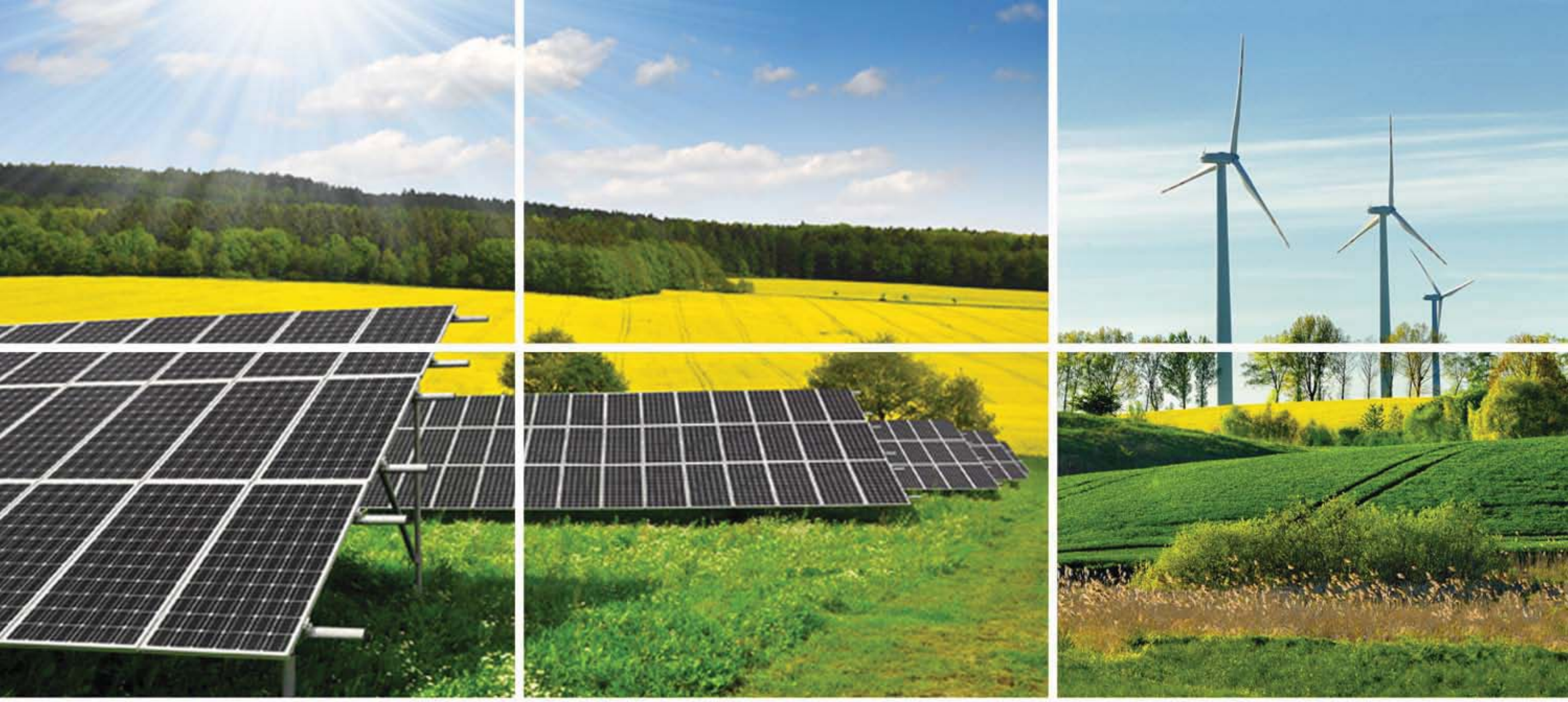

Renewable Energy at Scale in the U.S. and Europe:

Lessons Learned and Best Practices

American Council On Renewable Energy (ACORE)

RENEWABLE ENERGY AT SCALE IN THE U.S. AND EUROPE: LESSONS LEARNED AND BEST PRACTICES

NOVEMBER 2014

AMERICAN COUNCIL ON RENEWABLE ENERGY (ACORE)

ACORE, a 501(c)(3) non-profit membership organization, is dedicated to building a secure and prosperous America with clean, renewable energy. ACORE seeks to advance renewable energy through finance, policy, technology, and market development and is concentrating its member focus in 2014 on National Defense & Security, Power Generation & Infrastructure, and Transportation. Additional information is available at: www.acore.org

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EXECUTIVE SUMMARY

In recent years, a combination of system cost reductions and policy mechanisms have driven private-sector investment in and the scale-up of renewable energy deployment in the U.S. and Europe. Several U.S. states are exceeding their renewable energy goals ahead of schedule, and renewable energy is responsible for generating more electricity in many European countries than ever before. Over the past several years, a combination of private sector ingenuity, investment, and government policy drove significant cost reductions, technology improvements, and scale-up of the renewable energy industry on both continents. In the U.S., renewable energy now accounts for 17% of total power generation, with Bloomberg New Energy Finance projecting that the industry will add 272 GW of renewable generating capacity by 2030, bringing domestic renewable capacity to one-third of the generation mix. In Europe, 2030 estimates are that over half of its power generation is estimated to be zero-emissions resources, up from 29% in 2013. This is primarily due to renewable capacity additions and pending large-scale nuclear retirements. However, even with supportive policies, these projections are low for what the renewable energy industry is capable of producing.

At the same time, developments in natural gas extraction are creating transatlantic opportunities, as well as, challenges: stringent environmental standards are raising performance requirements; central generation fleets in many jurisdictions are aging; and transmission and distribution systems require significant expansion and upgrades. A significant capital investments and an updated policy framework are required to modernize the power generation sector and assure reliable service. These issues, along with new technological innovations, regional differences in resource availability, the changing nature of customer relations and usage patterns, emerging financing structures, and an uncertain policy outlook, all present challenges and opportunities for this sector. Going forward, renewable energy policies and targets need to account for the all-in cost of production to further incentivize the deployment of zero-emissions resources.

Focusing on transatlantic experiences, this review discusses how best to integrate increasing amounts of renewables into power systems while ensuring system performance, reliability, and resiliency. The review examines the costs and benefits of renewable energy at scale, the efficacy of state and local policies in Europe and the U.S., and challenges and solutions to grid integration. The review also identifies best practices in key renewable energy markets to inform discussions in the U.S., Europe, and elsewhere on the future of renewable energy policy and the role of renewables in the evolving power market system. This review examines these key issues, and provides recommendations with an emphasis on reaching and improving integration at scale while providing a series of industry perspectives with useful analysis, data, and insight for renewable energy and utility stakeholders, including:

- Suggested outcomes for the successful integration of renewable energy at scale
- Best practices to better inform policies and market structures that deal with scalable deployment
- Market solutions for issues related to transmission, distribution, variability and the integration of resources

A group of government and prominent private organizations authored the articles in this Review: the Embassy of the Federal Republic of Germany, U.S. Department of Energy Loan Programs Office, IBM, Energy Future Coalition, and Akin Gump Strauss Hauer & Feld LLP.

Transforming Germany's Energy System: Opportunities and Challenges

Michael Weber
German Embassy

Among the world's highly industrialized countries, Germany has embraced an ambitious strategy to transform its electricity sector through scale-up of renewable energy sources (RES) and a reduction in energy consumption. The *Energiewende* – the transformation of Germany's energy system – is aimed at lowering greenhouse gas emissions by 80 to 95% by 2050, fully phasing out the use of nuclear power by 2022, halving primary energy consumption by 2050, and increasing the share of renewable energy sources in gross electricity consumption to 80% (see Table 1).

The German government views this path as essential to securing an "environmentally sound, reliable, and affordable energy supply."[1] The transformation of Germany's energy system is not only a response to climate change but also an effort to bolster future prosperity and competitiveness, secure job growth, and spark innovation and modernization.

The U.S. perception of the Energiewende ranges widely, from admiration to critical disbelief. Criticism often centers on the alleged high costs of a large RES scale-up. However, solely focusing on the short-term costs of the transition fails to recognize its broader economic and environmental benefits, as well as the actual, *all-in* costs of a continuation of the status quo.

MACROECONOMIC BENEFITS OF TRANSFORMING GERMANY'S STATUS QUO

The enormous increase in the use of renewable energy in Germany's electricity generation, from 6% of the total electricity supply in 2000 to 25.4% in 2013,[2] has already created tangible economic, environmental, and security benefits, such as a reduction in fossil fuel imports and a decline in greenhouse gas emissions versus business as usual. However, these benefits are often not made transparent because traditional cost-benefit analyses only include benefits to which a monetary value can be directly assigned. Recently, more inclusive analyses have attempted to address this issue by looking at the wider socio-economic benefits of renewable energy resources.[3] A study commissioned by the German Environment Ministry estimates that the quantifiable benefits of reduced environmental damage and avoided fossil fuel imports for electricity, heating, and transport presently outweigh the costs of Germany's RES scale-up in these sectors.[4] Moreover, studies assessing the long-term costs of a transition to a largely renewables-based energy system conclude that a successful transformation initially requires incurring incremental costs greater than those required under business-as-usual scenarios, but that overtime these investments produce net savings as the costs of renewables continue to decline.[5]

[1] BMWi/BMU (2010): Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply. 28. September 2010: http://www.germany.info/contentblob/3043402/Daten/1097719/BMUBMWi_Energy_Concept_DD.pdf
[2] BMWi (2013): Erneuerbare Energien im Jahr 2013, Februar 2014
[3] http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=418
[4] ISI/ DIW/ GWS /IZES (2013): Monitoring der Kosten und Nutzenwirkungen des Ausbaus erneuerbarer Energien im Strom- und Wärmebereich im Jahr 2012: http://www.impres-projekt.de/impres-wAssets/docs/BMU_Monitoringbericht.pdf
[5] For example: SRU – German Advisory Council on the Environment (2011), *Pathways towards a 100% renewable electricity system*, SRU,Special Report, Berlin.

TABLE 1: STATUS QUO AND QUANTITATIVE ENERGIEWENDE TARGETS

Category	2011	2012	2020	2030	2040	2050
Greenhouse gas emissions						
Greenhouse gas emissions (compared to 1990)	-25.6%	-24.7%	at least -40%	at least -55%	at least -70%	at least -80% to -95%
Renewable energies						
Share in gross electricity consumption	20.4%	23.6%	at least 35%	at least 50% (2025: 40 to 45%)	at least 65% (2035: 55 to 60%)	at least 80%
Share in gross final energy consumption	11.5%	12.4%	18%	30%	45%	60%
Efficiency						
Primary energy consumption (compared to 2008)	-5.4%	-4.3%	-20%		-50%	
Gross electricity consumption (compared to 2008)	-1.8%	-1.9%	-10%		-25%	
Share of electricity generation from combined heat and power plants	17.0%	17.3%	25%			
Final energy productivity	1.7% per annum (2008–2011)	1.1% per annum (2008–2012)	2.1% per annum (2008–2050)			
Buildings						
Primary energy requirement	–	–	–		around -80%	
Heat requirement	–	–	-20%		–	
Rate of modernisation	approx. 1%	approx. 1%		doubling of levels to 2% per annum		
Transport						
Final energy consumption (compared to 2005)	-0.7%	-0.6%	-10%		-40%	
Number of electric vehicles	6,547	10,078	1 million	6 million	–	

Source: Federal Ministry for Economic Affairs (BMWi), Second Monitoring Report "Energy of the Future", Summary, p. 4

The following section discusses variables that underline the need to take a broader, more inclusive look at costs and benefits to better comprehend the wider social benefits of Germany's RES scale-up.

Economic Benefits

The most obvious economic benefit of renewable energy scale-up is the cost savings from importing fewer fossil fuels. Unlike the U.S., Germany does not have an abundance of natural resources, but instead imports almost 70% of the primary energy it consumes.[6] The cost of importing fossil fuel is a burden on the overall economy. In 2011, Germany spent €85 billion (US $107 billion) on fossil fuel imports. This was equal to 3.3% of GDP, up from 0.8% in 1995.

The fast growth of domestic RES since 2000 has been able to slow this trend by preventing further increases in imports. In 2013, this resulted in savings worth €10 billion (US $12.5 billion). Import savings alone therefore already make up half of the approximately €20 billion (US $24 billion) Germany spends annually for its RES support scheme. Moreover, energy efficiency improvements accounted for an additional savings of around €26 billion (US $33 billion).

A further economic benefit of scaling up RES in Germany has been job creation. In 2013, the

[6] http://bmwi.de/BMWi/Redaktion/Binaer/Energiedaten/energiegewinnung-und-energieverbrauch1-heimische-gewinnung-import,property=blob,bereich=bmwi2012,sprache=de,rwb=true.xls

renewable energy sector employed 371,400 workers. By 2020, this number is forecasted to grow to 600,000. Energy efficiency improvements have similarly achieved positive effects and were responsible for 436,000 jobs in 2012. Additionally, and a result of predictable RES costs, many new jobs are expected to be created in traditional sectors, such as the steel and electrical industries, which are important players and benefactors in the renewable supply chain.

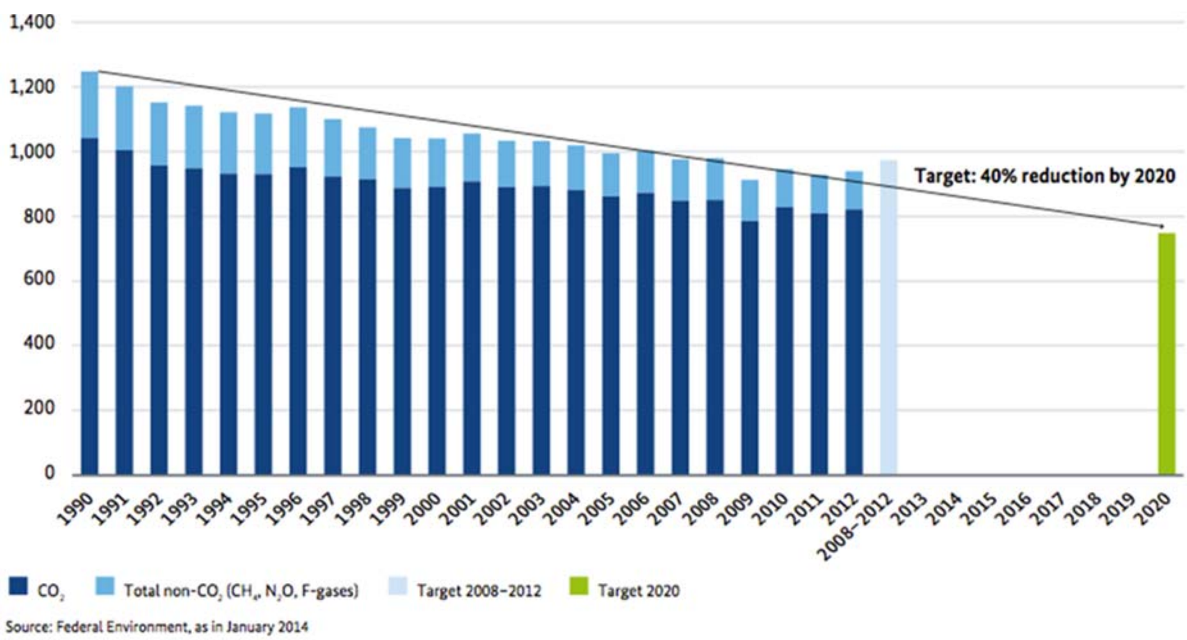
The expansion of renewable energy also has a positive effect on local communities, especially rural areas, due to the decentralized nature of RES such as onshore wind, biomass, and solar PV. Investments in these technologies have created local jobs, increased regional purchasing power, and have brought in more federal and local tax revenues. Private individuals and farmers together account for almost half of Germany's investments in RES.[7] These investments greatly benefit small and medium-sized local enterprises, which are responsible for the construction, operation, and maintenance of installations.

Lastly, the German patent and trademark office recorded 2,200 new patents in the renewable energy sector in 2012, a sharp increase from 1,300 in 2009. This increase not only signals that further technological improvements are possible, but also that German companies are striving to remain global leaders and drivers of innovation and modernization.

