ENERGY 2030: FINANCING A GREENER FUTURE

Financing Green Energy in a Low Fossil Fuel Price World and Managing Stranded Asset Risk

Citi GPS: Global Perspectives & Solutions

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Reconciling Cheap Fossil Fuels in a Low Carbon World
De-risking Through Pubic Sector Involvement
Stranded Assets in Practice

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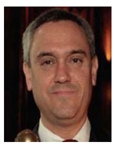
Innovations in Alternative Energy Finance



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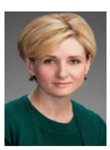

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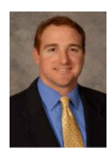

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ENERGY 2030: FINANCING A GREENER FUTURE

Financing Green Energy in a Low Fossil Fuel Price World and Managing Stranded Asset Risk

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In our August 2015 Citi GPS report **Energy Darwinism II**, we took an objective look at the economics of the global warming debate, to assess the incremental costs and impacts of mitigating the effects of emissions, to see if there is a 'solution' that offers global opportunities without penalizing global growth, whether we can afford to do it (or indeed whether we can afford not to), and how we could make it happen.

After looking at the macroeconomic effect, we decided to switch gears and investigate the microeconomics of a changing energy environment. In this new report, we take a look at the competitive dynamics between fossil fuels and renewables and question whether renewables will remain competitive in a lower-for-longer fossil fuel environment, and subsequently, can renewables still be competitive in a zero subsidy environment. Financial innovation will be key to making this a reality.

Technological breakthroughs in oil and gas production (shale technology) as well as renewable technology have led to precipitous cost declines in both energy mediums. With incremental efficiency gains and cost declines tailing off as renewables technologies mature and given financial costs are a large part of the overall costs for renewable power plants, the authors believe financial innovation could provide the next leg of cost declines for renewables to maintain their competitive position with fossil fuels. Given that cost of capital differs greatly between regions, financing costs of capital intensive renewables projects can indeed constitute the close to half of overall costs.

To investigate how innovations in renewable energy finance and policy support for green finance could alter competitive dynamics of renewables vs. fossil fuels, the report considers total costs of new power plants forecasted to 2030 under a 'high' and 'low' financing scenario and finds that financing costs matter.

Equally important as renewables to global climate change mitigation are the dynamics of inter-fuel competition and namely the battle between coal and gas. While new plant economics seem to favor the rise of natural gas, regional variation in costs and power demand growth could dampen its ascent, to the benefit of coal. There is therefore a need for governments to assess appropriate policies to assure not only support for renewables but also for natural gas. In a changing energy environment, the issue of stranded assets is relevant as there is fear that policies aimed at climate change could lead to large amounts of stranded assets and potentially creating the inadvertent effect of companies holding back on needed investments to fuel the planet.

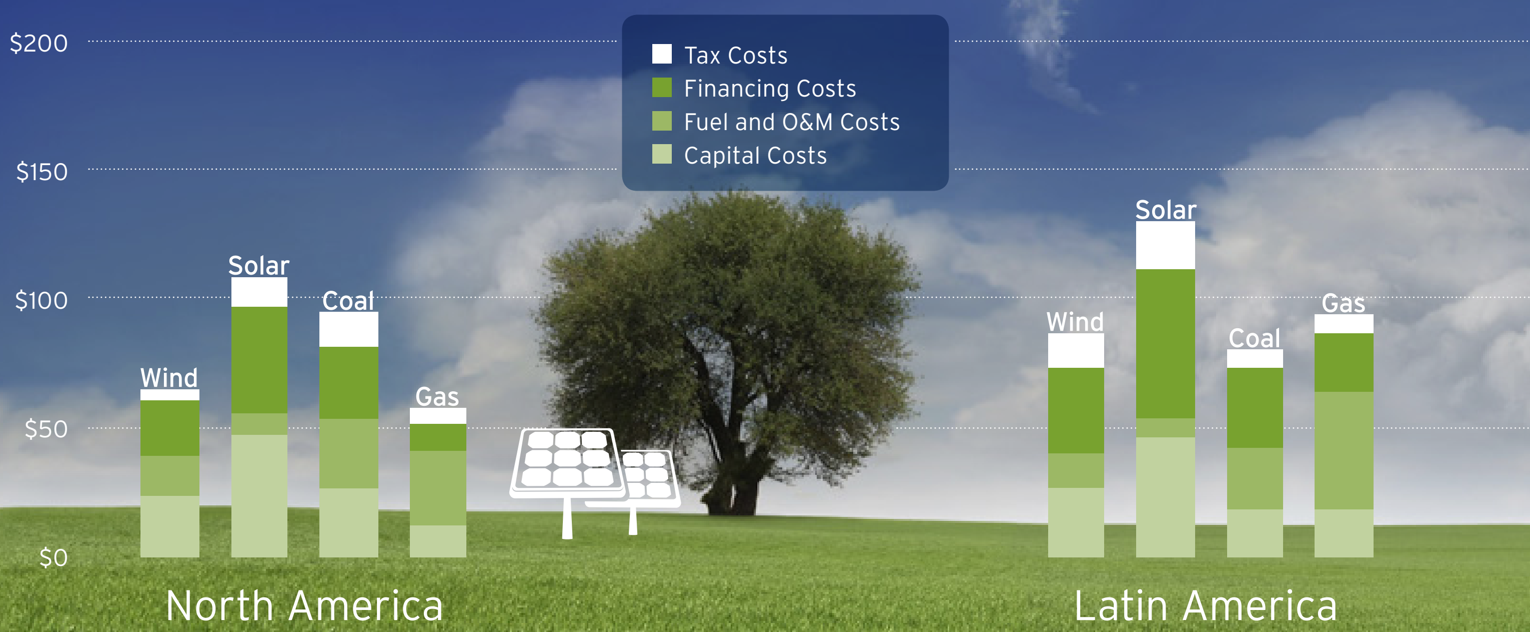
Most importantly, the report investigates the future of new energy financing by exploring the core alternative energy project finance strategies that are critically important in many regions. It also drills down on the key components of broader financing strategies that address the role of currency risk in emerging markets, hedging strategies for project finance, public sector de-risking measure, participation of development finance institutions and the securitization of distributed energy production.

