EXECUTIVE SUMMARY:
Carbon price instead of support schemes: Wind power investment by the electricity market

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While investments in conventional electricity production technologies are mostly driven by their market revenues on day-ahead markets which present important price-risk and volume-risk, the future incomes of RES-E projects are ensured by specific mechanisms which guarantee long term revenues and so, are estimated with a low level of risk. From that perspective, investments in RES-E are not linked at all to market-price signals. But in the context of the current debate on RES-E support mechanism, it is argued that RES-E investment should be market-based as other conventional power plants. Because of its closeness to the competitive threshold, this paper considers on-shore wind power as an illustrative case to explore the conditions of market-driven RES-E entry through the incentive of a constant carbon price. We assume that wind power entries do not benefit from specific promotion mechanism but are triggered by its profitability compared to dispatchable thermal units. Economic profitability of generating power plants is estimated under the incentive of higher hourly electricity market prices which include a high and stable carbon price.

This study of market-driven investments in wind power is based on a System Dynamics (SD) model which simulates endogenous evolution of the electricity mix over several year. This endogenous evolution of the technology mix is obtained by the formalisation of investment decision-making based on estimated revenues that each new plant could generate on the energy market. The decision process requires to anticipate the future profitability of different generating technologies by modelling market evolution in a set of scenarios. These future scenarios include assumptions on weather (which directly influences electricity demand and wind generation), macroeconomic growth and political orientation through a carbon price. As other power plants, wind production is sold on the energy market. In case of an excess of wind production compared to electricity demand, the surplus does not receive payment.

Different market simulations are computed with different levels of constant carbon price in two scenarios of initial systems and a scope of technology options: (case A) the generic one with a pure fossil-fuel based system without nuclear and (case B) the diversified one with a system with a mix of fossil-fuel and nuclear plants. The three main keys of our results are presented below.

**** Estimated carbon price required for market-drivent investments in wind power**

In the first case without nuclear, the SD simulations show that the threshold value of the carbon price beyond which wind power is selected by the representative investor is €70 per ton of CO_2. This value obviously depends on our assumptions on power plants' costs and a sentivity analysis is presented in the paper. Nevertheless, the significant point is that this value is higher than the value of € 40 per ton of CO_2 estimated on the basis of levelized cost of electricity[1] (LCOE) computed with the same power plants' parameters. This effect was also mentioned in the litterature (Joskow, 2011) and is confirmed by our

[1] Levelized cost of electricity (LCOE) is a cost estimation of producing one MWh of electricity for a given technology. It takes into account all the costs that occur during the whole life of the unit (investment cost, annual operation and maintenance cost, variable cost).

analysis.

**** Effect of nuclear on wind power development**

if we keep the nuclear option open as a low carbon technology, results show that market-driven development of wind power becomes more complicated. In particular, because nuclear is insensible to the carbon price (no emmissions of CO_2), the carbon price needed for investments in wind power is very high. In the case of an important existing nuclear capacity, wind power investments are only observed in our simulations with a moratorium on new nuclear development and a high carbon price.

**** Endogenous limit of wind power development**

The variable cost of wind power is very low (close to zero). Consequently, introduction of wind power decreases the energy price during hours of wind power generation and thus, decreases the profitability of wind power assuming that additional wind capacities will generate electricity with the same pattern as existing ones. This effect of wind power on the energy price is represented in the modelling and this allows to observe that wind power suffers from what could be called a “self-cannibalisation”.

Finally, the study suggests that the transition to full market integration of on-shore wind power and more generally variable RES-E should be gradual and supported by strong political commitments reflected by a high and stable carbon price. Indeed, the assumption of a policy based on a fixed and high carbon price requires strong political commitments that may not arise in reality. Moreover, further work sould investigate to what extent CO_2 price should be significantly higher to trigger investments in wind power plants if uncertainty on carbon price and risk aversion of investors are taken into account.