Environmental Benefits

An increased use of RES in place of greater use of conventional fossil resources also results in substantial environmental benefits. For example, lower levels of air pollution can substantially reduce cardiovascular and respiratory disease.[8] Similarly, replacing fossil fuels with RES helps to mitigate the

FIGURE 1: DEVELOPMENT OF GREENHOUSE GAS EMISSIONS (CO2 EQUIVALENT IN MILLIONS OF METRIC TONS)



Source: Federal Ministry for Economic Affairs (BMWi) (2014), *Second Monitoring Report "Energy of the Future"*, Summary, p. 14

[7] p.9 http://www.unendlich-viel-energie.de/media/file/323.72_Renews_Spezial_Wirtschaftsstandort_Deutschland_online_apr14.pdf

[8] http://www.who.int/mediacentre/factsheets/fs313/en/

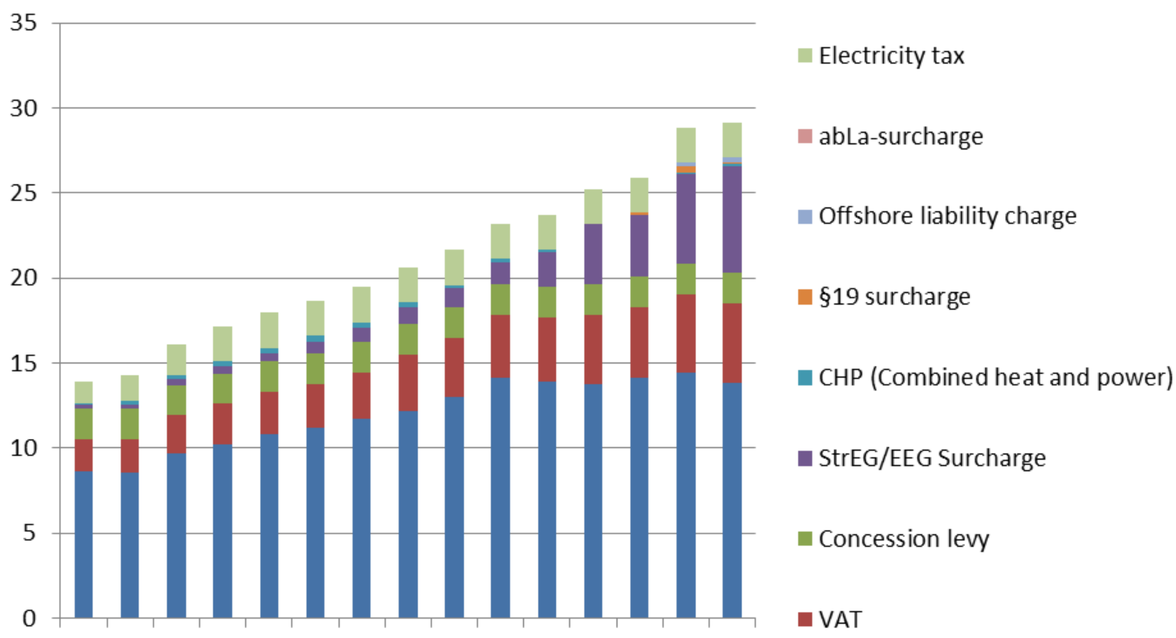
adverse impacts of global climate change by lowering greenhouse gas emissions. The switch to lower-emission energy resources has been key in ensuring that Germany is in compliance with its international commitments under the Kyoto Protocol (a 21% reduction in emissions on average for 2008 to 2012) (see Figure 1).[9]

Critics point to Germany's 2.4% increase in greenhouse gas emissions from 2011 to 2013 as being due to the increased use of coal power, in response to Germany's energy transition, and, more specifically, to the country's reduced use of nuclear power. The government has identified this concerning trend as a threat to Germany's 2020 emissions reduction goals and announced that it will present a strategy by the end of 2014 to ensure Germany remains on track to meeting these goals, including by addressing its use of coal power.

However, these criticisms neglect market dynamics independent of the Energiewende. Among these are the U.S. shale boom, which has increased U.S. coal exports and depressed international coal prices, leading to increased use of coal versus natural gas in Europe. Moreover, the EU emissions trading system has failed to provide sufficient market signals to shift production towards climate-friendlier alternatives due to an oversupply of emission allowances largely caused by the global economic crisis in 2008. Many experts also suggest that the emissions increase reflects a temporary uptick in coal power due to a cold 2012/2013 winter, as well as an increase in German electricity exports due to comparable lower wholesale prices in Germany versus some of its neighboring countries. [10]

Moreover, the new round of coal plant construction is not a result of the decisions of the Energiewende but has happened in spite of it; these plants had been planned years before the Energiewende launched. The foreseeable retirement of a significant number of old coal power plants also likely will alter

FIGURE 2: HOUSEHOLD ELECTRICITY PRICES (EUROCENTS PER KWH)



Source: BDEW (2014): BDEW Strompreisanalyse 2014, p.6: http://bdew.de/internet.nsf/id/20140702-pi-steuern-und-abgaben-am-strompreis-steigen-weiter-de/$file/140702%20BDEW%20Strompreisanalyse%202014%20Chartsatz.pdf

[9] Monitoring report p.11
[10] http://us.boell.org/2014/06/06/german-coal-conundrum

Germany's power plant fleet and its emission intensity.

Security

Germany imports 98% of its oil, 88% of its natural gas, 87% of its hard coal consumption,[11] and 100% of its uranium. This dependency makes Germany not only vulnerable to international price shocks but also to conflicts, wars, and natural disasters in other parts of the world. The present crisis in Ukraine is the latest reminder of such dangers, but also shows the potential benefits for energy security when an energy system is largely built on domestic RES and optimizes energy efficiency.

The transformation of the German energy system will not fix possible supply disruptions in Russian energy imports overnight, but it does offer a viable long-term solution to becoming independent of Russian gas imports over the next decades.[12]

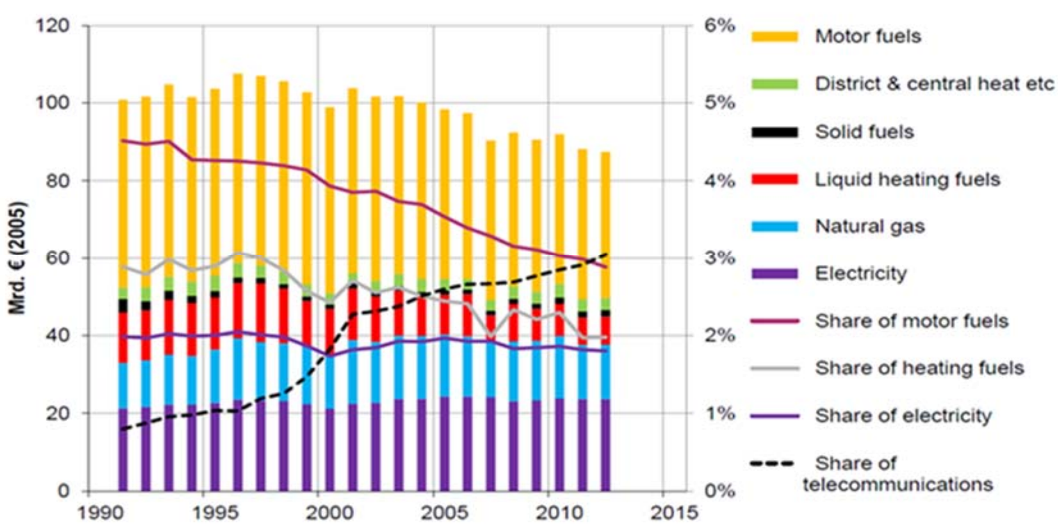
COSTS OF TRANSFORMING GERMANY'S ENERGY SYSTEM

Critics of the German Energiewende point to rising electricity prices for households and argue that German industry is becoming less competitive as a result. The discussion over rising prices is at the heart of current debates in Germany and central to a series of reforms passed in 2014 (see next section). While it is the responsibility of the government to avoid or at least minimize further price increases resulting from an expansion of RES, a closer look at household and industry pricing shows a less alarming picture.

Household Pricing

While an average three-person household paid roughly €0.14/kWh (US $0.18/kWh) for electricity in 2000, today this amount has increased to about €0.29/kWh (US $0.36/kWh).[13] The EEG surcharge – a

FIGURE 3: GERMAN HOUSEHOLD SPENDING ON ENERGY



Source: Agora Energiewende/ Dr. Patrick Graichen (2013): Insights from Germany's Energiewende. Lessons Learned and Key Challenges for the Power Sector in Germany, p.18: http://www.dnimediow.org/files/1372251827_graichen_energy_transition_11062013.pdf

[11] Arbeitsgemeinschaft Energiebilanzen (AGEB), Importabhängigkeit der deutschen Energieversorgung 2013. Infografik Nr. 4/2014, September 2014, http://www.ag-energiebilanzen.de/21-0-Infografik.html

[12] http://www.gruene-bundestag.de/fileadmin/media/gruenebundestag_de/themen_az/energie/PDF/Erdgassubstitution_final.pdf

[13] p.6 http://bdew.de/internet.nsf/id/20140702-pi-steuern-und-abgaben-am-strompreis-steigen-weiter-de/$file/140702%20BDEW%20Strompreisanalyse%202014%20Chartsatz.pdf

levy added to consumer bills to pay for the provisions of the Renewable Energies Act – is often cited as the reason for these price hikes. However, this is only partially true. The surcharge has indeed increased from €0.0116/kWh in 2008 to €0.0624/kWh in 2014 and therefore accounts for 41% (49% including VAT) of the increase. Yet, the cost of electricity production from conventional fuels also has increased by €0.05/kWh since 2000 and is another key reason why electricity prices have spiked.

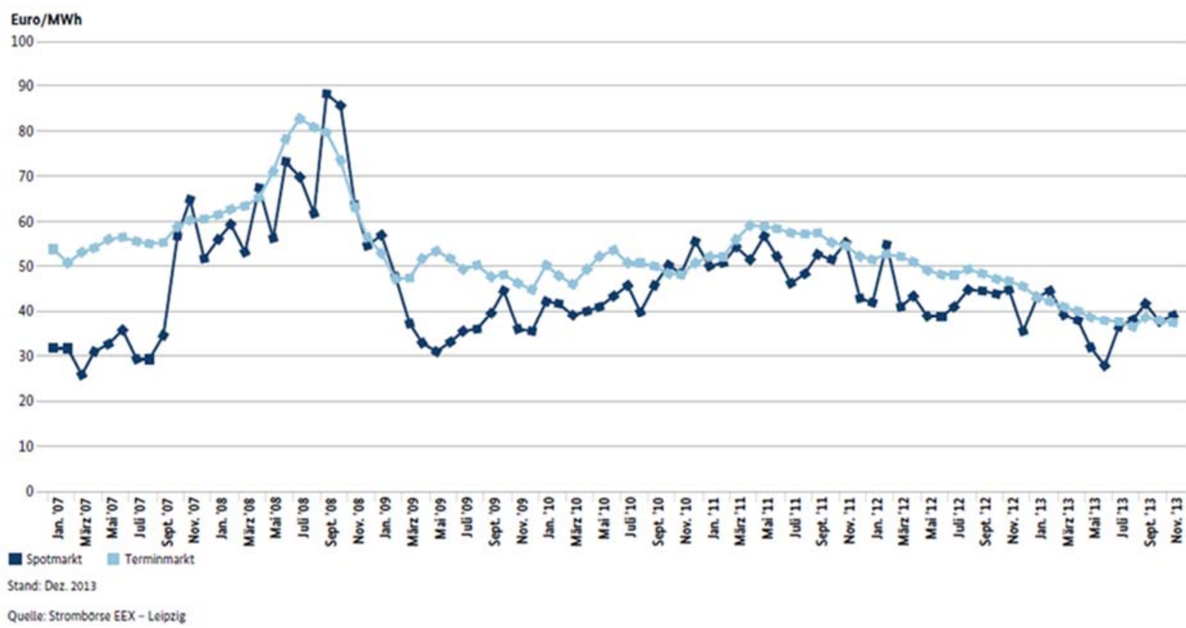
Falling wholesale electricity prices (see Figure 4) also have had a direct effect on the costs of the Renewable Energies Act. The EEG surcharge is estimated to be the difference between the guaranteed price received by renewable energy producers through Germany's feed-in tariff and the wholesale price of electricity. A lower price on the European Energy Exchange in Leipzig, for example, therefore translates into a higher EEG surcharge.

Any electricity price increase undoubtedly poses a burden on low-income households. However, to assess the effect of electricity costs on average households, it is useful to look at how much they spend on electricity consumption as a percentage of their total expenditures. This percentage has remained relatively stable, at around 2%, and is comparable to the amount U.S. consumers pay. Therefore, on average, growing household incomes have offset rising electricity prices (see Figure 3).

Industry Pricing

The discussion on the development of electricity prices and Germany's international competitiveness is particularly relevant for Germany's energy-intensive industries and companies that face a high degree of international competition from countries with weaker environmental regulations. While there is danger that these types of energy consumers could be negatively affected by higher electricity prices, the Energiewende has in fact so far largely benefited them for several reasons. First, these companies are largely exempt from the EEG surcharge and therefore do not have to pay for the costs of transitioning to an energy system based on RES. Moreover, they tend to buy their electricity on the wholesale market, where prices have dropped

FIGURE 4: DECLINING WHOLESALE ELECTRICITY PRICES



Source: BMWi (2014): Energiedaten: Ausgewählte Grafiken:
http://bmwi.de/BMWi/Redaktion/PDF/E/energiedaten-ausgewaehlte-grafiken,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

an average of 30% since Germany's decision to retire half of its nuclear power plants following the Fukushima nuclear disaster.

The reason for this price decline can be described as "the merit order effect": once a wind farm or a solar park is built, it produces electricity at almost no additional cost. Owners of conventional power plants, on the other hand, have to incur additional costs, such as fuel purchases, to produce electricity. The merit order is a way of ranking electricity generation technologies in ascending order of their short-run marginal (variable) costs of production. Those with the lowest marginal costs are the first to be called upon to meet demand. The plants with the highest marginal costs are the last to be asked to produce. The increased use of RES is pushing power plants with comparatively higher marginal costs out of the market, thereby reducing the clearing price and benefiting German heavy industry.

Contrary to reports about German heavy industry becoming less competitive, reduced wholesale prices have in fact provided a competitive advantage to many energy-intensive German companies, and has caused industries in neighboring countries to petition their governments to reevaluate their wholesale market structures.