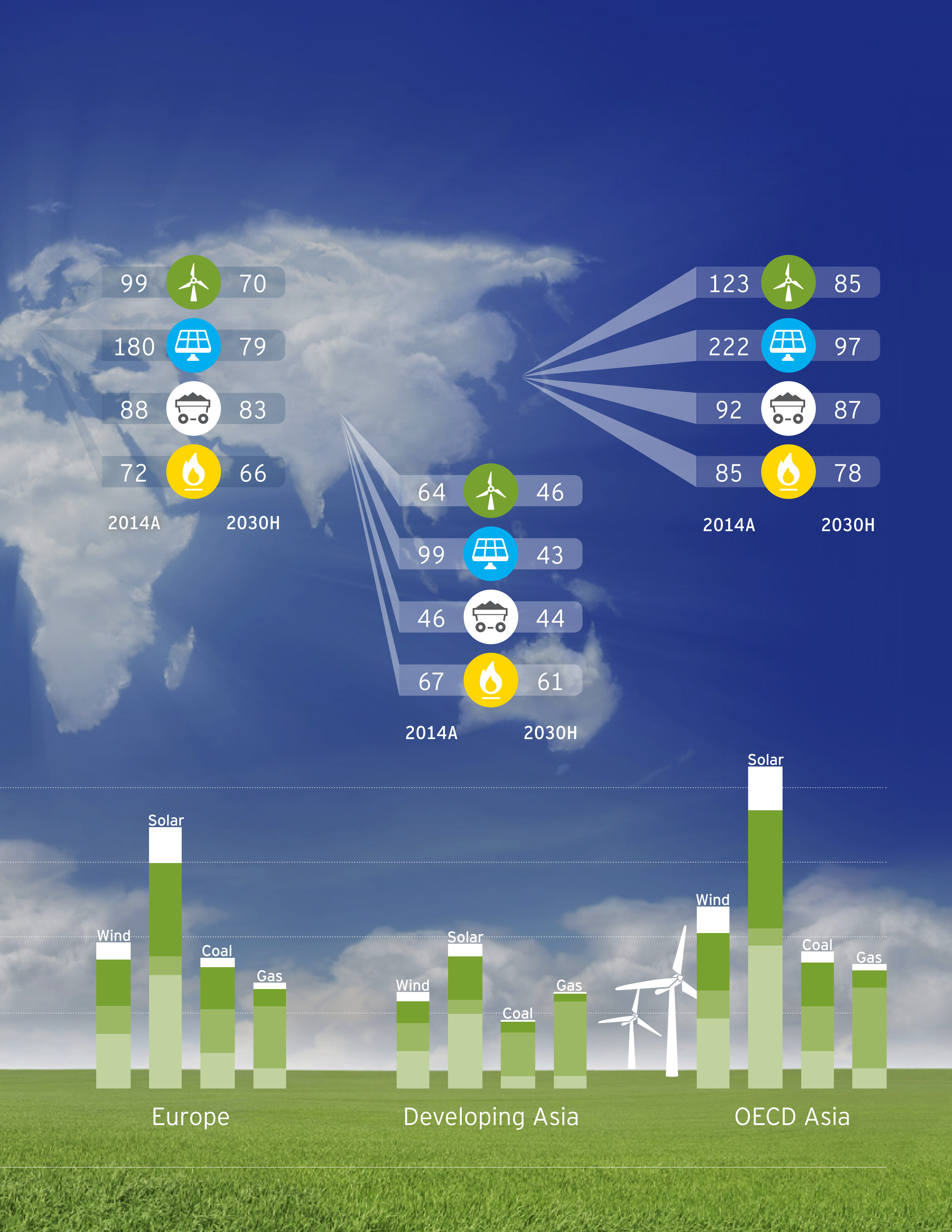
Renewables vs. Fossil Fuels

Hypothetically, what happens to renewable energy competitiveness when financing costs are lowered?

Cost of a new power plant in 2014 and in a hypothetical "falling renewables financing cost" scenario out to 2030 ($/MWh)
Source: NREL, IRENA, IEA, EIA, Citi Research
(A = Actual, H = Hypothetical)

Financing is a large percentage of overall costs for renewables making financial innovation important (2015, $/MWh)
Source: NREL, IRENA, IEA, EIA, Citi Research





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Energy 2030: Commodities Analysis

Introduction

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Innovative finance may soon become the critical lynchpin for mitigating climate change. While the costs of renewables continue to fall, a new era of lower-cost fossil fuels is upon us, sharpening the competitive landscape. The impact of cheaper fossil fuels will ripple through the global energy system. But even as the economics of competition are being altered, the position of renewable energy vs. traditional fuels continues to be strengthened by rapid innovation in technology, policy and finance.

Renewable energy costs have seen precipitous declines as technologies have evolved and efficiencies have improved

The good news is that renewable energy costs have experienced precipitous declines over the last several years as technologies have evolved and efficiencies have improved. See Citi's GPS report "Energy Darwinism II" for extensive analyses on the subject. But the very maturation that has driven cost reductions in the past may require new sources of innovation in the new competitive environment. Solutions, in addition to technological innovation, are key to reducing the costs of renewables at a pace that most climate scientists suggest is required. The emergence of new energy technologies, from renewables and efficiency, to smart grid and electrification of transportation, requires financing solutions.

