EMISSION IMPACTS OF WIND POWER

Wind energy will displace fuel consumed in other power plants and thereby reduce emissions. The fact that wind energy will also increase balancing needs has raised concern about the less-efficient use of other power plants due to cycling up and down to balance the system. However, studies show that emissions due to increased cycling of power plants are small compared to the benefits of reducing their overall generation and fuel use.

How does wind power reduce emissions?

Wind power is a renewable electricity generation source that does not emit CO_2 in operation. It has very low life cycle CO_2 emissions when compared with fossil fuelled generation. When wind power is generated it will displace generation from power plants, reducing their fuel use and emissions of CO_2, NO_X, SO_X, and particulates.

What power plant generation and fuel will be displaced depends on the cost structure of operating power plants, as well as timing. During each hour, the generation that has most expensive operational costs will be reduced, usually fossil fuelled generation. If the fuel displaced is coal, the emission benefits are greater than when displacing natural gas. Examples of studies showing the emission reductions of wind power can be seen in Figure 1.

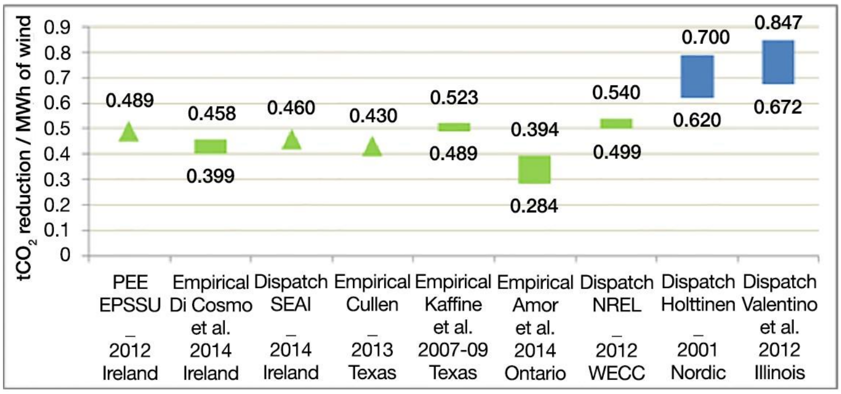

Figure 1. *Examples of wind power impact on emission reductions, as grams of CO_2 per kWh wind power generated. The green ones are from power systems where wind power replaced mostly gas-fired generation and the blue ones where mostly coal-fired generation is replaced (Source: Holttinen et al., 2014).*

Does wind power variability cause extra emissions?

At high levels of wind generation, fuel-consuming generators will experience steeper ramps and will be starting up and shutting down more often. This is to respond to changing dispatch orders to compensate for total fluctuation in system - variation in wind generation and demand.

When fossil fuel power plants start up, ramp output up or down, or operate at less than full load, they are less efficient in fuel use than when they run continuously at full load. This results in more CO_2 and other emissions.

Detailed studies have shown that even in power systems with large amounts of wind power, extra emissions from balancing needs are not much. The main impact of replacing coal and gas generated electricity and reducing fuel use and emissions is order of magnitude greater than increased emissions from cycling the power plants.

For example, providing 33% of annual electricity needs with wind and solar energy, balancing related emissions are less than 2% of the emission reductions from decreased fuel use. (Source: Lew et al., 2013) (Figure 2 and 3).