GERMANY'S FEED-IN TARIFF SCHEME AND REFORMS

Germany's feed-in tariff scheme stimulated greater deployment of renewable energy resources and larger cost reductions than originally anticipated. The feed-in tariff's original design did not adjust to the rapidly declining technology costs in a timely fashion. RES deployment consequently spiked, but so did the overall costs of the scheme. The government has since addressed this problem by managing the number of RES installations coming online through specific annual growth targets for each renewable energy technology and more rigorous and frequent adjustments to feed-in payments (see Figure 5). Exceeding the planned growth rate now results in steeper degression rates – i.e., the percentage change in feed-in tariff payments over time. Conversely, if capacity is added at a slower-than-expected rate, the degression of the feed-in tariff is more gradual (see Figure 6). The greatest emphasis has been put on further expansion of wind and solar PV because of their

FIGURE 5: EEG 2014 REFORMS: FEED-IN TARIFF ADJUSTMENTS AND DEGRESSION RATES

	Corridor	Remuneration in ct/kWh	Degression
Hydropower	-	3,50 – 12,52	-0.5 %/a from 2016
Landfill, sewage and mine gas	-	3.80 – 8.42	-1.5 %/a from 2016
Biomass	100 MW (gross)	5.85 – 23.73 (dependent on fuel and size)	-0.5 % every three months from 2016
Geothermal		25.20	- 5.0 %/a from 2018
Wind energy onshore	2,400 – 2,600 MW (net)	Standard tariff: 8.90, for at least 5 years; Minimum 4.95	-0.4% every quarter from 2016
Wind energy offshore	-	Initial tariff: 15.40 for min.12 years; Option: 19.40 for min. 8 years if installed before 2020 Minimum 3.90	Standard tariff: - 0, 5 ct/kWh in 2018, 1 ct/kWh in 2020 - 0,5 ct/kWh/a 2021; Option: - 1 ct/kWh in 2018
Solar energy (PV)	2,400 – 2,600 MW (gross)	9.23 – 13.15 (and tenders for ground-mounted PV)	-0.5 % per month from 09/2014

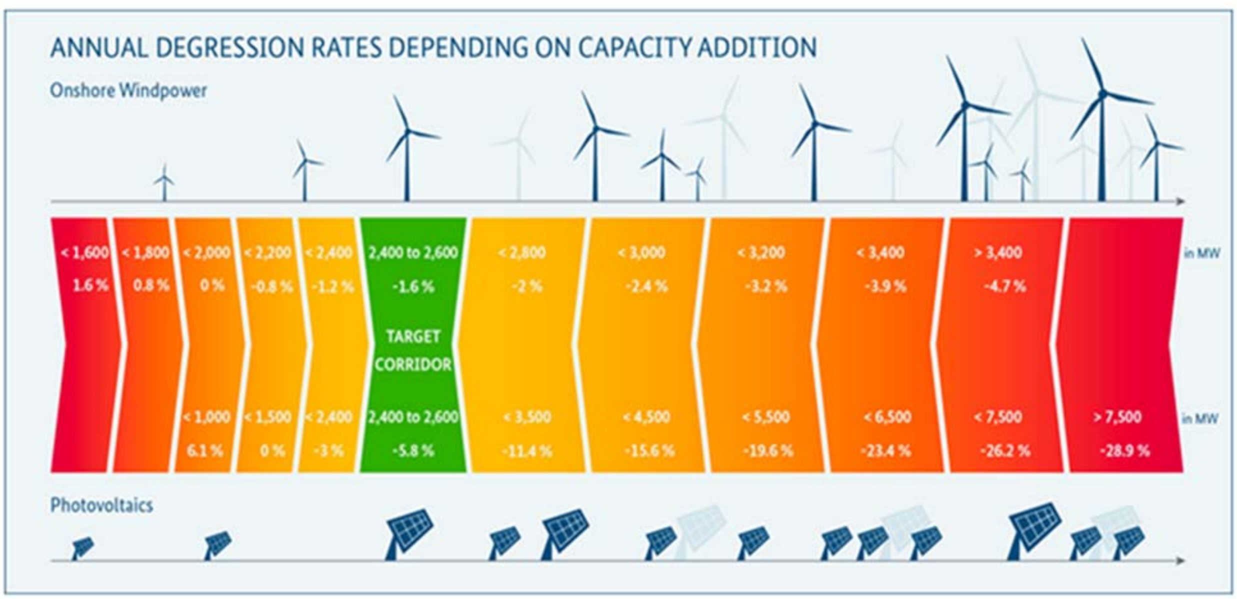
Source: EEG-Draft 26.06.2014 http://www.bmwi.de/BMWi/Redaktion/PDF/E/eeg-beschlussfassung-20140626-bundestag,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf comparable cost effectiveness relative to other sources.

The most recent EEG reforms, which went into effect as of August 1, 2014, aim to further ensure that the costs of the feed-in tariff scheme are kept under closer control. Average financial support across all eligible renewable technologies has been decreased from €0.17/kWh to €0.12/kWh by 2015.[14] This newest round of feed-in tariff cuts proves the cost-effectiveness of RES development in Germany. Onshore wind power has become a particularly cost-efficient alternative, outcompeting new conventional power plants in locations with reliable wind sources. Large-scale solar PV, and even small rooftop solar installations, have reached cost levels similar to those of new combined cycle or coal-fired plants. Moreover, today's feed-tariffs for new wind and solar PV in Germany are up to 50% less than those offered for new nuclear power in the UK, according to the Hinkley Point C agreement.[15]

Thanks to the lower feed-in tariff rates, further RES expansion will have only marginal effects on the total costs of the support scheme. The EEG surcharge is expected to remain rather constant in the range of €0.06/kWh to €0.065/kWh over the next few years.[16]

Adopting a longer time horizon, most experts believe based on bottom-up technological analyses that RES

FIGURE 6: FLEXIBLE ADJUSTMENT OF CAPACITY EXPANSION



Source: BMWi (2014): Gesetzentwurf der Bundesregierung zum Erneuerbare Energien Gesetz, 08.04.2014: http://www.bmwi.de/BMWi/Redaktion/PDF/Gesetz/entwurf-eines-gesetzes-zur-grundlegenden-reform-des-erneuerbare-energien-gesetzes-und-zur-aenderung-weiterer-bestimmungen-des-energiewirtschaftsrechts,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

[14] http://www.bmwi.de/DE/Themen/Energie/Erneuerbare-Energien/eeg-reform.html
[15] http://www.agora-energiewende.org/fileadmin/downloads/publikationen/Analysen/Comparing_Costs_of_Decarbonisationtechnologies/Agora_Analysis_Decarbonisationtechnologies_web_final..pdf
[16] http://www.oeko.de/oekodoc/1825/2013-495-de.pdf and http://www.agora-energiewende.de/fileadmin/downloads/publikationen/Hintergrund/EEG_2014/Agora_Energiewende_Hintergrund_EEG_2014_29082014_web.pdf

costs will further decrease.[17] Fossil fuel costs, on the other hand, are much more difficult to predict. Growing global energy demand makes a sustained period of low fossil fuel prices rather unlikely. The shale boom and a resulting drop in natural gas prices so far has been only a North American phenomenon. The cost of coal power is particularly difficult to predict, but the growing need to address the adverse effects of climate change through more comprehensive policies, such as carbon pricing, will likely lead to an increased cost of coal.

Aside from the greater emphasis on cost effectiveness, the newest round of reforms also has been intended to improve market integration of RES. Plant operators therefore will be required to sell directly into the market under a market premium model. Under this approach, renewable power producers sell electricity to the wholesale market and receive the revenue from the sale as well as a market premium that reflects the difference between the average wholesale price and the feed-in tariff for the specific technology. The goal of the premium payments is to encourage producers to engage in more market-based behaviors such as forecasting, selling planned production on the energy exchange, and balancing scheduled delivery with actual production.

More market competition also is intended to be introduced through a gradual shift towards an auctioning regime. By 2017, the government plans to start a tendering system under which Germany's grid agency will organize auctions to solicit additional capacity and to determine support levels. Details of this new set-up still will have to be addressed, but a pilot case for ground-mounted PV will commence in 2015.

CONCLUSION

Germany's decision to transition to a RES-based electricity system is an important energy security strategy among large, highly industrialized countries to ensure a long-term, reliable and affordable supply of electricity while significantly reducing carbon and other air pollution. Germany's experience so far has shown that it is possible to successfully integrate scalable levels of renewables. Moreover, the economic, environmental, and geopolitical benefits are estimated to outweigh the costs. At the same time, however, criticism about the growing cost of Germany's support scheme should not be disregarded. The government is endeavoring to control further price increases. The latest round of reforms advances progress toward a sustainable policy framework. Observers of German energy policy can expect more of such reforms over time. The Energiewende is not a one-off set of policies but a long-term strategy that naturally requires continuous monitoring, adjustments, and fine-tuning.

Germany is an interesting case study for countries deciding whether to pursue similar goals, reflecting both best practices and important lessons. The German feed-in tariff system's success in driving down deployment costs has positive global implications, as the costs for RES scale-up, particularly for solar PV, today are only a fraction of what they were 10 years ago.

Nonetheless, every country's energy situation is different. The U.S. has a different energy resource mix, with an abundance of both renewable and fossil fuel resources, but undefined national energy objectives, stronger political opposition to climate change policy, and a very different political system – and is thus pursuing its own course. The combination of state market demand and federal tax policies in the U.S., coupled with industry-led manufacturing and technology cost reductions, have contributed to impressive growth in renewable energy generation. In a number of states, renewable energy is now cost-competitively supplying power at scale similar to Germany's nationwide level, often as

[17] IRENA (2013): Renewable Power Generation Costs in 2012: An Overview, p. 79: http://www.irena.org/DocumentDownloads/Publications/Overview_Renewable%20Power%20Generation%20Costs%20in%202012.pdf

the cheapest source of new power. Looking ahead, the declining costs of renewable energy will likely drive even more generation in Germany and the U.S., with most generation in those states with renewable energy incentives or other policies that capture the all-in costs and benefits of energy generation and use.

Renewable energy is an important and growing component of the German and U.S. power systems.[18] From transmission infrastructure needs to the role of energy companies, both countries should work together to address the challenges that lie ahead in building energy systems based on greater shares of renewable energy.

ABOUT THE AUTHOR

Michael joined the German Embassy in Washington, DC as a Policy Advisor for Energy and Climate issues in September 2013. One of his tasks is to co-manage the Transatlantic Climate Bridge, a project platform to enhance transatlantic cooperation in energy and climate issues. Prior to working at the Embassy, Michael was Research Coordinator for the Climate and Energy Program at the Worldwatch Institute in Washington, DC. His research focused on low-carbon development strategies, renewable energy policy, and the socio-economic impacts of renewable energy development. Michael has also served as an economist at the German Advisory Council on the Environment (SRU) in Berlin, Germany, where he advised the German government on renewable energy and natural resource policy. Michael studied at the Hertie School of Governance and the Georgetown Public Policy Institute and received his Master in Public Policy in 2009. He also received a Master of Arts in Economics and Politics from the University of Edinburgh.

[18]See for a first evaluation of lessons learned: http://www.brookings.edu/~/media/Research/Files/Reports/2014/09/transforming%20electricity%20portfolio%20renewable%20energy/Transforming%20Electricity%20Portfolio%20web.pdf

COMPLEX CHALLENGES IN EU AND THE U.S.: HIGH-VOLTAGE TRANSMISSION SYSTEM

Ben Springer
Energy Future Coalition

If unsatisfied, the need for increased high-voltage transmission may hinder ambitious renewable energy targets around the globe. In 2009, the European Union (EU) implemented its "20-20-20" targets to address climate change by mandating, among other tactics, that 20% of EU energy consumption come from renewable resources by 2020. The scheme varies member nations' targets to account for their existing energy mix and potential to increase renewable energy production.

Similarly, in the United States (U.S.), 38 states and the District of Columbia have adopted renewable energy portfolio standards (RPS) or goals. The targets range from ambitious (New York at 29% by 2015; Hawaii at 40% by 2030) to less significant (South Carolina's non-binding goal is 2% by 2021). They vary in part to reflect market dynamics and existing levels of renewable production, but politics also play a significant role.

While the political and economic situations in the U.S. and EU continue to move in favor of renewables, governments and citizens understand little about the high-voltage transmission grid's role in attaining renewable energy targets. Whether dealing with 28 EU member countries or 48 US contiguous states, the physical and technical complexity of building the electric grid, and the regulatory overlay of managing it, are compounded in cross-border development. Yet, when the proper infrastructure, regulations, and market designs are in place, an efficient, high-voltage grid plays a critical role in balancing load, countering intermittency, and feeding remote but affordable renewable power into electricity markets.

PHYSICAL AND TECHNICAL CONSTRAINTS

On both continents, the physical and technical attributes of the existing grids are inadequate to maintain reliable, safe, and secure electricity supply. In Europe, it is estimated that over €100 billion (US$126 billion) is needed for critical interconnection projects by 2022.[19] Similarly, the investment gap for transmission in the U.S. is estimated to be US$37 billion (€29 billion) by 2020.[20] When added to the need for greater flexibility, control, and capacity to accommodate greater levels of renewable generation, the staggering magnitude of the challenge of building the grid of the future comes into sharp focus.

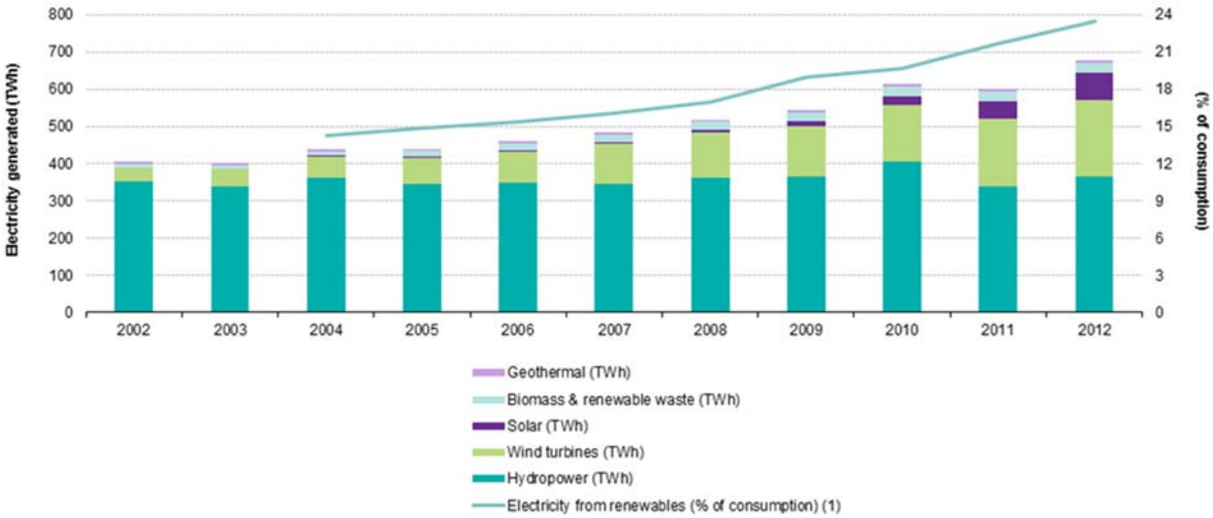
Europe

The existing European grid poses significant obstacles to cost effectively reaching the goal of 20% renewables by 2020. Across the continent, there are abundant renewable resources. Yet the diverse evolution of national electricity grids, along with limited cross-border interconnections, has complicated the transmission and distribution of electric power.

For example, the United Kingdom (UK) has limited interconnections with other countries, which hampers its ability to balance its electric grid with greater resources across broader areas. This has led to a situation in which reserve margins could drop to

[19] ENTSO-E, Ten-Year Network Development Plan 2012, Project for Consultation, draft version for Public Consultation 1 March – 26 April 2012, p. 61.
[20] American Society of Civil Engineers, 2013 Report Card For America's Infrastructure, http://www.infrastructurereportcard.org/a/#p/energy/investment-and-funding

ELECTRICITY GENERATED FROM RENEWABLE SOURCES WITH PERCENT CONSUMPTION, EU-28

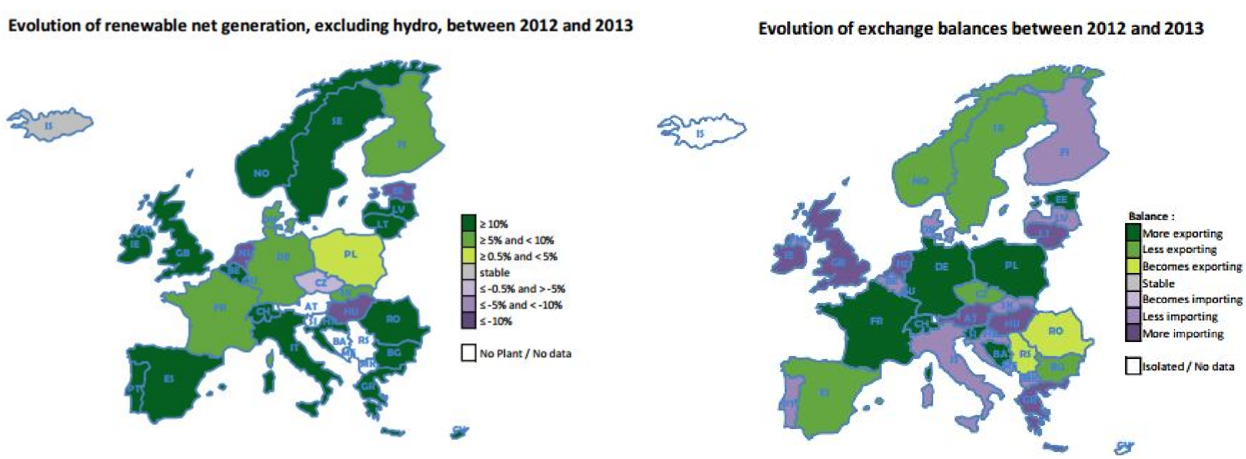


(1) 2002 and 2003: not available.
Source: Eurostat (online data codes: nrg_105a and tsdcc330)

a perilous 2%. Even with the maximum amount of power flowing through its existing interconnections from continental Europe, those margins are expected to be no greater than 8%.[21] In addition to greater security of supply and economies of scale, the UK Office of Gas and Electric Markets argues that interconnections offer the ability to "transfer excess renewable generation between countries in a future with high penetration of intermittent generation."[22] Because the UK is not yet halfway to its 2020 target of 15% renewables, the ability to import clean power would significantly help the country in achieving its renewable energy goals.