Financial innovation will be critical in the next phase of renewables cost reduction when currently as much as half of the total cost of renewables could be financing costs

Finance can be at the forefront of this effort by providing affordable ways to fund the high upfront capital needs of large renewable energy projects, or finding ways to tap the massive opportunity in distributed energy and energy efficiency. Indeed, in addition to the economic and policy environment, our analyses of the competitive dynamics in power markets reveals that financing costs should be a major determinant in the economic viability of renewable energy in many regions.

Innovative financing options are already starting to be used effectively

Significant strides have already been made. Structures for securitizing renewable energy, for more complex domestic and foreign project finance and for reducing currency risk in foreign projects, are some of the innovations in this space that are discussed in detail in this report. Some private sector financing also involves construction financing, debt financing (bank term loans and bond market private placements), mezzanine financing (mezzanine debt, leasing, tax equity), pool financing (inverted leases, asset-backed securities (ABS), Real Estate Investment Trusts (REIT), master limited partnership (MLP), YieldCo) and derivative hedging (interest rate, FX, commodities, power). Government policies can also help to de-risk projects and lower the cost of capital. In the end, the shape and pace of government policies is potentially a major accelerant as support for clean energy continues to grow globally.

Cleaner-burning natural gas has displaced coal in the US

But, for the broader picture of global emissions, the potential for cheaper natural gas to displace coal globally could be critically important. This potential has already been witnessed over the last five years in the US, which saw dramatic declines in CO_2. For nearly two decades, discoveries of cleaner-burning natural gas have outpaced those of petroleum and it is now clear that global gas resources are distributed in many more countries than petroleum and are also found offshore and in deep waters around the world. The long heralded "Golden Age of Gas", promulgated a half decade ago by the International Energy Agency, was supposed to catalyze this shift internationally and harken to a new era when gas would supplant coal as the baseload for power generation.

Conventional wisdom generally believes renewables and gas are winners while coal is the biggest loser…but this might not be the case globally

Yet markets, left to their own devices, may not be as supportive of gas-fired generation as commonly anticipated. Though Citi estimates that the cost of a new natural gas plant is lower than that of a new coal plant in many parts of the world, natural gas is still typically more expensive than coal on an operational cost basis. In regions where power demand growth is flat or declining, these economics could actually favor coal over gas, as seen in recent years in the European power market. Without cleaner-burning gas to substitute for coal in power generation and for oil in transportation, it will be difficult to reach an appropriate level of carbon reduction around the world. There is thus a need for governments to assess appropriate policies to assure not only support for renewables but also for lower carbon fuels, including natural gas. Moving from a cost-based to more value-based energy markets would involve pricing negative externalities generated from pollution and climate change. An economically optimal way to achieve this goal would be to price carbon.

Climate change policies can help the move away from coal but also increase the risk of stranded assets leading to the possibility of inadequate energy investments to bridge the gap to a cleaner future

But even targeted and appropriate policy support might have additional consequences in the form of stranded assets. There has been an accelerating fear that climate change policies could “strand” hundreds of billions of dollars of fossil fuel assets globally. Such a large risk might prompt companies to hold back on the portion of fossil investment still needed to fuel the economy. The stranded asset fear, in short, could lead to inadequate investments to bridge the gap to a cleaner future. We believe such fears are exaggerated yet the problem of stranded assets looms large in current debates over “what to do” about climate change. The underlying concern, fed by growing divestment by sovereign wealth funds, university endowments and other fiduciaries of their coal and other “dirty fuel” assets, is that coal and oil sands have become to some degree the new tobacco.

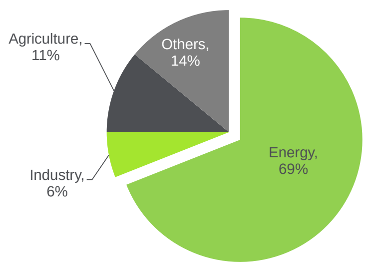
Stranded assets are another issue causing confusion such as the natural process of phasing out assets that are replaced by cheaper substitutes or new technologies

Perhaps the most dramatic statement of the stranded asset issue came in a speech by Bank of England Governor Mark Carney at a Lloyd’s of London dinner on September 28, 2015, in which he warned that between one-fifth and one-third of the world’s proven reserves of oil, gas and coal were at risk if the world were to meet a 2 degree Celsius targeted limit on the average global change in temperature. Citi Chief Economist Willem Buiter reviews the stranded asset issue in Part C of this report. We find that there are several confusions at work here, including the natural process of phasing out assets that are replaced by cheaper substitutes or new technologies, summed up by the notion that the Stone Age didn’t end because of a scarcity of stones.

The bulk of the report that follows focuses on the interaction of these issues, starting with an overview of the current state of the fossil fuel and renewables markets and their outlook for the future, including the competitive dynamics and policies likely to drive future growth. The next section presents an overview of financial innovations that are becoming increasingly important for the growth of alternative energy. We find that the future for renewable energy is as bright as ever, despite cheaper fossil fuels and ups-and-downs in equity prices of renewable energy companies. The role of finance more broadly in enhancing the competitiveness of renewable energy becomes critically important, by helping to recycle capital and optimize the allocation of risk and funding of projects. We conclude with a discussion of stranded assets.

