT and coal; 5% for nuclear and CCS; and a lifetime of 30 y for CCGT, 40 y for nuclear, coal and CCS plants
** Load factor of 80% (7000h)
***Hypothesis on fossil fuel price € 5.1 per MMBtu (Feb 2017) and coal price is € 75 per ton (Feb 2017) and respective thermal efficiency: CCGT: 55% ; coal plants:38.5% ; coal with CCS: 29.3%.

## Appendix C

## Calculation of equilibrium prices of carbon and electricity between nuclear and CCS wiht a capital cost of 10.5 % with CCCGT and coal plant with a capital cost of 8%

| | Gas CCGT<br>Capital cost 8%<br>Sur 25 ans | | | Coal plant<br>Capital cost 8%<br>sur 25 ans | | | Nuclear plant<br>Capital cost<br>12.5% sur 25 ans | | | Coal with CCS<br>Capital cost<br>12.5%sur 25 an | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Emission factor ($tCO_2$/MWh) | 0.35 | | | 0.8 | | | - | | | 0.11 | | |
| | | | | | | | | | | | | |
| Investment cost (k€/MW) | 800 | | | 1,400 | | | 4,000 | | | 2500 | | |
| Annual O&M cost (k€/MW.year) | 20 | | | 30 | | | 75 | | | 60 | | |
| Annualised inv. cost (k€/MW.year) | 75 (at 8%) | | | 131 (at 8%) | | | 493 (at 12.5%) | | | 318 (at 12.5%) | | |
| Total fixed cost (k€/MW.year) | 95 | | | 161 | | | 568 | | | 378 | | |
| | | | | | | | | | | | | |
| Fixed cost / MWh (€/MWh) on 7000h/y** | 13.6 | | | 23 | | | 81.1 | | | 54 | | |
| Fuel cost (€/MWh)*** | 32 | | | 21 | | | 10 | | | 27.5 | | |
| Total cost w/o carbon (€/MWh) | 45.6 | | | 44 | | | 91.1 | | | 81.5 | | |
| | | | | | | | | | | | | |
| Hypothesis carbon price in €/$tCO_2$ | 60 | 120 | 132 | 30 | 54 | 60 | 30 | 60 | 132 | 45 | 54 | 63 |
| Carbon cost (€/MWh) | 21 | 42 | 46.2 | 24 | 43 | 48 | 0 | 0 | 0 | 5.0 | 6.0 | 7.0 |
| | | | | | | | | | | | | |
| Total costs for each carbon price (€/MWh) | 66.6 | 87.6 | 91.8 | 68 | **87** | 92 | 91.1 | 91.1 | 91.1 | 86.5 | 87.5 | 88.5 |

Source for the costs: IEA-NEA. 2012. Projected Costs of Generating Electricity: 2012 Edition. OECD/IEA.

* With a discount factor of 8%. for CCGT and coal; 12.5% % for nuclear and CCS; and a lifetime of 30 y for CCGT, 40 y for nuclear, coal and CCS plants

** Load factor of 80% (7000h)

***Hypothesis on fossil fuel price € 5.1 per MMBtu (Feb 2017) and coal price is € 75 per ton (Feb 2017) and respective thermal efficiency: CCGT: 55% ; coal plants:38.5% ; coal with CCS: 29.3%.