Germany, on the other hand, finds itself with a preponderance of renewable generation as a result of its *Energiewende* program. While much of

GROWTH OF RENEWABLE GENERATION VS. EVOLUTION OF EXCHANGE BALANCES IN EUROPE



Source: ENTSO-E

[21] https://www.ofgem.gov.uk/ofgem-publications/88523/electricitycapacityassessment2014-fullreportfinalforpublication.pdf
[22] Ibid.

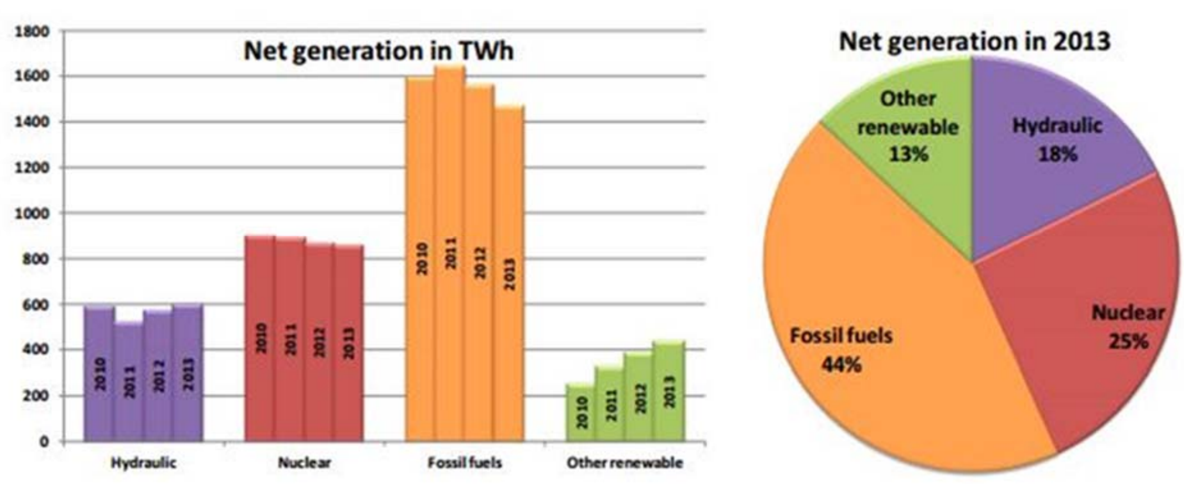
Germany's renewable energy production will be consumed domestically, expanded transmission capacity can enable renewable energy to flow to the most economically efficient markets, both within and outside of the country. German officials have acknowledged the challenges; recently, a transmission system operator (TSO) acknowledged that Germany, "did not synchronize renewable energy [deployment] with the build-up of necessary transmission lines."[23] Germany is now alleviating infrastructure deficiencies domestically by connecting the renewable-rich north to the industrial south, but is eager for more opportunities to export renewable energy.

Noting both the burden of isolation and the hunger for interconnection, in 2007, parallel policy development addressed both electricity restructuring and climate change. The European Network of Transmission System Operators for Electricity (ENTSO-E) began operation in 2009, concurrent to the implementation of the "Europe 2020" strategy. The European Commission mandated that ENTSO-E enhance cooperation among 41 member TSOs with the goals of "ensuring the secure and reliable operation of the increasingly complex network; facilitating cross-border network development and the integration of [renewable energy sources, and]; enhancing the creation of the Internal Electricity Market, IEM."[24]

Historically, ENTSO-E has played a critical role in establishing the guidelines[25] and facilitating the processes that have brought about 128 new cross-boundary interconnections as of 2013. These interconnections have allowed nearly double the amount of renewable generation onto the grid, while fossil and nuclear generation has decreased.

Despite ENTSO-E's progress to date, much more needs to be done to attain the EU's energy and climate policy goals. ENTSO-E's second Ten-Year Network Development Plan calls for interconnection capacity to double by 2030 to support renewable energy targets, and identifies 100 potential projects to do so.[26]

EVOLUTION OF OVERALL ENTSO-E NET GENERATION

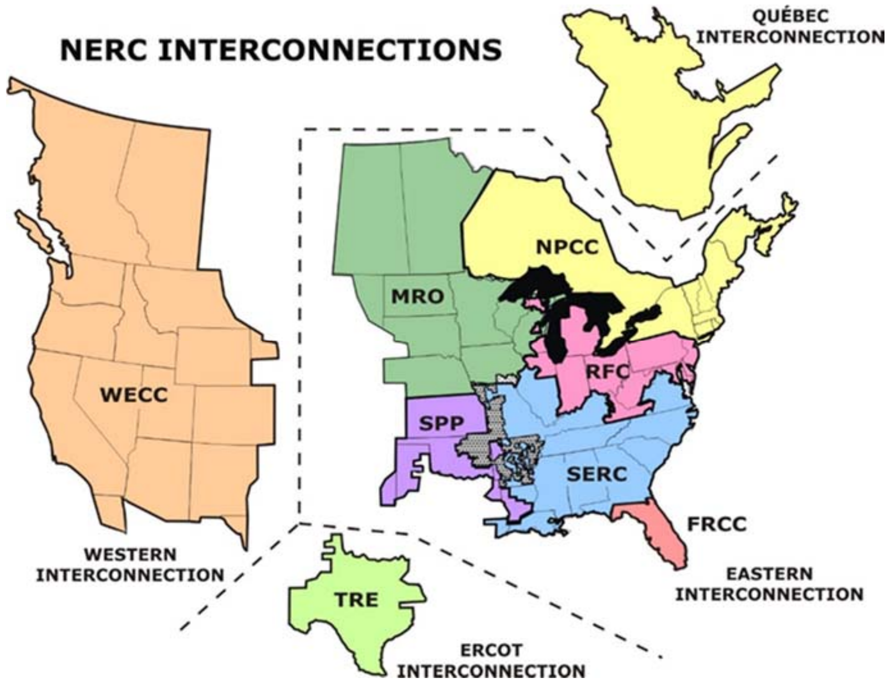


Source: ENTSO-E

[23] Ebinger, Charles, et. al. "Transforming the Electricity Portfolio: Lessons from Germany and Japan in Deploying Renewable Energy. Brookings Institution, September 2014, p. 20.
[24] https://www.entsoe.eu/about-entso-e/inside-entso-e/official-mandates/Pages/default.aspx
[25] For more information, visit: https://www.entsoe.eu/major-projects/network-code-development/Pages/default.aspx
[26]https://www.entsoe.eu/Documents/TYNDP%20documents/TYNDP%202014/140710_Draft_TYNDP%202014_Exec%20Summary_Consultation.pdf

United States

The U.S. grid is divided into two major alternating current (AC) systems – the Western and Eastern interconnections, which are tied together by six high-voltage direct current (HVDC) connections. Naturally, this limits the ability to move power efficiently across the country. Efforts are underway to build an additional four HVDC connections.[27] Another project, the Tres Amigas SuperStation, seeks to connect the Eastern and Western Interconnections with the ERCOT Interconnection of Texas.



Source: North American Electric Reliability Corporation

There are also severe transmission capacity constraints at the regional level. Some constraints arise from aging or inadequate infrastructure, while others result from the "seams" between competing and neighboring regional transmission operators or independent system operators (RTOs/ISOs). Historically, the dense population centers of New England and the Mid-Atlantic have created severe congestion and constraints. Increasingly, though, the less populated Midwest is seeing congestion from "high and growing levels of wind generation that cannot be delivered from western sources to more distant loads, and the lack of additional transmission to enable further development in renewable-rich areas."[28] The cost of congestion in these regions can reach into the billions of dollars. As economics and public policy drive greater levels of renewables into the generation portfolio, congestion costs may rise without needed infrastructure upgrades.[29]

Jurisdictional conflicts complicate efforts to mitigate congestion by enhancing or expanding transmission. Transmission lines crossing one or more states are subject to approval from each state involved, often leading to disagreements about cost allocation, siting, and other political factors. Recently, the Federal Energy Regulatory Commission (FERC) issued Order 1000 mandating regional transmission planning and cost-allocation procedures in an effort to streamline development of needed transmission facilities.[30] Additionally, Order 1000 requires planners to consider climate and renewable policies as well as potential benefits in planning lines and assigning costs. While these provisions were challenged, a recent federal appellate decision upheld the key parts of the Order.[31] Other regional authorities are also implementing streamlined planning processes to help integrate renewable

[27] http://www.npr.org/2009/04/24/110997398/visualizing-the-u-s-electric-grid
[28] U.S. Department of Energy. "National Electric Transmission Congestion Study Draft for Public Comment." August, 2014. http://energy.gov/sites/prod/files/2014/08/f18/NationalElectricTransmissionCongestionStudy-DraftForPublicComment-August-2014.pdf
[29] http://energy.gov/sites/prod/files/2014/02/f7/TransConstraintsCongestion-01-23-2014%20.pdf
[30] http://www.ferc.gov/industries/electric/indus-act/trans-plan.asp
[31] http://www.cadc.uscourts.gov/internet/opinions.nsf/9642B5B52A1B402785257D350052548A/$file/12-1232-1507702.pdf

generators into the grid.[32] These innovations are critical to lay the foundation for the flexible, integrated system the National Renewable Energy Laboratory (NREL) predicts can get the U.S. well above 80% renewable energy by 2050.[33]

REGULATING AND MANAGING THE GRID

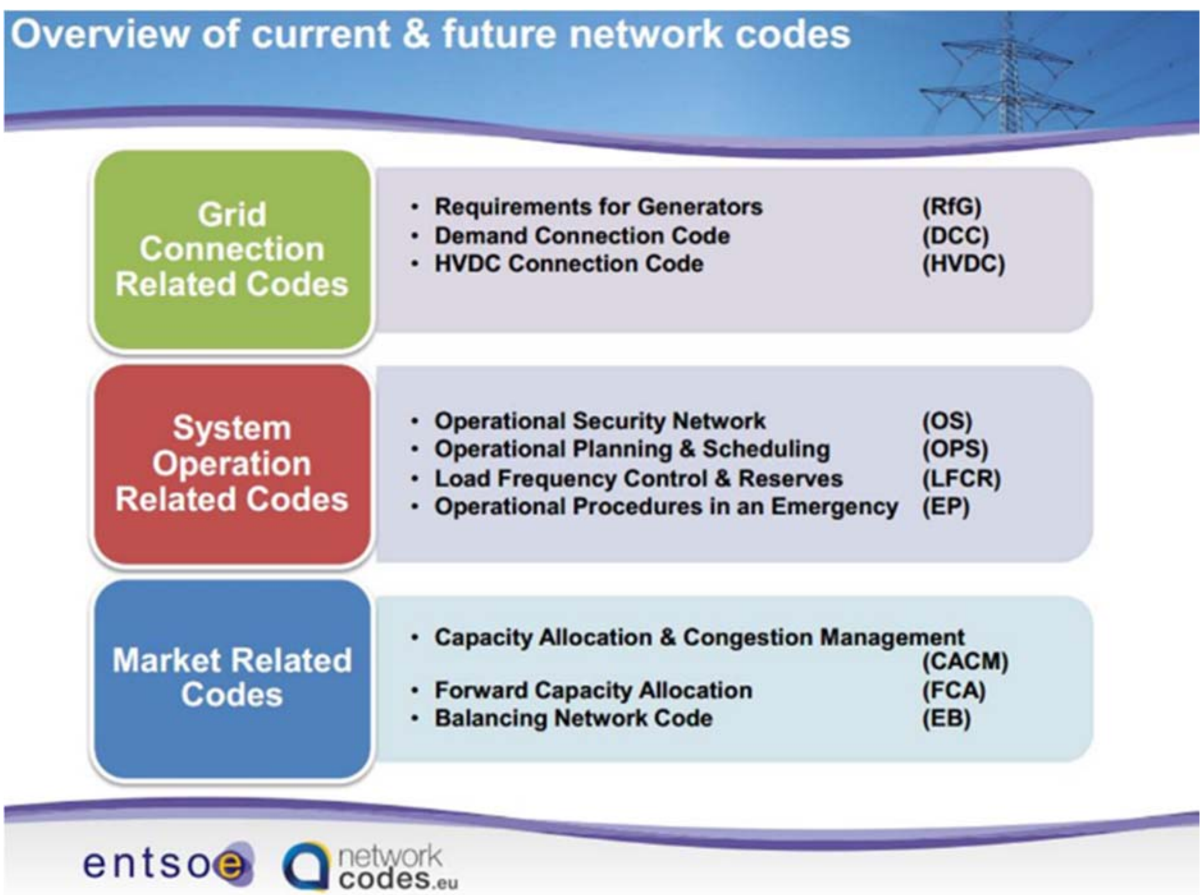
Operating and optimizing the grid under traditional circumstances is a remarkable feat of coordination and engineering. Even more so, accommodating a shifting and increasingly diverse generation portfolio requires innovative new regulations and controls, in addition to more advanced technology, modeling and analytics.

Europe

One of ENTSO-E's key tasks is to develop and implement legally binding network codes that govern transmission operations and allow a safe, secure grid with high levels of renewable energy and greater economic efficiency. There are ten codes in three categories under development.

The "System Operation Related Codes" are being designed to enhance communication among all 41 member TSOs; standardize forecasting, scheduling, and adequacy protocols; and clarify what is expected of TSOs, market regulators, and specific large generators and consumers.

Meanwhile, several groups of regional TSOs are attempting to coordinate modeling, planning, and dispatch, adding a layer of both granularity and coordination. The Transmission System Operator Security Cooperation (TSC) has developed a unique IT system to share data, particularly in order to integrate wind energy and manage cross-border



[32] https://www.misoenergy.org/Planning/Pages/RegionalGenerationOutletStudy.aspx
[33] http://www.nrel.gov/analysis/re_futures/

power flows.[34] Similarly, the Security Service Center (SSC) is coordinating its two member organizations in analyzing day-ahead congestion projections and harmonizing system security standards.[35]

The Coordination of Electricity System Operators (Coreso) contains members of both TSC and SSC, and serves to provide longer-term measures to develop two-day-ahead, day-ahead, and close-to-real-time modeling to help manage renewables on the system.[36] In 2012, Coreso worked with a data provider to launch a modeling system capable of creating wind and solar generation forecasts for Europe. In 2014, Coreso was able to implement two-day ahead forecasts for members, which enables more specific adequacy planning.[37] These efforts are foundational as Europe moves towards a single internal energy market, and to managing greater flows of power across borders.