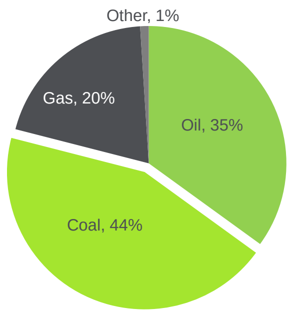
Part A: Reconciling Cheap Fossil Fuels in a Low Carbon World

Figure 1. Shares of Global GHG Emissions by Sector



Source: IEA, Citi Research

Figure 2. Share of Global CO_2 Emissions by Fuel



Source: IEA, Citi Research

The future of energy markets and climate are inseparable. Energy has always been the leading source of global carbon emissions, contributing 69% of all greenhouse gas (GHG) emissions.[1] This basic math of climate change dictates that understanding the trajectory of emissions requires understanding how the global energy market will behave and evolve. Seemingly minor changes in major fossil fuel markets – such as a switch from coal to gas – can have outsized impacts on emissions. The major shifts now underway in global energy markets are therefore critical for climate pathways as well as financial markets.

But now, the confluence of cheaper energy and greater climate and environmental policy are poised to reshape energy markets by catalyzing large-scale shifts in fuel use and investment. The momentum of climate and environmental policies that might fundamentally alter energy use in the global economy is building, but that momentum could be challenged by cheaper oil, coal and gas that are better positioned to compete with cleaner alternatives.

At the intersection of these forces is potentially the largest beneficiary and one of the most important tools for global emissions mitigation – renewable energy. But climate policy does not imply the abdication of competitive economics – whether and how renewable energy can compete will still matter immensely to its growth and viability as a climate solution, particularly in a lower fossil fuel price regime.

(1) The New Reality of Cheap Oil

The unconventional oil revolution, a product of this century, has turned on its head basic assumptions about oil prices, OPEC and long-term energy costs, making oil prices lower than anyone would have dreamed in 2010 and posing a big challenge to the economics of renewable fuels. Three new sources of oil were tapped into on a large scale for the first time ever as a result of high prices in the first decade of the 21st century – oil produced from oil sands, deep water and shales. As a result, in the first five years of this decade, Brazilian oil output grew by over 25%, Canadian production surged by over 40% and US liquids output rose by close to 90%, and the total liquids emanating from these sources, including natural gas liquids, climbed to close to 20-mb/d of the world's ~95 mb/d of liquids output.

Assumptions on oil are now of long-term supply abundance at lower prices vs. peaking oil supply at higher prices

Given the abundance of the resource base now available and the dramatic cost deflation that is unfolding in unconventional plays, assumptions of peaking oil supply at higher prices are being replaced with assumptions of long-term supply abundance at lower prices. Surprising to many analysts, unconventional oil is increasingly cost competitive with traditional lower cost supplies, including from the Middle East. While the 30% or so cost deflation in shale oil (and gas) plays over the past year is starting to tail off, cost deflation has a long way to go still not only in the shales but also in both deep water and oil sands.

[1] Source: IEA. Note that other gasses and variables in addition to CO_2 are important in climate modeling. See http://www.ipcc.ch/. CO_2 however is one of the most important gasses and factors determining the rates of climate warming.

Cost deflation is pointing to stabilization of the global oil price plus elasticity in shale supply in response to prices

Cost deflation is pointing to global oil potentially stabilizing in a band between ~$55-$75/bbl. What's more, the new supply, especially from shales, appears to be significantly elastic in its response to prices, yet another new condition, which is the opposite of the traditional view that supply is inelastic to price changes in the short term. As a result there is increased confidence that when oil prices recover, supply from shales will recover rapidly as well and the US will remain capable of seeing shale production grow by upwards of 1-m b/d annually for a while, just as it had in the period 2010-2014 before prices collapsed. Further expansion of shale resource development to other countries seems inevitable, including to Canada and Russia where shale resources are abundant and fracking techniques are in their infancy of use, as well as to China, Mexico, Australia, and North Africa among other places. As these resources are developed and shale production rises as a share of global output a bigger base of production should assure continued limitations on how high prices could reach before being checked by new production.

Demand is changing with increased energy efficiency in emerging markets and slower demand growth in oil product vs. growth in GDP

Coupled to these new supply sources are changes on the demand side that are resulting in an increase in energy efficiency in emerging markets and a stunning reduction in the rate of growth of oil product demand in relation to GDP growth. Global oil demand looks set to be capped at around the 1% per annum level or lower, even if global GDP returns to 4%+ levels in the years ahead. The more widespread adoption of climate change policies to limit the role of oil in the economy and to substitute natural gas for oil in the transportation fuel mix should drive demand growth even lower, probably to levels well under 1% per annum, making it increasingly likely that additions to supply from increasingly competitive unconventional fuels could be ample to meet rising world demand.

As a result of new supply pressures Saudi Arabia in late 2014 forced other OPEC countries to change OPEC's underlying policy, abandoning the role of global central banker to oil markets (adding or reducing liquidity as needed to keep prices at higher than market clearing levels would otherwise have been and instead to gain and protect market share). This new policy looks to be fairly permanent, even if it undergoes moderate change, designed to maximize revenue. It reflects a clear understanding that if prices are too high, unconventional oil supplies, particularly from shales, can come roaring back fairly quickly, and this too suggests that oil prices will be capped going forward well under $90 a barrel and most probably under $80.

There is effectively a change in attitude on the value of oil

In effect there has been a change in attitude toward the value of oil on a net present value basis, pointing to a new view that oil in the ground is worth less than oil taken out of the ground and produced, another profound change from the traditional way of thinking about oil as an exhausting resource whose value would increase over time.

Politics within OPEC point to lower prices and more competitive markets

The dynamics of politics within OPEC have also changed and point to lower prices and more competitive markets. It used to be the case that more often than not OPEC countries could set aside their competitive situation and join together in common action to lift prices by reducing output. New market conditions make that very difficult to accomplish without subsidizing new unconventional production. Combine that with a less rapidly growing market and competition among the large producers for limited market share has made producer interactions with one another a zero-sum situation where any one party's gain is a loss for someone else with the fear of losing market share in the short run from any production cutback risking losing that market share on a more permanent basis.

