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The Power Markets Project studies and promotes market policies that align with clean energy goals. It is a project of PaulosAnalysis, with financial support from the Heinrich Böll Foundation, the Cynthia and George Mitchell Foundation, and the Rockefeller Brothers Fund. Thanks to this support a delegation of German energy officials and experts was able to go on a fact-finding tour of the United States that included visits to Texas, PJM, and Washington, DC.

Aligning Markets with Clean Energy Policy

The pace of adoption for wind and solar power will hinge on whether market design policies can be changed to welcome them and accommodate their rapid growth. A key question at the top of Germany's policy agenda is whether the current energy-only market is up to the task of ushering in the Energiewende without causing economic catastrophes for market participants.

Bentham Paulos

I. Introduction

Germany's drive toward more renewable energy, energy efficiency, and low carbon emissions – the *Energiewende* – is not an isolated incident. On the contrary, many places around the world are seeking the energy independence, technological advancement, and clean environment that clean energy can deliver.

But because Germans are out front and have a technologically advanced, first-world economy, the eyes of the world are upon them. And being in the vanguard, they are the first to discover what works and what doesn't, and to face the problems that arise.

One fundamental discovery[1] of the *Energiewende* has been that wind and solar electricity are going to be the workhorses of the future. They are cheap and getting cheaper, they have a large resource to tap, they are domestic energy sources, and they don't pollute. Other renewable sources, like biomass, hydropower and geothermal energy, are either largely

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exploited already, are more expensive, have other uses like providing heat or transportation fuels, need more time to develop, or have limited potential.

Other options have limits, too. Germany has committed to phasing out nuclear power by 2022, in response to public opposition over safety issues. Coal is not likely to square with Germany's carbon reduction goals, given its significant carbon footprint and a public unease about carbon sequestration.

This leaves natural gas, which is almost entirely imported, with Russia the largest source. Current political tensions in Russia and Ukraine are a clear reminder of the energy security threat that comes with natural gas.

Another finding from the *Energiewende* is the fundamental importance of improving energy efficiency. Reduced demand can solve many of the concerns about sufficient capacity, as well as reduce pollution and save money for consumers. Efficiency and other demand-side approaches can also help integrate wind and solar.

Given the alternatives, using wind and solar to supply a more efficient system looks like the best bet. But wind and solar are only available when the weather commands, while electricity is needed around the clock and demand must be met at all times, or the system collapses. To make such a system work, two sets of problems must be solved – engineering and finance.

A. Technical tasks

It is starting to look like the technical issues of integrating wind and solar are not really an impediment. Grid operators have many tools in their toolbox[2] to keep the lights on as wind and solar production increase.

Dispatchable power plants have always been the first option for integration, and will remain so, whether powered by renewable or other fuels. They will have to be cleaner and more flexible, and they can be.

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Better transmission links not only connect remote renewables to cities, they also reduce variability by moving power around in real time and tapping a bigger pool of both demand and supply.

The demand side of the system is becoming increasingly interactive, as appliances, lighting, and motors can be controlled using Internet and wireless communications. Converting surplus electricity into thermal storage, such as by pre-heating water or pre-cooling buildings, has vast potential.

Excess wind and solar output can also be redirected into making other products, like hydrogen or synthetic fertilizer. They can even be curtailed when necessary.

And electricity storage – often touted as the only solution for variable renewables – is an increasingly viable option. Grid-connected batteries are seeing better cost and performance thanks to advances made for electric vehicles. Large-scale storage using water and compressed air are mature technologies.

These options are generally well understood by grid operators. Not all are cost-effective or valued by markets or system planners, especially in our current system. But in a future system that is heavily reliant on solar and wind, and in which carbon emissions are capped, these many tools will be put to work.

B. The money problem

Perhaps the bigger problem with a power system dominated by wind and solar is the money problem. While some economists have pointed to what they call ''the missing money'' problem, renewables are causing a different disruption.

In an energy-only market, producers are paid enough to cover their own operating costs, but not enough to incentivize new

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