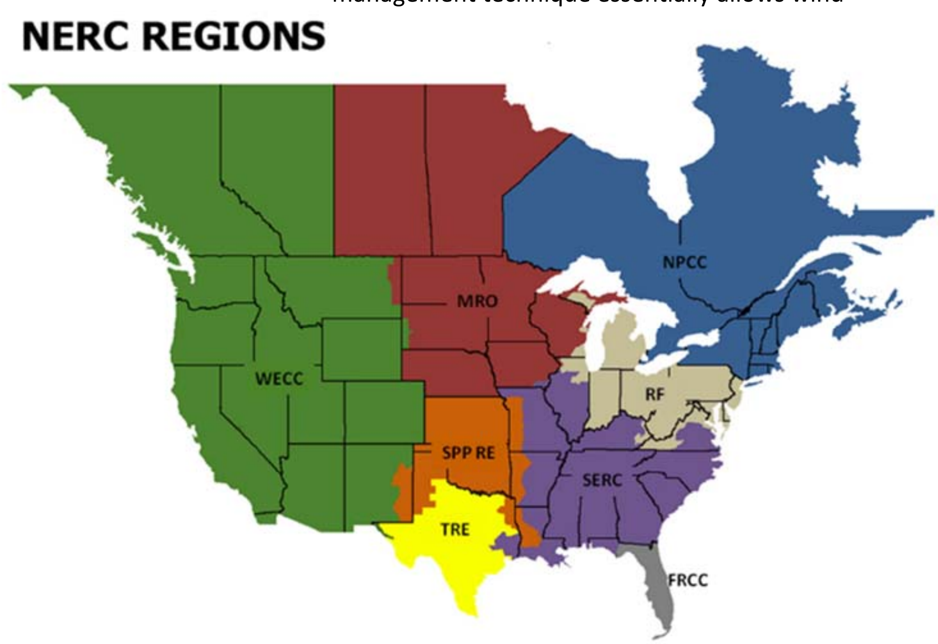
United States

There are more than 130 balancing areas in the U.S., each with its own unique generation, transmission, and load profile. The North American Electric Reliability Corporation (NERC) wields FERC-delegated authority to set standards for, among other items, reliability, operations, modeling, and analysis for the U.S. bulk power system. Eight regional entities monitor and enforce compliance with NERC codes.

In 2007, NERC recognized that all areas of the country would soon be coping with an influx of renewable generation on the system. In response, it created the Integration of Variable Generation Task Force.[38] The Task Force has put out a series of studies and recommendation reports on practices and metrics to help with the integration of this renewable capacity, though NERC has yet to issue standards specifically targeted at the integration of renewable resources.

Some RTOs/ISOs are proactively attempting to manage integration challenges. While they primarily function as energy markets, these organizations often include multiple balancing authorities and serve to coordinate grid operation, generation dispatch, and forecasting. The Midcontinent Independent System Operator (MISO) has developed unique tools to help plan for and integrate substantial amounts of wind generation, while maintaining reliable power supply and market efficiency.

Perhaps the tool with the most impact is "Dispatchable Intermittent Resources." Enabled by frequent, near-real-time wind forecasting, this management technique essentially allows wind



Source: North American Electric Reliability Corporation

[34] http://www.tscnet.eu/what-we-do/
[35] http://www.securityservicecentre.eu/default.aspx
[36] http://www.coreso.eu/mission/vision-towards-the-future/
[37] http://www.coreso.eu/regional-renewable-energy-forecast-integrated-in-the-day-ahead-report-2/
[38] http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC-CAISO_VG_Assessment_Final.pdf

power to be a controllable resource that can match demand and market signals. The benefits of more predictable wind energy include improved congestion management performance, more accurate market prices, fewer curtailments of wind, and superior overall system performance.[39]

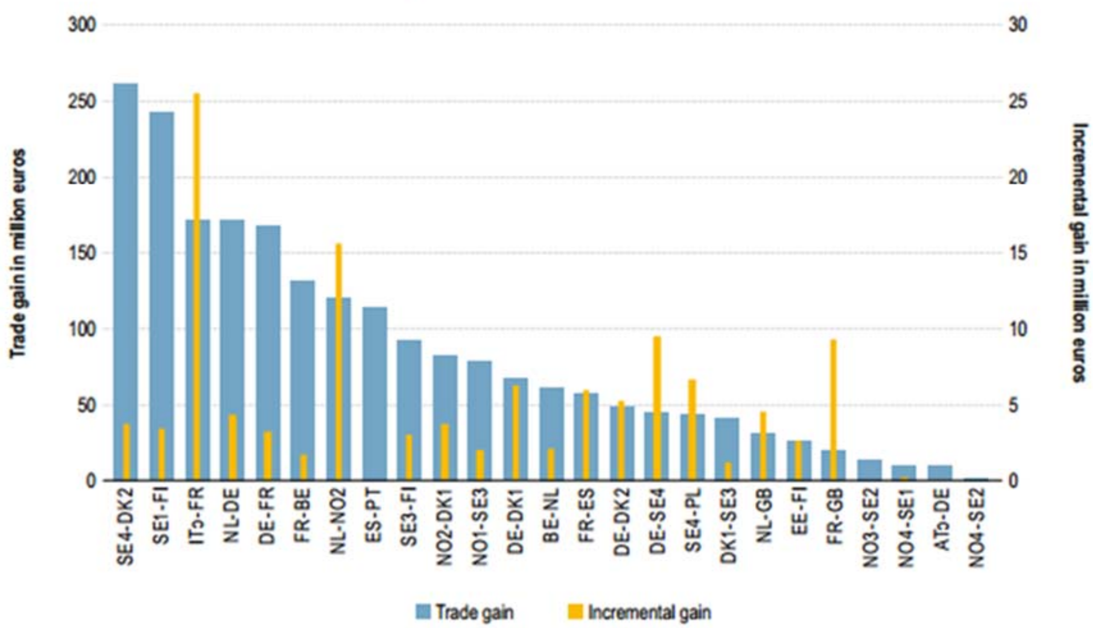
Additionally, MISO has implemented a novel "zonal approach" to transmission planning. Each zone is "designed to optimize wind generation placement and to minimize distance to other fuel sources, such as natural gas."[40] These zones are then connected into the grid via "Multi-Value Projects" (MVPs). The MVPs take into account renewable energy policies at the state and federal levels. They also must provide measurable economic value across multiple pricing zones with MISO and aid in system reliability.

Through this holistic planning approach, the MISO projects will generate nearly US$50 billion (€40 billion) in benefits through cheaper renewable power, greater system optimization, and avoided costs. [41]

MARKET STRUCTURES

Like most other industries, the power sector can benefit from competitive markets. Putting in place appropriate regulations and systems for an industry that has developed in disparate ways is complex. Incorporating renewable energy and climate change policies adds further challenges. Harmonizing these priorities in a way that captures the greatest efficiencies – and cost savings for consumers – is central to the electricity system of the future.

Figure 20: Simulation results: gross welfare benefits from cross-border trade and incremental gain per border – 2012 (million euros)



Source: PCR project, including APX, EPEX SPOT, Nord Pool Spot, GME, OMIE

Note: ɔ indicates that the zone is a GME zone; DK, NO and SE with a number refer to the different bidding zones in Denmark, Norway and Sweden.

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[39] https://www.misoenergy.org/Library/Repository/Report/DIR%20Implementation%20Guide.pdf
[40] https://www.misoenergy.org/Library/Repository/Communication%20Material/One-Pagers/Transmission%20Planning%20MVP.pdf
[41] Ibid.

Europe

A 2012 study by the Agency for the Cooperation of Energy Regulators showed the potential for billions of euros in efficiency gains from increased transmission capacity and market integration. Competition across a broader area allows power to flow economically from lower-priced areas to more expensive ones, leading to lower average prices.[42] A pilot project was inaugurated in February 2014 among 14 EU members for day-ahead power trading.

Transmission interconnections and sufficient capacity are essential to an integrated market. A recent analysis of the state of market integration, or "coupling," suggests transmission constraints can lead to price differentiation even in adjacent, coupled markets.[43]

Running counter to efforts to further integrate European markets are national policies and structures, such as renewable energy support schemes that only support domestic generation, and domestic capacity markets. Both of these mechanisms are designed to protect economic competitiveness and security of supply, but they can result in lost benefits from broader and more effective allocation of resources.[44] For example, the UK is planning a national capacity market with payments going only to domestic capacity providers, to "reduce risks to security of supply in the medium term and beyond."[45] The UK's direction is understandable, particularly in light of their thin reserve margins. Yet even more money could be saved in the broader market – enabled by more transmission interconnection capacity – due to greater competition and less overall capacity needed to secure supply.[46]

To help address transmission constraints and optimize market integration and the flow of power, the EU has created the Connecting Europe Facility (CEF). CEF is making €5.85 billion (US$7.38 billion) in grants available to expand cross-border transmission supporting renewable energy. The funding is aimed at projects that "would normally not make it into the investment programmes of infrastructure developers."[47] The ambitious funding will help Europe meet its climate and clean energy goals, and the attenuating economic benefits, swiftly.

United States

The U.S. finds itself in limbo following the wave, and subsequent cessation, of deregulation and restructuring. Parts of the country retain vertically integrated monopoly structures for utilities, while others have separated power generators from transmission and distribution companies. This has led to various market structures across the country. Presently, seven RTO/ISO-organized markets are in operation, two of which are confined to single states: Texas and California.

In different ways, these RTOs/ISOs have accomplished what the EU's IEM aspires to achieve. They operate wholesale capacity markets across broad regions, oversee the transmission planning process, and drive value for customers by capturing efficiencies from market competition. PJM,

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[42] http://www.dice.hhu.de/fileadmin/redaktion/Fakultaeten/Wirtschaftswissenschaftliche_Fakultaet/DICE/Discussion_Paper/109_Boeckers_Haucap_Heimeshoff.pdf

[43] Ibid. pp. 32-33, 36

[44] Ibid. pp. 26

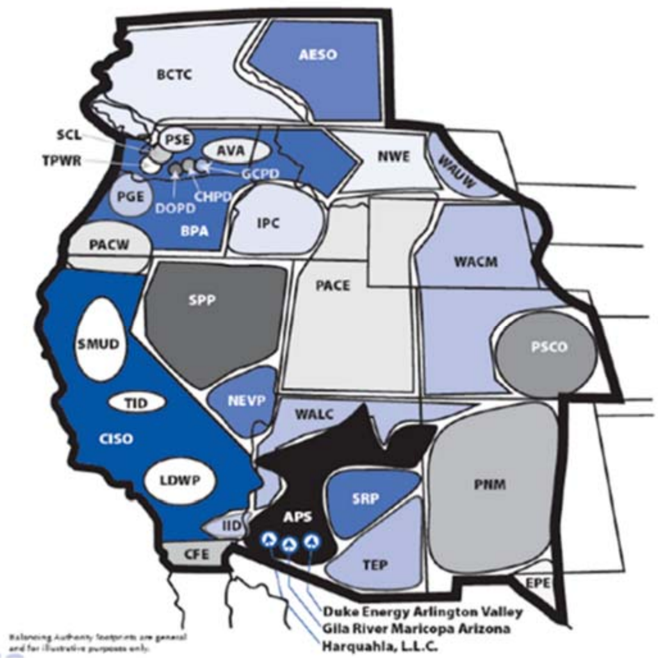
[45] https://www.ofgem.gov.uk/ofgem-publications/88523/electricitycapacityassessment2014-fullreportfinalforpublication.pdf

[46] http://www.dice.hhu.de/fileadmin/redaktion/Fakultaeten/Wirtschaftswissenschaftliche_Fakultaet/DICE/Discussion_Paper/109_Boeckers_Haucap_Heimeshoff.pdf p.26

[47] http://inea.ec.europa.eu/en/cef/cef_energy/cef_energy.htm

operating in the Mid-Atlantic and Midwest, has managed to increase the availability of renewable energy to its members while also reducing wholesale costs. This is in large part due to the “price suppression” effect of renewable energy, which has zero marginal costs and therefore drives down the market clearing price. In fact, Synapse Energy Economics modeled US$2 to 7 billion (€1.6 to 5.6 billion) in net benefits by 2026 after transmission build-out if states in PJM were to double their renewable portfolio standards.[48] PJM and other markets also allow for other non-generation resources, such as demand response and energy efficiency, to bid into the market, reducing barriers to the integration of variable renewable resources.

BALANCING AUTHORITIES IN THE WESTERN ENERGY COORDINATING COUNCIL

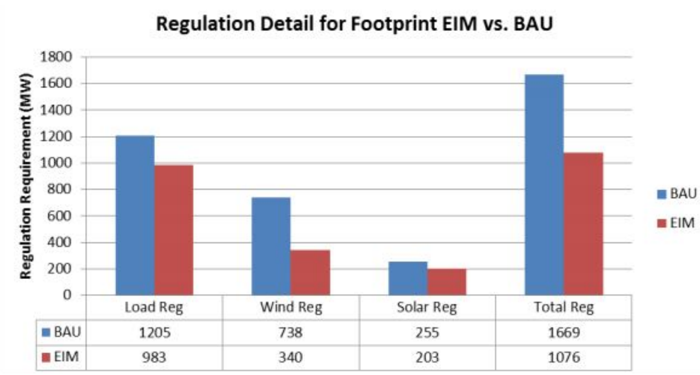


The economic and climate benefits of RTOs/ISOs have led to their expansion, as well as to competition among them. The territories of MISO and PJM, the two largest RTOs/ISOs, intertwine and would benefit from enhanced interconnection. The two organizations are working to address the operational issues at the seams and have set up a Joint and Common Market Initiative with the goal of developing a combined market.[49]

By contrast, there are 38 independent balancing authorities in the Western Interconnection, each responsible for generation dispatch, forecasting, and reserve adequacy. As renewable energy continues to gain prominence on the grid, balancing the electric load in small, isolated areas becomes increasingly challenging. NREL and others have been leading the development of tools for balancing authorities in the West to enhance planning and coordination to accommodate greater renewable generation and reduce inefficiencies. These include intra-hour scheduling and dispatch coordination.[50] The resulting savings stem largely from reduced reserve and grid regulation requirements, particularly for wind and solar.[51]

Unlike Europe, the U.S. failed to implement “Standard Market Design,”[52] and also lacks a centralized funding mechanism similar to the CEF. To address the investment gap, a handful of states have set up Renewable Energy Transmission Authorities to provide state support for the development of transmission for renewable power. A prime example is the New Mexico Renewable Energy Transmission Authority, which formed a public-private partnership with a developer to build a 200-mile line to connect 1,500 MW of wind to markets in the Four Corners region.[53] In the absence of coordinated planning in RTOs/ISOs, this innovative approach can help states

[48] http://www.synapse-energy.com/sites/default/files/SynapseReport.2013-05.EFC_.Increased-Wind-Power-in-PJM.12-062.pdf
[49] http://www.pjm.com/committees-and-groups/stakeholder-meetings/stakeholder-groups/pjm-miso-joint-common.aspx
[50] http://energyexemplar.com/wp-content/uploads/publications/Balancing%20Authority%20Cooperation%20Concepts%20-%20Intra-Hour%20Scheduling.pdf
[51] http://www.nrel.gov/docs/fy12osti/54660.pdf
[52] http://www.ferc.gov/EventCalendar/Files/20050719123006-RM01-12-000.pdf
[53] http://www.westernspiritcleanline.com/site/page/project-description



	BAU	EIM	Reduction
Total Regulation	2765	1607	42%
Spin	2236	977	56%
Non-Spin	4472	1955	56%
Total	9473	4539	52%

acquire affordable renewable energy to help meet their RPS targets.

CONCLUSION

Transmission will play an important role in the pursuit of renewable energy goals and efforts to mitigate the effects of climate change. As the electricity system evolves, so, too, must the ways in which the grid is planned, paid for, and regulated. While the challenge is tremendous, forward-thinking efforts to modernize the transmission system and its management in Europe and the U.S. are showing meaningful results. Continuing these efforts, while allowing for flexibility as the power industry evolves, is essential to achieve the clean, affordable, and reliable energy future we seek.