Dynamics in natural gas are also changing with cheaper supplies driving international prices down

Natural gas supplies as well are seeing similar forces at work. Not only have natural gas discoveries outpaced those in oil, but increasingly cheaper supplies from unconventional places, including shales and deep water, are driving international prices down. The traditional linkage of internationally-traded natural gas to oil prices might have made sense when invented by Japan's government to induce gas suppliers to produce liquefied natural gas. But in a world of abundant supplies with more and more gas available on a spot basis, gas prices also need to come down. (See section (2) below). As in oil, increasingly over time it appears that there will be growing incentives for large international suppliers like Russia and Qatar to take the lead given by Norway and to search for the best ways to maximize the volume of exports to preserve and not relinquish market share.

The future of primary fuels appears to be increasingly challenging for renewable fuels

So whether looking at petroleum, or natural gas, or incredibly abundant coal resources, the future of primary fuels globally appears to be increasingly challenging for renewable fuels – especially given their interruptible nature and the lack of a breakthrough as of yet in battery storage technology.

(2) Gas: Shale Revolution Pressuring Global Prices

Despite vast supply and falling prices, gas is fighting against coal and renewables for market share in the global power sector

The explosive growth of cheap natural gas supply has led us to "the Golden Age of Gas".[2] But rapid growth of shale gas production and major discoveries globally have depressed prices (see LNG Landscape; Finding a Home for US LNG). Yet despite the vast supply and falling prices, gas is fighting against coal and renewables for market shares in the power sector globally. We examine developments in US gas and global LNG in this section.

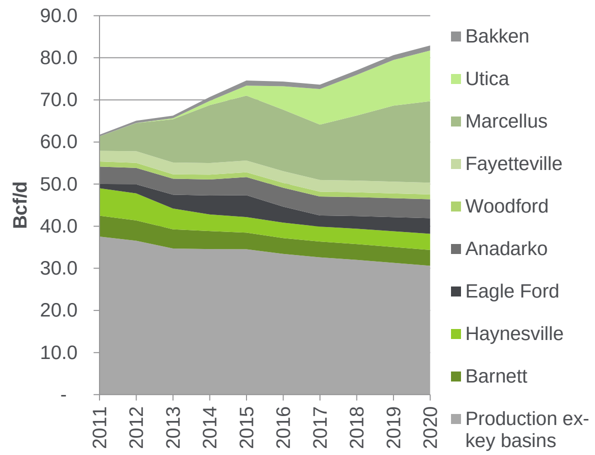
(2.1) US Natural Gas

With massive reserves, North America should be able to expand its gas exports

The combination of a massive reserve base and relentless technological progress promises to keep gas prices low. Although "fracking" began in natural gas, enhanced techniques developed in recent years for oil production are now being reapplied to natural gas production, boosting output. With a low cost base, North America should be able to expand its gas exports, with export growth possible if and when the global market demands it. More modest domestic consumption growth, efficiency gains in gas production and low services costs are all keeping a lid on prices not just now, but for a good half decade or longer ahead.

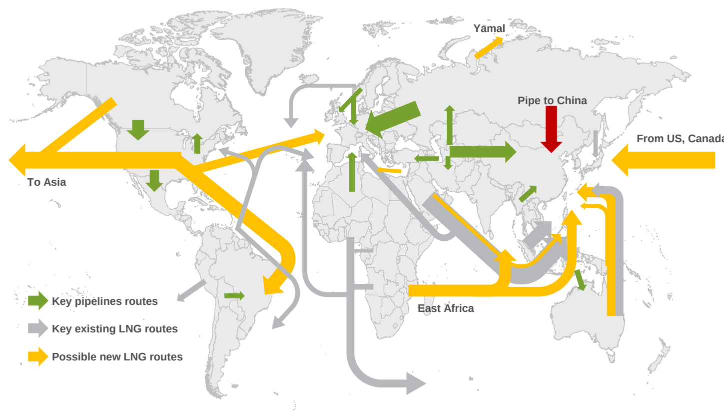
[2] We refer to a well-known proclamation from the International Energy Agency.