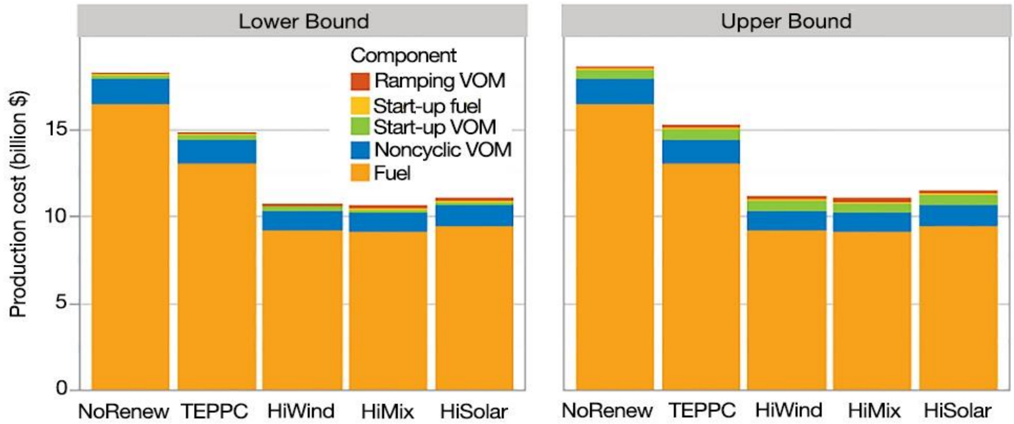

Figure 2. *Most of the operation costs and emissions result from fuel use. Ramping and start-ups present less than 1% share of the costs over a year, even with a high share of variable renewables. Example of simulated Western U.S. operational costs from one year, with up to 33% share of wind and solar (Source: Lew, et al., 2013).*

How can operators ensure lower extra emissions from balancing power systems?

When anticipating larger shares of wind and solar energy in a power system, it will be important to increase the flexibility of new fossil fuelled power plants. Increased flexibility can decrease the operational costs and emissions of the overall power system because it provides more options for balancing. Flexibility can be shared with neighbouring regions through the use of interconnecting transmission (trading electricity). Wind and solar power plants can offer fast response. Another new source of flexibility is offered by the consumer, called demand response.

	Emission Reduction Due to Renewables	Cycling Impact
CO_2	260–300 billion lbs 29% – 34%	Negligible Impact
NO_x	170–230 million lbs 16% – 22%	3–4 million lbs
SO_2	80–140 million lbs 14% – 24%	3–4 million lbs

Figure 3. *The increase in plant emissions from cycling to accommodate variable renewables is very low compared to the overall reduction in CO_2, NO_x, and SO_2 due to adding renewables. (Source: WWSIS2, 2013) (1 million lbs = .45 million Kg).*

Emission reductions for future low carbon energy systems

Achieving more than 80% emission reductions tend to be more expensive than the first emission reduction from reducing fossil fuels in electricity generation. Deeper decarbonisation means electrifying other energy sectors like transport and heating. This brings new electricity consumption.

Associated publications

- Holttinen, H. et al. (2019). **Design and operation of power systems with large amounts of wind power**. Final summary report, IEA WIND Task 25, Phase four 2015–2017. https://community.ieawind.org/task25/ourlibrary
- Holttinen, H, Kiviluoma, J, Pineda, I, McCann, J, et al. (2015) **Reduction of CO2 emissions due to wind energy - methods and issues in estimating operational emission reductions**. IEEE Power & Energy Society General Meeting, 26 - 30 July 2015, Denver, USA: IEEE. Proceedings. doi:10.1109/PESGM.2015.7286288
- Lew, D. et al. (2013). **The Western Wind and Solar Integration Study Phase 2**. NREL/TP-5500-55588. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy13osti/55588.pdf
- SEAI (2014). **Quantifying Ireland's Fuel and CO_2 Emissions Savings from Renewable Electricity in 2012**. www.seai.ie/News_Events/Press_Releases/2014/245m-of-fossil-fuel- savings-from-use-of-renewable-electricity-in-2012.html

More information

This Fact Sheet draws from the work of IEA Wind Task 25, a research collaboration among 18 countries. The vision in the start of this network was to provide information to facilitate the highest economically feasible wind energy share within electricity power systems worldwide. IEA Wind Task 25 has since broadened its focus to analyze and further develop the methodology to assess the impact of wind and solar power on power and energy systems.

See our website at
https://community.ieawind.org/task25

See also other fact sheets

Storage and Wind Power Fact Sheet
Balancing Power Systems with Wind Power Fact Sheet
Electrification Fact Sheet
Wind Integration Issues Fact Sheet