ABOUT THE AUTHOR

Ben Springer is a Senior Associate with the Energy Future Coalition, a broad-based, non-partisan energy policy initiative. He works on progressive, bipartisan energy policy issues including transmission, utility sector reform, energy efficiency, and biofuels. He earned a Bachelor's of International Studies and Religious Studies from the University of South Carolina, and a Master's of Politics and International Studies from Uppsala University in Sweden.

Loan Guarantees for Scaling Up Innovative Technologies

Peter W. Davidson
U.S. Department of Energy Loan Programs Office

First-of-their-kind projects often face challenges securing full commercial financing because their technologies have not before been deployed at commercial scale in the United States. By providing loan guarantees, the U.S. Department of Energy's (DOE) Loan Programs Office (LPO) aims to help bridge this financing gap and support the creation of new clean energy markets.

This paper outlines how LPO has used loan guarantees to encourage debt market participation by commercial lenders. The paper focuses on the role of loan guarantees in launching a robust U.S. utility-scale photovoltaic (PV) solar market and how LPO can continue to use its authority to scale up renewable energy in the United States.

BRIDGING THE COMMERCIAL DEPLOYMENT FINANCING GAP

The DOE LPO issues loans and loan guarantees to finance deployment of innovative energy projects and advanced technology vehicle manufacturing facilities in the United States. These projects and facilities support the Administration's efforts to reduce greenhouse gas emissions and move the United States closer to its clean energy future while the nation continues to be a global leader in clean energy technology.

LPO plays a critical role in the market by taking on risk of lending to projects that use innovative technology. This bridges the gap for commercial lenders who are often unwilling or unable to take on the risk of innovative technology until it has a solid history of commercial operation. Once the technology is proven at scale through the first few projects financed in part by DOE, the private market takes over financing successive projects.

LONG-TERM, LOW-COST FINANCING

A DOE loan guarantee can support debt from either a commercial lender or the Federal Financing Bank (FFB). To date, a majority of loans that DOE has guaranteed have been financed through FFB, which is able to offer interest rates based on the equivalent U.S. Treasury rate, plus a credit-based spread of approximately 0.5%-1.5%.

Additionally, loans guaranteed by DOE can provide long-term financing, up to 30 years, based on the useful life of the asset. This longer tenor is attractive because cash flow for the project is usually extended over the life of typical 20- to 30-year power purchase agreement. Commercial loans generally have a tenor no longer than 15 years.

This long-term, low-cost financing accelerates the deployment of innovative renewable technologies and provides confidence to commercial lenders for future projects.

LOAN GUARANTEE EFFECTS ON THE RENEWABLE MARKET

One of the reasons some commercial lenders are typically unwilling to take the financial risks of innovative technologies is a lack of performance data that would allow them to assess the technical and operational risks of the projects. LPO helps to address this issue with a team of financial, technical, environmental, and legal professionals with expertise in innovative technologies. LPO's professionals conduct rigorous due diligence for each transaction, which provides important lessons and information for future transactions financed by commercial lenders.

Financial Institution Partnership Program

The Financial Institution Partnership Program (FIPP), introduced in 2010, brought co-lenders into LPO projects. FIPP is based on a syndicated lending structure with which most financial institutions are familiar. Private sector lenders performed the initial diligence and loan structuring before bringing a deal to DOE. After determining that an application met DOE's eligibility and program criteria, DOE worked co-operatively with the private sector lenders on in-depth due diligence and documentation. The 550-megawatt (MW) Desert Sunlight PV project near Palm Springs, CA is a representative FIPP project. The project was developed by First Solar. GE Energy Financial Services and NextEra Energy Resources each acquired half of the equity in the project contemporaneously with the closing of the project's FIPP loan. The FIPP loan included a partial DOE guarantee of the $1.46 billion in loans provided by a syndicate of private institutional investors and commercial banks, headed by lead lenders Goldman Sachs Lending Partners LLC and Citigroup.

New Investors in Renewable Energy

Some of the innovative projects in LPO's portfolio have attracted investors that have not previously been involved in the renewable space. Google made its first significant clean energy investment in the Ivanpah concentrating solar power project, which was financed in part by a DOE-guaranteed loan. One of Warren Buffett's first significant clean energy investments, through MidAmerican Energy Holdings Company, was in the Agua Caliente PV solar project, which was also financed in part by a DOE-guaranteed FIPP loan.

The First Tax Equity Deal in DOE's Portfolio

LPO has also cooperated with project sponsors who sought new tax equity investors (an approach used by sponsors to maximize the value of available tax credits as the facility approaches commercial operation). Working with LPO to reach agreement on related amendments to the loan guarantee agreement, Abengoa Solar, Inc. brought in Liberty Interactive Corp. as a $300 million tax equity partner to the Solana concentrating solar power project just prior to the facility becoming operational. This was the first tax equity deal in DOE's portfolio and attracted a significant investor into the clean energy marketplace for the first time.

Clean Energy Investment in Public Markets

Publicly traded yield companies (yieldcos) are an emerging trend in clean energy finance, which are allowing institutional and retail investors to provide equity for clean energy projects. Yieldcos use the well-known structure of a public company to leverage and recycle capital while inviting a new class of investors to clean power generation projects. One of the first examples in the clean energy space was NRG Yield, formed by NRG Energy in connection with the California Valley Solar Ranch, a $1.2 billion loan guarantee recipient. Likewise, LPO worked with Abengoa to permit transfer of ownership of the Solana and Mojave concentrating solar power projects to Abengoa Yield. In total, yieldcos have acquired over 8 GW of assets in their portfolios – 78% renewable energy – and have raised a total of $3.8 billion since 2013.[54]

Utility-Scale Photovoltaic Deployment

The utility-scale photovoltaic (PV) solar industry in the United States provides an example of how LPO's role at the onset of commercial deployment helps to accelerate a technology's advance to commercial maturity.

In 2008, no PV solar projects larger than 20 megawatts (MW) existed in the U.S. Yet, the utility-scale PV project pipeline exceeded 6,000 MW in announced projects by 2009.[55] Commercial lenders were unwilling to take the technology risk associated with scaling up to PV projects larger than 100 MW. Project sponsors that were willing to invest equity in the projects and had agreements with electric

[54] https://financere.nrel.gov/finance/content/deeper-look-yieldco-structuring
[55] https://www.seia.org/sites/default/files/us-solar-industry-year-in-review-2009-120627093040-phpapp01.pdf

utilities to purchase the power were left without debt to complete financing for these projects.

To address the lack of commercial debt, LPO issued $4.65 billion in loan guarantees in 2011 through the Section 1705 Program for the country's first five PV projects larger than 100 MW. These projects total 1.5 gigawatts (GW) in capacity. After the Section 1705 Program expired on September 30, 2011, 17 more PV projects larger than 100 MW have been commercially financed without DOE loan guarantees and represent 3.8 GW of total electric capacity. Overall, U.S. utility-scale PV deployments have increased, setting a record by installing 2.3 GW in 2013.[56] Growing deployment has driven down costs with utility-scale solar PPA prices decreasing by approximately two-thirds between 2008 and 2014.[57]

FUTURE LOAN GUARANTEES FOR RENEWABLE ENERGY

DOE has $40 billion in remaining loan and loan guarantee authority – including up to $4 billion for renewable energy and efficiency energy projects. The Renewable Energy and Efficient Energy Projects Loan Guarantee Solicitation is intended to support technologies that are catalytic, replicable, and market-ready. While any project that meets the appropriate requirements is eligible to apply, DOE has identified five key technology areas of interest: advanced grid integration and storage; drop-in biofuels; waste-to-energy; enhancement of existing facilities including micro-hydro or hydro updates to existing non-powered dams; and efficiency improvements.

For its open solicitations, LPO is promoting co-lending in its transactions. With fewer dollars available for guarantees of debt for renewable projects than dollars that were available under the Section 1705 Program, co-lending would allow LPO to maximize the number of projects that it can help finance through smaller loan guarantees for more projects. LPO seeks to accelerate commercial debt financing for innovative renewable technologies by working cooperatively with financial institutions to share due diligence experience.

ABOUT THE AUTHOR

Peter W. Davidson was appointed by President Obama in May 2013 to serve as the Executive Director of the Loan Programs Office (LPO) at the U.S. Department of Energy. Mr. Davidson oversees the program's more than $30 billion portfolio of loans and loan guarantees, making it the largest project finance organization in the U.S. government.

Prior to leading LPO, Mr. Davidson was Senior Advisor for Energy and Economic Development at the Port Authority of New York and New Jersey and was the Executive Director of New York State's economic development agency, the Empire State Development Corporation. Before entering government service, Mr. Davidson was a media industry entrepreneur and an executive in the investment banking division of Morgan Stanley & Co. Mr. Davidson has a BA from Stanford University and an MBA from the Harvard Business School.

[56] http://www.pv-tech.org/news/us_installed_record_2.3gw_utility_scale_solar_in_2013_says_snl_energy
[57] http://www.greentechmedia.com/articles/read/Five-Things-You-Should-Know-About-the-US-Utility-Scale-PV-Market

MUNICIPALITIES PLAYING A LEADING ROLE IN U.S. RENEWABLE ENERGY DEVELOPMENT

Dino Barajas
Akin Gump Strauss Hauer & Feld LLP

In an ever-changing, evolving global economy, renewable energy developers and investors are looking for the panacea that encourages continued economic growth and revitalizes new project development in the United States' renewable energy sector. As investor-owned utilities (IOUs) achieve required state renewable portfolio standards (RPSs) levels, their willingness to seek even more power purchase agreements (PPAs) for renewable energy projects appears to be declining. Additionally, corporate off-takers have become more discerning in who they are willing to contract with for their renewable energy off-take requirements. The combined pressures of fewer PPAs in the market and increased demands imposed by potential off-takers has made the U.S. quite a competitive renewable energy market. The present transitional market phase has created challenges for both power producers and integrators. For the U.S. to continue progress towards scalable levels of renewable energy deployment, near term solutions must be implemented during this time of market uncertainty.

The challenges in the market are compounded by a reduction in the size of contracted megawatts (MW) under available PPAs.[58] This makes cost reductions from economies of scale even more difficult. Opportunities to secure PPAs of 200 or 300 MW under a single contract are increasingly scarce and hyper-competitive. Developers and investors are now looking for opportunities to aggregate potential projects from a single energy off-taker in multiple or serial stages.

The large influx of renewable energy into power grid systems in some markets, traditionally dominated by fossil-fuel energy production, also raises issues relative to grid stability and energy storage needs. While renewable energy is fully cost competitive in many markets, these additional cost considerations can make it more challenging for new projects to garner energy off-taker attention.

Luckily, there are many paths to the market, and municipal utilities provide a pathway to harness various market forces and provide opportunities for renewable energy developers and their investors. They are in the unique position of being able to use their energy-offtake purchasing power to address the economic development needs of their constituents and communities. Unlike IOUs, which primarily focus on profitability for their investors, municipal utilities can consider other components such as community economic development commitments among selection criteria for new renewable energy providers. Such favorable conditions magnify municipal utilities' purchasing power and clout.

Economic development takes many forms. In some cases, job creation and capital investment commitments can be the objective measures by which prospective renewable energy developers may be assessed. At a time when the U.S. economy continues to stagnate and state budgets are strained, private-sector economic development programs are a method of leveraging the public sector's purchasing power and amplifying the

[58] "The Sustainable Energy in America Factbook Provides the Leading Independent Analysis and Market Intelligence for Clean Energy Sectors in the U.S." *Business Council for Sustainable Energy*, 2014. http://www.bcse.org/sustainableenergyfactbook.html.

benefits, which renewable energy brings to local communities.

Three to five years ago, IOUs dominated the market with annual requests for proposals for large-scale renewable energy projects. Now that large-scale RFPs are less common, municipalities are serving as favorable opportunities for deployment. By working with municipal utilities, renewable energy developers and their investors gain a strong creditworthy off-taker, which is extremely attractive to project finance lenders and tax equity investors.

The benefits of local job creation and capital investment by renewable energy developers also help local politicians and energy policymakers sell the benefits of renewable energy to their local constituents. These jobs are often higher paying, providing long-term benefits to the local communities, and also continue beyond the initial construction period of the renewable energy project with which they were associated.

The key for municipal utilities is a realistic economic development structure that provides flexibility to the renewable energy developer and its investors, such that the types of jobs created can evolve over time as the activities of the developer progress. Additionally, to the extent that a developer is provided with the option to select between greater job creation and capital investment interchangeably, project participants can adjust their compliance with the program requirements based on the unique characteristics of the local community in which they are trying to operate.

Job creation and capital investment requirements should also be calculated by taking into account the aggregate economic footprint of all project participants (including contractors and advisors). This would permit the benefits to ripple through numerous sectors and have a multiplying effect on the local economy.[59] The potential types of economic development goals are only limited by the creativity of local policymakers. In some cases, policymakers may elect to generate long-term future benefits within their communities by requiring that some portion of the economic development efforts be focused on education and job training. Educational programs may ensure that jobs are not simply transferred into a local community from other established labor bases in surrounding areas (with the aim of creating a temporary higher tax base during the construction phase of a project), but instead that local community constituents will have an opportunity to learn specialized technical skills that will lead to long-term, higher-paying jobs in the renewable energy sector.

The renewable energy industry has already witnessed a success story using the sliding scale economic development model: the City of San Antonio’s Alamo solar projects. CPS Energy, San Antonio’s municipal-owned utility, successfully tendered a RFP for a 400 MW solar project build-out, being developed in seven distinct stages as the developer, OCI Solar Power, achieves the required economic development milestones.[60] The Alamo series of projects is the largest solar development presently being built in the U.S. and serves as a model of the role that municipal utilities have in shaping the future of renewable energy development.[61] The aggregate construction costs for the investment are estimated to be US$1.2 billion, and the overall economic effect for the City of San Antonio is estimated to be US$700 million annually.

Although the entire renewable energy sector stands to benefit from economic development programs, the solar industry is in a unique position to benefit from this type of structure, given the ability of solar developers to scale-up their projects in smaller phases. The ability to aggregate smaller projects into

[59] "The Socio-economic Benefits of Solar and Wind Energy." *International Renewable Energy Agency*, 2014. http://www.irena.org/DocumentDownloads/Publications/Socioeconomic_benefits_solar_wind.pdf.
[60] "CPS Energy Works for You." San Antonio's Energy Future and You. March 22, 2014. Accessed October 31, 2014.
[61] "Texas: Alamo Energy Projects." OCI Solar Power. January 1, 2014. Accessed October 31, 2014. http://www.ocisolarpower.com/texas.html.

a larger overall offtake arrangement also preserves the purchasing power of the municipal utility and makes any request for proposals issued by it attractive to developers and investors. Project finance lenders and tax equity investors may also prefer these smaller, reproducible projects because each one is a ring-fenced, standalone project that can easily be financeable with lower overall transaction costs across multiple financings.

Additionally, having municipal utilities take a leadership role in renewable energy development will help state energy policy makers coordinate their efforts promoting RPSs with local public utility agencies. These coordinated efforts would also lead to increased benefits to a state's overall economic well-being and help coordinate public spending on a state-wide level.

The critical decision for municipal utilities is to flex their economic muscles and enhance their purchasing power. Applying the public sector's budget already earmarked for energy purchases, while requiring additional public benefits as part of the purchased good, is an important way to stretch every public dollar while promoting increased green energy production.

The future growth of the U.S. renewable energy sector will depend in part on the ability of industry participants to be creative in structuring innovative offtake arrangements. The municipal utility economic development model will helpfully be one of those alternatives.

ABOUT THE AUTHOR

This article was prepared by Dino Barajas, partner with Akin Gump Strauss Hauer & Feld LLP specializing in project finance and renewable energy transactions. Mr. Barajas has worked in the energy sector for the last 20 years. He received his J.D. from Harvard Law School. Tel: (310) 552-6613; email dbarajas@akingump.com.