Figure 3. Future US Gas Production Growth Driven by a few Key Shale Plays…



Source: EIA, state data, Woodmac, Citi Research

Figure 4. Map of Future Global Gas Flow

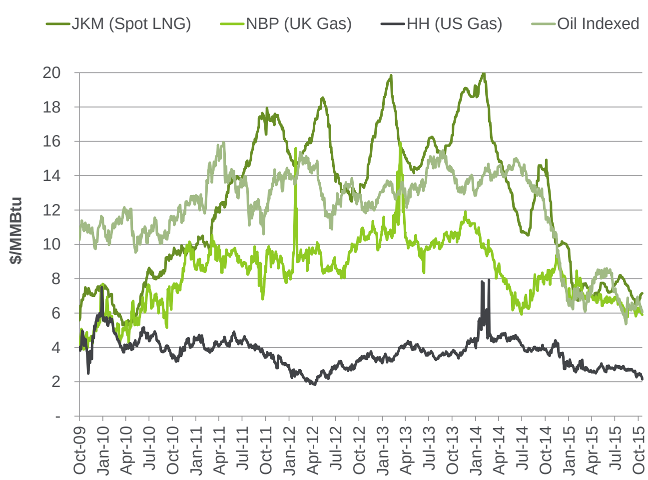


Source: EIA, IEA, Citi Research

(2.2) LNG: Global Supply on the Rise, Price Competition More Fierce

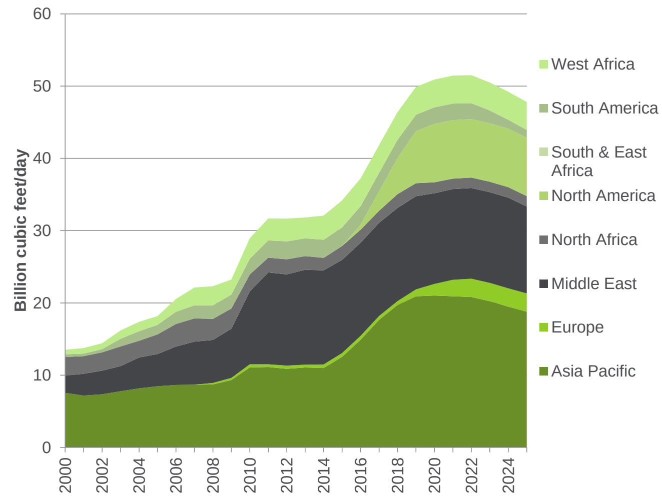
Australia and the US are ramping up exports in a world that is already oversupplied with gas. Despite the global oversupply, firms and countries continue to discover sizeable new fields and are developing existing ones. (See "Global Gas: Watch out US shale, here come Iran and Egypt" (Sept 2015) and "Next Move in the US-Russia Energy Duel" (Jun 2014) for details) Indeed, the world looks poised to remain awash in gas for some time and for lower pricing to persist.

Figure 5. Global Gas and LNG Prices



Source: Platts, Citi Research

Figure 6. US Gas Exports to Add to the Global LNG Oversupply to 2020



Source: Woodmac, company reports, Citi Research

Further downward pressure on global gas prices comes from a breakdown of traditional LNG pricing

The breakdown of traditional LNG pricing, linking natural gas prices to oil prices, puts further downward pressure on global gas prices. US LNG as the marginal supply globally looks increasingly likely to set gas prices in markets worldwide. This is because US gas supplies are by law not restricted by destination and because the initial lifters of US LNG are "mid-stream" agents likely to sell spot to the highest bidder and highest priced market. The conventional way of pricing and understanding the market involving oil-indexed, destination- and volume-restricted gas supplies is increasingly giving way to gas-indexed, flexible supplies. More flexible contracts from the US allow for market-based pricing while greater competition also helps to liberalize global LNG markets thereby driving down prices.

Modest demand growth in key regions such as Japan, China and Europe should keep prices low amid oversupply

On the demand side, more modest growth in key regions, such as Japan, China and Europe, should keep prices low amid oversupply, at least for a couple of years. Japan could cut LNG demand by 1 to 2-Bcf/d as nuclear reactors resume operation.[3] China was supposed to be the growth engine for gas and LNG but demand growth has slowed substantially on weak macro conditions and unfavorable pricing inside the country. Perhaps by the end of this decade Chinese policy changes could make a big difference on demand, but in the meantime the demand outlook looks weak in China as well as in India. Reversing the long-term decline in European gas demand looks challenging with sluggish macro growth and improving energy efficiency. Although the Middle East, Southeast Asia and South America should have strong growth rates, their markets are too small to be comparable to Japan, China, India and Europe.

The pressure on gas prices may still not be enough to make gas sufficiently competitive vs. coal

Nonetheless, outside of the shale bubble in North America and the LNG surge in Australia, the pressure on gas prices may still not be enough to make gas sufficiently competitive vs. coal. With rapidly falling costs of renewables, gas may even become a loser within North America particularly if policy remains supportive of renewables going forward.

Lower gas and coal prices can delay the dominance of renewables in the years to come

Although gas demand growth for power generation, as a bridge from coal to renewables, could be lower than many had expected, the supposed dominance of renewables in the years to come, as capital costs have rapidly fallen, may have to wait as gas and coal prices have also dropped. Renewables could regain their recent competitive momentum with lower financing costs.

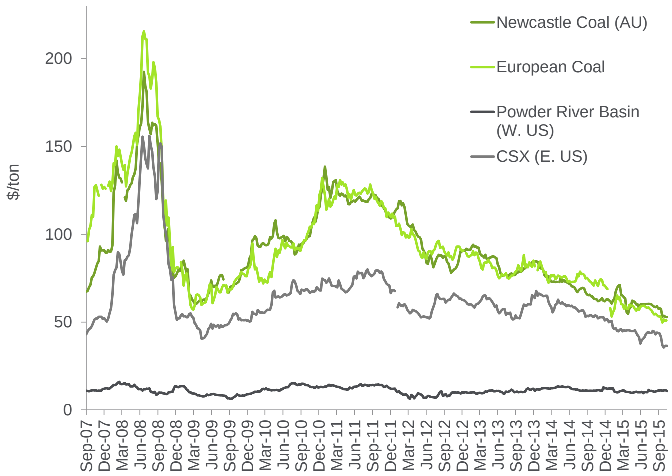
(3) Dirty but Cheap: Dethroning King Coal Is Difficult without Policy Help in Many Regions

Nearly all major coal markets are oversupplied

Global coal markets are awash in excess capacity, reflected also in depressed prices in a hangover from the heavy investment of the commodity super cycle years in the first decade of this century. Nearly all major markets – the US, China and the global seaborne market – are oversupplied. In a world were coal demand growth is increasingly challenged by cheaper renewable energy and gas, the oversupply will take longer than most people anticipate to work off.

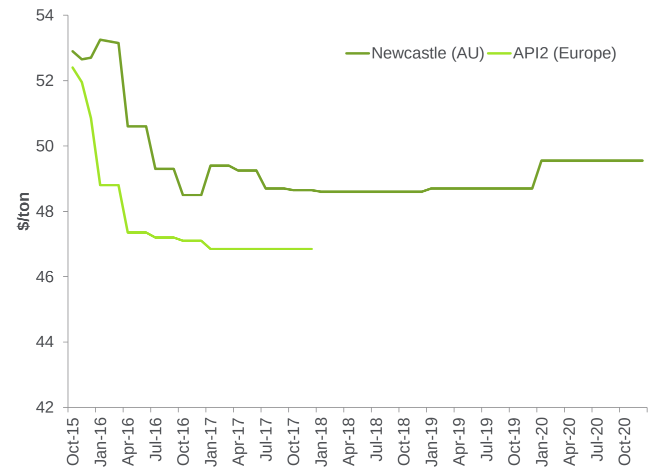
[3] Nuclear restarts, crucial to the government's newly released long-term energy plan post-Fukushima, is one of several seismic shifts underway with substantial long-term impacts on global LNG. Other developments include: (1) phased liberalization of Japan's energy markets in 2016, 2017 and after; (2) joint procurement of LNG; and (3) expiration of long-term LNG contracts in large volume.

Figure 7. A Dramatic Run-Up in Coal Prices in the Early 2000s Sparked Huge Amounts of New Investment; the Market Remains in a "Hangover" of Overcapacity



Source: Bloomberg, Citi Research

Figure 8. Futures Curves for International Coal Prices Suggest Additional Downside and Little Optimism for Recovery

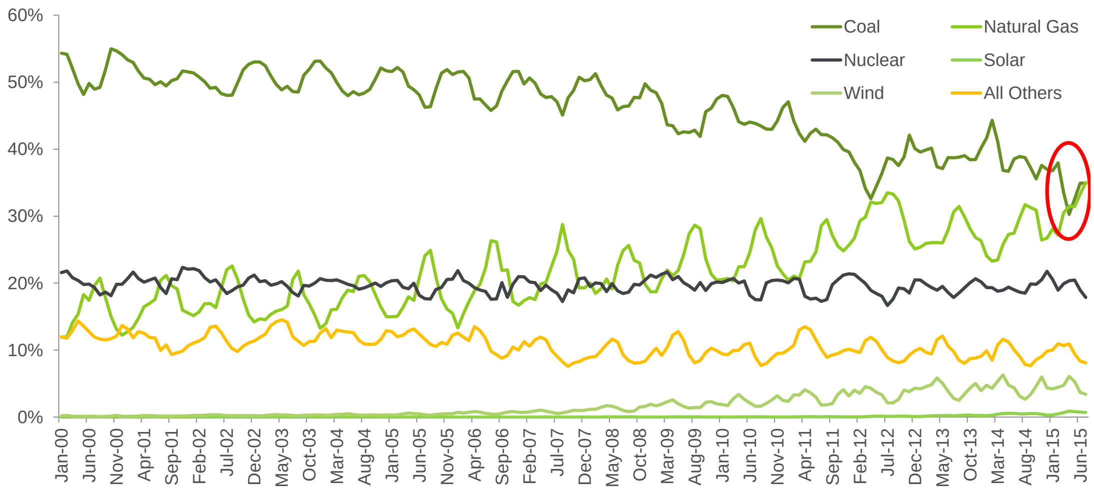


Source: Bloomberg, Citi Research

The war on coal has been won by cheap natural gas in the US

In the US the war on coal has been won so far by cheap natural gas. Power markets sourcing expensive coal from underground mining in the East are sitting on top of two of the world's lowest cost gas plays: the Marcellus and Utica shales.

Figure 9. Coal's Once Dominant Share of US Electricity Is Being Challenged by Natural Gas, Which Has Recently Taken the Lead Position



Source: EIA, Citi Research

As gas prices have continued their march lower in the midst of staggering productivity gains in hydraulic fracturing, gas' inroads into coal's once safe territory have gone farther. Additionally, new environmental regulations, such as the Clean Power Plan that more strictly regulates coal pollution, have added liability to building new coal plants and forced more coal-fired power plants to retire.

Outside the US, coal remains a much cheaper source of power generation

In the rest of the world, however, the story is very different. In nearly every economy except the US, coal remains a much cheaper source of power generation.[4] Even in Europe, with a €9/ton carbon burden, burning coal is still far more profitable than burning gas, due in large part to the high costs of imported gas (see above chart). In addition to oversupply, mining costs have compressed by 30% in the last three years, even with lower prices, cushioning producers.

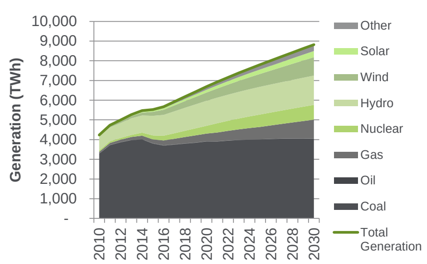
The prospects for significant increases in coal pricing that might hinder the competitiveness of renewables or gas appear limited, and hinge crucially on India and China. In the US, cheap natural gas should keep a tight lid on coal prices, limiting prospects for significant uplift.

Growth in coal demand in emerging Asia may not be as robust as earlier predicted

Growth of coal demand in emerging Asian economies may not be as robust as many have predicted. Peak Chinese coal demand for power generation may happen soon – and might have happened already. Citi first called for Chinese coal demand to peak in the early 2020s in 2013 (see The Unimaginable: Peak Coal in China). Since then, the trends driving this outcome have only become more pronounced – renewable energy growth has been aggressive, energy efficiency gains have accelerated and GDP has slowed faster than anticipated.

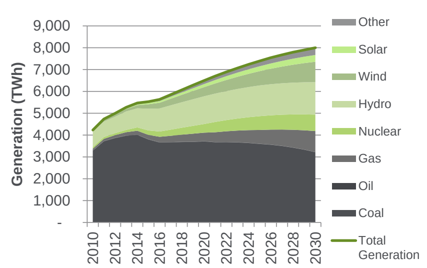
Figure 10 through Figure 12 below show potential pathways for Chinese coal demand under Citi's models.[5] As coal demand slows and domestic mining capacity remains healthy, reliance on imports should wane, reducing a key source of demand in global markets (see Commodities Quarterly). Though India offers a bright spot for coal demand, this may not necessarily be supportive of global markets, as domestic coal supplies have finally surged (see Survival of the Fittest).