CASE STUDY: INTEGRATION OF RENEWABLE ENERGY BY USING UNCERTAINTY

Rolf Gibbels and Amar Pradhan
IBM

The global energy industry has made great strides in deploying new resources for renewable power generation. Renewable energy makes up more than 20% of energy capacity in many electrical grids. However, most grids are unable to seamlessly integrate this carbon-free power. The estimated cost of curtailing wind power in North America was $2.6 billion in 2013. In addition, in some markets ancillary service costs are rising. In many grids this is the sole approach to effectively combat renewable power intermittency. This paper discusses how analytics, forecasting, and real-time planning solutions can directly improve the integration of renewable power sources. It details a 2008 project to automate economic dispatch and unit commitment (UCO) for Red Eléctrica, an electrical grid operator in Spain tasked with integrating greater than 30% renewable power; a case study of UCO 2.0, developed in 2013 to allow Hydro Quebec optimal coordination of a growing wind energy portfolio; and UCO 3.0, which incorporates advanced power forecasting as an input to stochastic modeling. Implementation of these processes has enabled a higher percentage of renewable power to be integrated into complex electrical grids at a lower cost.

1. INTRODUCTION

Wind and solar power rely on weather conditions. Generation intermittency can lead to uncertainty about future power availability. In markets without high confidence in future power production, electrical grid operators may need to employ costly contingencies, such as curtailing carbon-free renewable power or maintaining high levels of spinning reserves, whereby fossil power plants are paid to run generators under their maximum or ideal output to provide power in the case of a shortfall due to changing weather conditions. Such ancillary services are growing, from a base of 3-5% of U.S. electricity cost. Moreover, as renewables continue to provide a larger share of power capacity, such contingencies will not be sufficient. Other solutions, such as energy storage, are in development, but will best succeed when combined with sophisticated software and business process technologies. This article details how IBM and its clients are addressing these challenges through software tools and business processes to conduct advanced economic dispatch and unit commitment.

1.1 IBM's Road Map for Renewables Integration via Industry Software Solutions and Business Processes

IBM's longstanding expertise in renewables integration and forecasting has been a primary driver for its activities and research in the field of power generation. The intermittent and variable nature of renewable power can pose significant challenges. Harnessing data is becoming more and more critical to increasing machine availability, reducing downtime and optimizing performance. IBM asserts these challenges require a new approach to systems and information integration supported by a strong underpinning of advanced analytics. Systems built with this in mind can reduce the overall operational and maintenance expenses associated with integrating large-scale renewable power into the generation portfolio.

IBM identifies four phases of maturity along the progression path to large-scale renewable energy integration. Each phase is a critical step in reaching higher business value for all industry stakeholders:

1. **Build:** Support project planning, as well as financing and overall project viability with

integrated, effective systems, processes, and insights for improved design, siting, construction, and power forecasting.

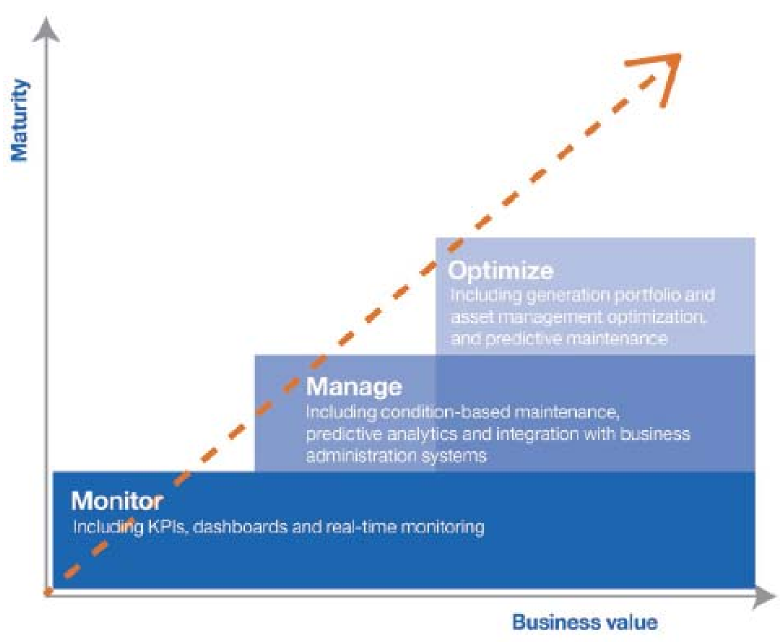
2. **Monitor:** Integrate fragmented monitoring systems and create common information models to monitor an entire generation fleet, and bring together systems and information from various original equipment manufacturers to enable better performance and compliance.

3. **Manage:** Integrate renewable and fossil power generation assets to improve the reliability and performance of all generation assets to manage energy source volatility.

4. **Optimize:** Plan for scalable integration of intermittent energy using advanced information management and predictive analytics to increase system flexibility, and balance conventional and renewable resources.

The following article focuses on the "Optimize" phase.

FIGURE 1: IBM'S ROADMAP FOR RENEWABLES



2. MAIN CONTENTS

2.1 Economic Dispatch[62] and Unit Commitment[63] Explained

Unit Commitment and Economic Dispatch (Unit Commitment Optimization, or UCO) models are used to schedule hourly production of power generators for periods up to a week in advance. The objective is to minimize the costs of operating the generators to optimize the forecasted customer demand. These costs include fuel, startup, carbon, etc. The constraints represent the requirement to serve hourly customer loads, various reserve requirements, minimum uptimes and downtimes for generators, and ramping limits for generators. UCO models are also increasingly used in the bidding process in power markets.

2.1.1 The current state of UCO technologies

UCO is the power-generation scheduling of a portfolio of assets, taking into account uncertainties. The optimization of assets takes into consideration a broad set of parameters prevalent in the power system. Parameters such as power production (e.g. weather uncertainty), maintenance, startup, shutdown, fuel, curtailment costs, demand, market price, distribution or transmission congestion, and similar factors. These parameters must be balanced to optimally schedule assets to deliver electricity to the market. Real-time data streams are fed into an optimization model, which outputs dispatch schedules that optimize unit commitment.

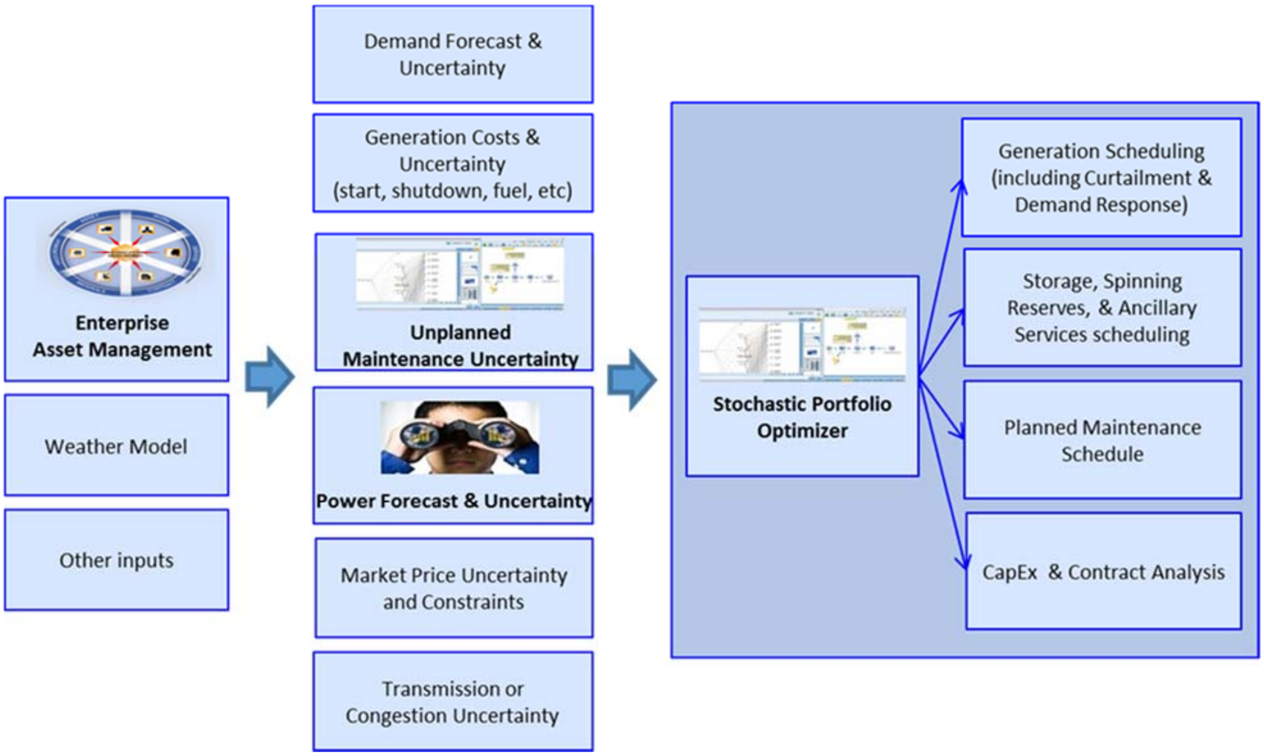
The following figure depicts some of the data streams that are inputted into an optimization engine, as well as some of the sample outputs used by asset schedulers.[64]

[62] The economic optimization process that determines a combination of generators and levels of electricity output to meet demand at the lowest cost, given the operational constraints of the generation fleet and the transmission system.

[63] Economic dispatch over a period of time.

[64]

FIGURE 2: ASSET MANAGEMENT OPTIMIZATION



attempts to optimally schedule these assets. The basic goals of schedulers are:

1. To ensure supply and demand match
2. To maximize profit
   - Reduce spinning reserves
   - Reduce renewables curtailment

Presently, most schedulers use deterministic modeling to achieve these goals. This modeling does not take into account the uncertainty of the given inputs, and certain assumptions are made to simplify the inputs.

Traditionally, ISO unit commitment decisions have been made using reserve adjustment methods, in which uncertainties in load and renewable generation are accounted for by imposing extremely conservative "Storage, spinning reserves, and to substantially overcommit resources as a means of ensuring that there is nearly always enough generation capacity to meet realized demand. As an example, in practice CAISO and some other ISOs use a programming approach, in which the system operating conditions are encoded as constraints, the outputs are treated as variables, and the objective is to minimize system operating cost.[65] Such methods solve issues related to matching supply and demand, but are not profit maximizing. For entities that are profit motivated, this approach is insufficient.

The approach of stochastic optimization is now being employed as a means of more accurately accounting for these uncertainties and reducing the problem of over commitment. Stochastic Portfolio Optimization enables schedulers to reduce margins of safety held via spinning reserves (and other ancillary services). Such extra costs of 3-5% are passed on to end consumers. Importantly, implementing Stochastic Portfolio Optimization allows schedulers to integrate

[65] http://energyexemplar.com/wp-content/uploads/publications/2014_Commercial/Large-scale%20Stochastic%20Optimization.pdf: For a full mathematical programming formulation of this problem, see, for instance, Padhy: Unit Commitment – A Bibliographic Survey. IEEE Transactions on Power Systems, 19(2):1196-1205, 2004, http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=01295033.

more uncertain supply (e.g. renewables) and uncertain load control (e.g. smart thermostats). A key financial aspect is the ability, over time, to reduce spinning reserves based on growing confidence in both the accuracy of the day-ahead forecast and, more importantly, confidence in the day-of timeframe, allowing a longer window for additional supply.

2.1.2 What are the macro shifts that necessitates a more robust UCO solution?

The task of scheduling generating assets has been affected by uncertainty and volatility from multiple areas. Advanced UCO seeks to address the following key factors:

1. Increases in intermittent, non-dispatchable renewable generation as a percentage of portfolios
2. Reduction in portfolio reserve margins due to retirement of nuclear and base-load coal plants
3. Unplanned maintenance uncertainty of large base-load plants
4. Increased usage of natural gas, which has significant price and availability volatility
5. Placement of renewable generation in locations with transmission options to load centers, to reduce line congestion and delivery uncertainty
6. Availability of a growing number of demand response solutions to respond to volatility
7. Availability of forward-looking energy products and hedges

The new challenges and opportunities listed above all require generating portfolios to be operated under greater uncertainty. Therefore, balancing authorities, utilities, and suppliers along the value chain must use tools that use uncertainty to the scheduler's benefit. Stochastic Portfolio Optimization provides such a tool.

2.2 UCO 1.0 - Automating UCO

Most electricity balancing authorities calculate unit commitment using in house built solutions. Many times a consultant is brought in for a few months to design and/or build a UCO system. These solutions tend to be based on various mathematical methodologies that are designed to find an optimal solution to a multi-function problem. Generally in such systems, individual constraint functions are stored (such as the cost to start up a given power generating asset), and then an optimization is run, testing various scenarios (or sets of conditions) to reach an optimal dispatch of resources. Such systems are generally:

1. Difficult to update with new constraints, generating resources, etc.
2. Built to use deterministic inputs.
3. Highly dependent on the accuracy of the input functions, specifically power and weather forecasts.

FIGURE 3: TRADITIONAL UCO

The following case study details a solution developed to optimize UCO and give the flexibility needed to update and address multiple complex variables.

2.2.1 Case Study – UCO 1.0 at Red Eléctrica de España

Formed in 1985 to create a unified power grid in Spain, Red Eléctrica de España (REE) was the first company in the world dedicated exclusively to power transmission and the operation of electrical systems. With more than 34,300 km of electricity lines and a current capacity of 91,071 MW, REE managed most of the Spanish high-voltage transmission grid and is responsible for the development, maintenance and improvement of the power network's installations.

REE was wracked by a combination of forces: production units with differing operations, markets with uncertain expected demand, opposing objectives, and uncertainty on how to better use each unit at any given moment. In addition, due to the need to comply with the measures established by the Kyoto Protocol, REE needed to increase the use of renewable energy sources and to reduce CO_2 emissions, dispatching all available wind energy.

Because conducting UCO requires a large number of variables to be considered over a time horizon, REE's home-grown solution had reached its limits. REE selected a suite of optimization tools to automate UCO: an Optimization Engine along with a Decision Manager to compare different scenarios and costs, as well as, a Development Studio, which was used as the integrated environment for building and maintaining the models solved by the Optimization Engine.

2.2.2 Results

REE's Operations Research personnel can now quickly and easily test generation scenarios. In addition, from a development and maintenance viewpoint, there has been a significant reduction in associated costs, as well as in the duration of the processes. Production costs decreased by €50,000-100,000 per day.

The automated UCO tools also helped the utility safely integrate the highest possible penetration of wind energy in the system, reducing its annual CO_2 emissions by 100,000 tons annually while also halving the use of noisy generators at night.

FIGURE 4: IMPLEMENTATION OF UCO 1.0 AT REE

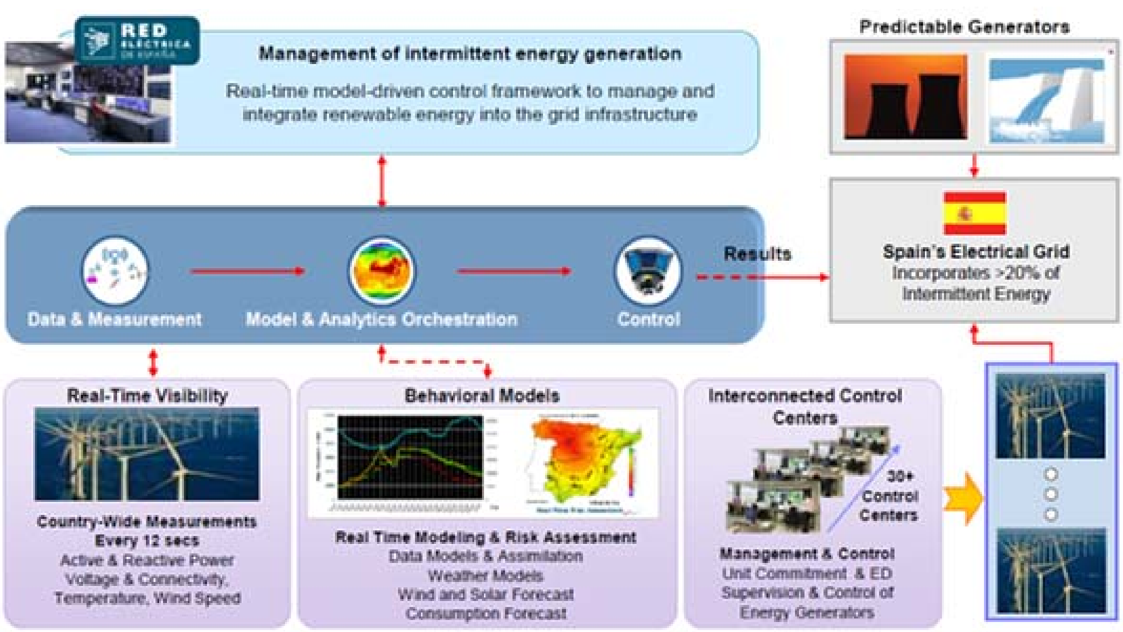
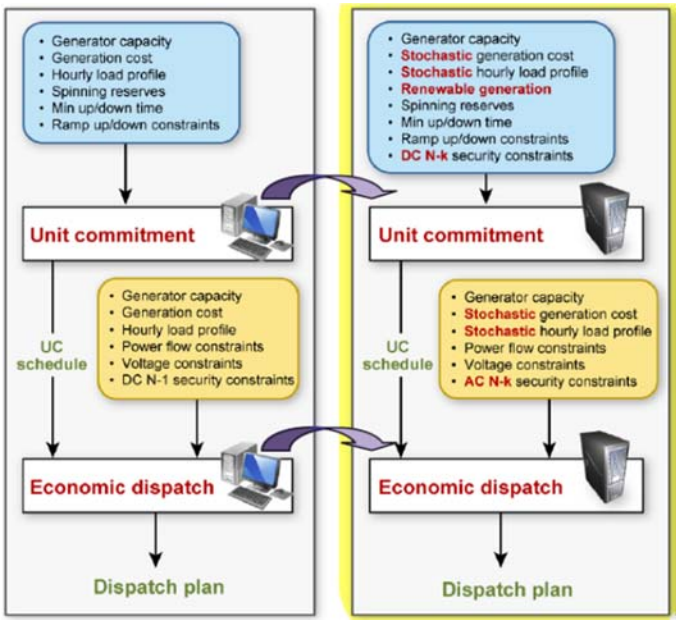


FIGURE 5: STOCHASTIC UCO



2.3 UCO 2.0 – Stochastic Modeling

Intermittent renewables generation in many cases has led utilities to build inefficient spinning reserve margins into the generation system to compensate for supply variation. IBM has developed systems that explicitly model uncertainty into UCO models, considerably reducing these margins. In a stochastic UCO approach, each of the uncertain parameters is associated with a set of possible scenarios encompassing the range of its possible outcomes. Each of these scenarios is paired with a probability that represents the likelihood that such a scenario will be realized. A programming methodology is used to determine the set of least-cost unit commitments that probabilistically account for each of the possible scenario realizations. The ability to consider a larger set of uncertain parameters, develop a larger set of scenarios, all within the time constraints, creates a more optimal solution.

Herein, such stochastic techniques were used and assumptions were made explicit in the model, rather than bluntly maintaining large reserves. In the following case study, spinning reserves use was reduced by up to 16%.

2.3.1 Case Study – UCO 2.0 at Hydro Quebec

Hydro Quebec manages the power generation and transmission for Quebec. This includes 20,900 miles of electricity lines and a present capacity of 43,892 MW (95% of which is hydro). Of the 60 hydro generating stations, 25 can be dispatched for balancing. Importantly, the authority has an ability to export almost 8 GW, and presently exports only ~3 GW of hydro power. If Hydro Quebec's wind resources are better understood, there is an opportunity to export up to 5 GW of wind power, which would generate an additional $2.2 billion/year in exports.

IBM's Wind and Hydro Integrated Stochastic Engine (WhISE) was developed by the Smarter Energy Research Institute (SERI) to help Hydro Quebec operate more effectively. WhISE considers:

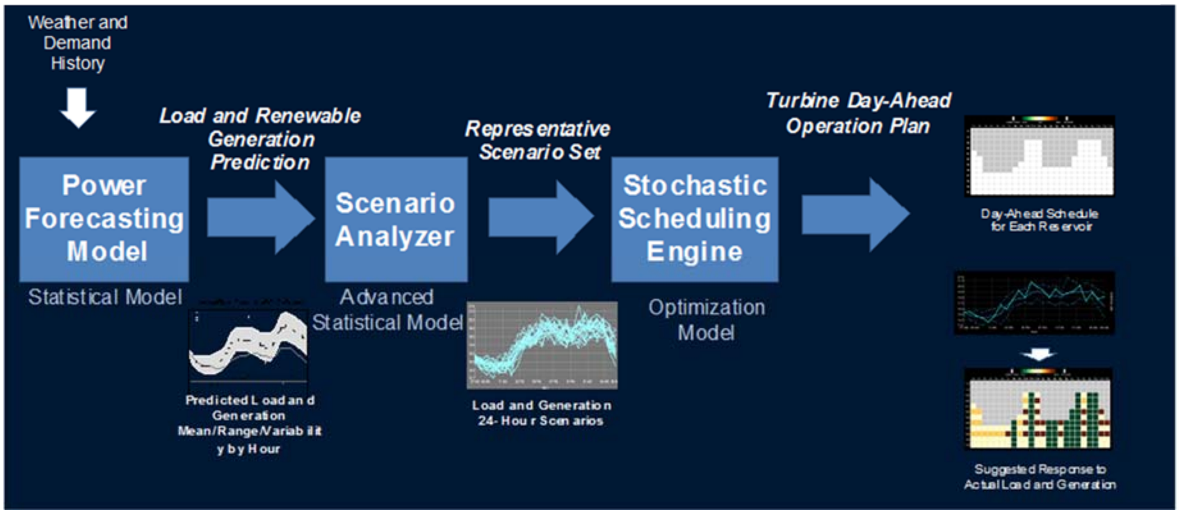
- Competing objectives like minimal disruption to turbines and minimal demand mismatch
- Diverse set of operational constraints
- Statistical models for variability and intermittency of demand and wind and solar generation

WhISE ouputs:

- Schedule for hydro turbines for each hour over the next day
- Plan on how best to respond to renewable output variability using scheduled turbines
- Minimize average renewable integration costs
- Maximize export of renewable generation

Knowledge of the statistical nature of uncertainty significantly reduces average cost of daily operations compared to deterministic tools that use just "worst-case reserve"-type balancing. This provides a better path to safe integration of a larger proportion of renewables into an existing generation portfolio. The conclusions of the project showed the advantages of planning under uncertainty:

FIGURE 6: IMPLEMENTATION OF STOCHASTIC 2.0 AT HYDRO QUEBEC



- 16% Average Improvement in Total Operational Penalty (an internal metric) under WhISE
- 11% Reduction in Worst-case Total Operational Penalty under WhISE
- >30% of Renewables now able to be integrated into overall portfolio while still maintaining stability

The tool answers questions for the utility such as:

- How to dispatch conventional generation to best balance renewables?
- Can shedding of renewables be prevented?
- What is the impact of renewable generation uncertainty on wholesale/spot market prices?
- How should contracts minimize costs of integration?

FIGURE 7: WHISE SCREENSHOT

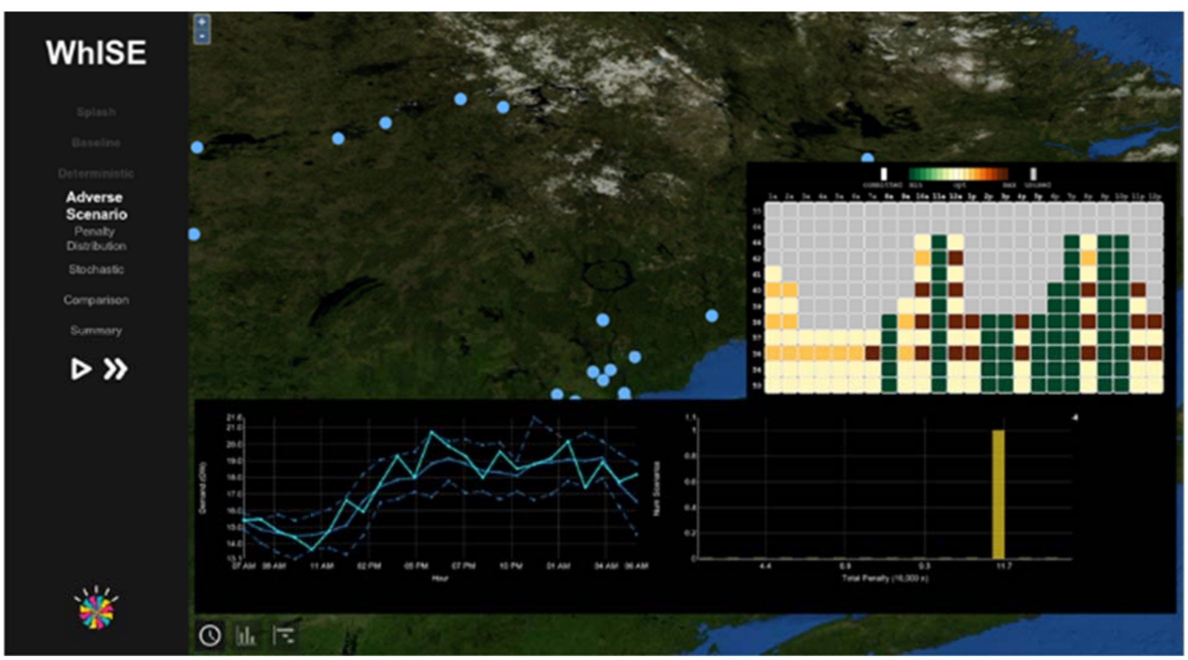
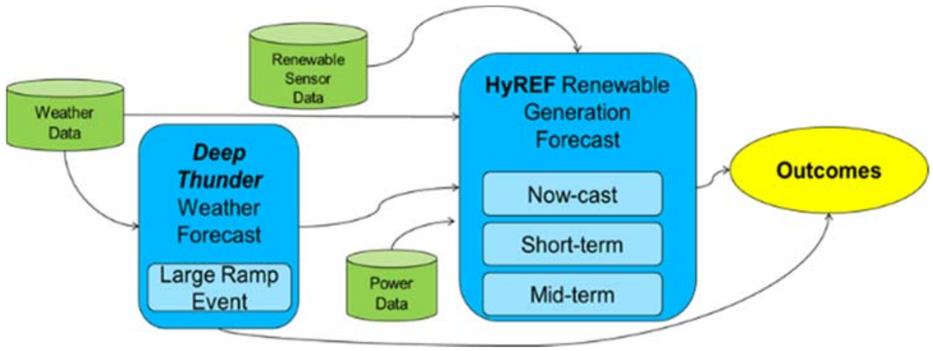


FIGURE 8: SCHEMATIC OF FORECASTING CREATION



- What is the impact of weather on the transmission grid?

- How should planning and dispatch adapt to the presence of massive distributed renewable generation?

2.4 UCO 3.0 – Improved Forecasting as an Input to UCO

The latest innovation in UCO is to further improve automated stochastic models by inputting advanced demand and supply forecasting.

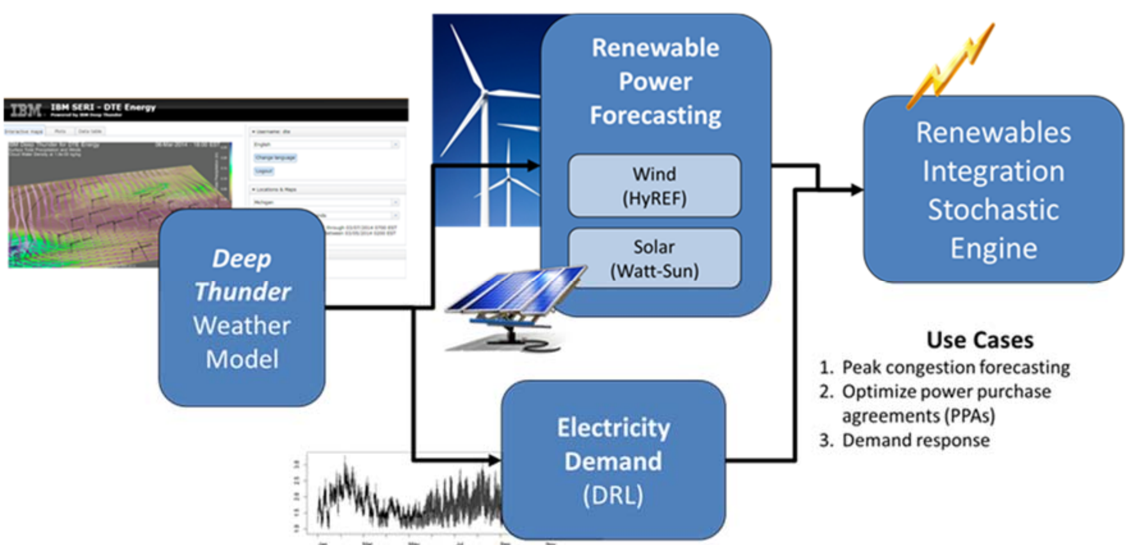
IBM's Business of Weather solution that produces weather modeling and forecasts to anticipate major weather events has been adapted to produce highly detailed power forecasts. This work has been summarized in IBM's Hybrid Renewable Energy Forecasting (HyREF) toolkit that combines weather modeling capabilities, sky-gazing cameras and imaging technology, sensors on renewable power generating assets, and sorts it through analytics software to predict incoming weather patterns and calculate power production performance, from 15-minute intervals up to 30 days in advance. The figure below outlines these two key components.

2.4.1 Case Study – UCO 3.0 at Transmission Company in New England

An electric cooperative in New England, along with their partners, has the challenge of integrating renewable power into their grid to improve their overall energy reliability and reduce their carbon footprint. The Chief Executive of the cooperative estimates that wind power curtailments alone cost the cooperative $1.5 million in 2013.

Weather forecasting used by the electric system in the region lacks the temporal and spatial resolution and accuracy to optimally drive decisions regarding

FIGURE 9: IMPLEMENTATION OF UCO 3.0 IN NEW ENGLAND



electric load on the demand side and integration of renewables on the generation side. IBM's weather-driven models and analytics for wind and solar power, and electric demand forecasting are being adapted and deployed. These models drive a stochastic UCO. The project therefore focuses on the following:

- Implementing an enhanced electric demand forecasting capability
- Implementing an enhanced renewables forecasting capability
- Implementing a stochastic UCO model that directly addresses the uncertainty of renewables to enable a higher percentage of renewables integration
- Enabling an operational weather and analytics computing environment on site

3. CONCLUSIONS

Many governments have implemented renewable energy generation targets in an effort to meet energy security, economic, environmental and societal goals. In fact, as of the publication of this paper, 38 US states and at least 119 countries have some kind of clean energy policy in place that either requires or provides financial incentives for the build-out of solar, wind, hydro, biomass or alternative fuels production. Energy providers who embrace advanced UCO will be well positioned to integrate these resources, increase economic value, and meet policy targets.

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ABOUT THE AUTHOR

IBM has dedicated researchers in a dozen labs across the world developing solutions for renewables integration. In addition, there are 15,000 analytics consultants working with Energy & Utility clients and others to improve operations via data. IBM has installed renewables integration solutions at some of the largest integrated system operators (ISOs), utilities, power producers, and OEMs. Our investment in this space of data analytics is upwards of $24 billion.

IBM and its partners are at the forefront of engaging power producers, utilities, grid operators, manufacturers, and other stakeholders to deploy intelligent systems to accelerate and smooth integration of renewable energy into the market place. This is a natural evolution of technology as the renewable energy industry continues its transformation from boutique to industrial-scale, rivaling incumbent power sources such as gas, nuclear, coal and oil.