Figure 10. China Coal Use Could Peak Soon Even Under a "Stable Econ Growth" Scenario



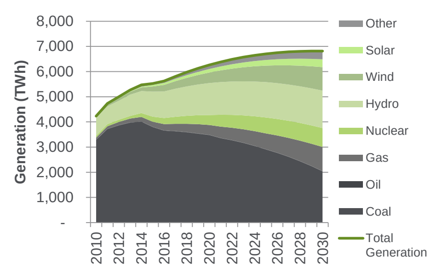
Source: CEC, IEA, Citi Research

Figure 11. China Coal Use Looks Set to Decline Under a "Transition" Economic Scenario



Source: CEC, IEA, Citi Research

Figure 12. A Sharper Slowdown in China Could Push Coal Use Down Quickly and for Good



Source: CEC, IEA, Citi Research

[4] For a detailed discussion of coal markets, see Morse, Richard and Thurber, Mark. "The Global Coal Market: Supplying the Major Fuel for Emerging Economies". Cambridge. 2015.

[5] These models capture coal use in the power sector and do not include industry and residential use.

Recent OECD announcements likely to have limited impact on coal demand growth

The recent announcement by the OECD on cutting public financing of coal power plants[6] would have some, but we believe limited, impact on coal demand growth. The OECD agreement does not cover ultra-supercritical coal plants — the most efficient kind of coal plants — or coal plants in very poor countries. In addition, the World Bank, the US Export-Import Bank and the European Investment Bank had already cut support prior to this announcement, so there has already been some impact. Some coal plants may opt to finance from other banks. Interestingly, in China, although more coal power plants are being built, coal demand might have peaked in 2013 already. Thus, coal plant capacity growth does not necessarily equal coal demand growth.

Renewables may not be dethroning coal just yet

With low coal prices, renewables may not be dethroning king coal just yet. We discuss later in the report why coal may be surprisingly resilient in a world with more renewable energy. Lower financing costs could give renewables the boost needed.

[6] http://www.oecd.org/newsroom/statment-from-participants-to-the-arrangement-on-officially-supported-export-credits.htm

Energy 2030: Consultant Analysis

(4) IRENA: Renewable Energy Cost Trends and Drivers

Michael Taylor
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The benefits of renewable energy are many and clear, but so in the past have been the barriers to their uptake. Market structures that hindered or even prohibited deployment, a lack of understanding of emerging renewable technologies, difficulty in accessing finance, high financing costs, inadequate regulatory frameworks, lack of remuneration for offsetting fossil fuel externalities (e.g. carbon and local air pollutant emissions), small markets, policy uncertainty and high costs have all played a role in hindering the deployment of renewables. Fortunately, with diligent work by industry, governments, financing institutions and regulators, many of these barriers are falling away.

Historically, renewable power generation deployment was hindered by high costs, however competitiveness has improved

One of the barriers to increased renewable power generation deployment was their high costs. However, the past decade has seen a dramatic, and sustained, improvement in the competitiveness of renewable power generation technologies. Around the world, renewables – if not already more competitive than was widely recognized – have benefited from a virtuous cycle of increased deployment leading to technology improvements and falling costs. Renewable power generation technologies have accounted for more than half of all new power generation capacity additions in every year since 2011, with a record high of more than 130 gigawatts (GW) added in 2014. This year looks set to be another record, with expectations of solar photovoltaic (PV) deployment of 55 GW and 56 to 58 GW for wind power.

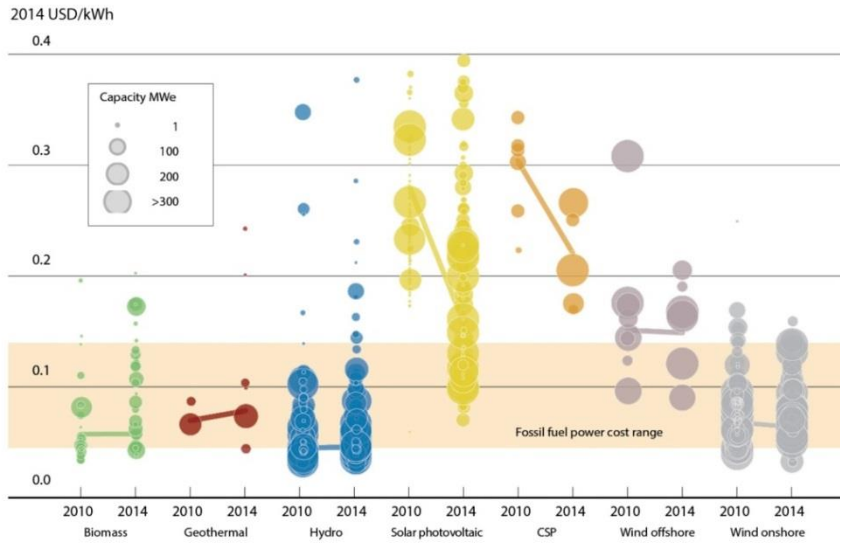
The Road to Competitiveness

Better data has helped increase policy effectiveness

Despite the fact that the economics of renewable power generation technologies are critical to understanding their potential role in the energy sector and how quickly, and what cost they can be deployed, most governments have not systematically collected the necessary cost data. The result is that too often misconceptions about costs or out-of-date data has undermined policy effectiveness. This has led, in some cases, to inefficient policy settings as the very rapid cost declines for solar PV, and to a lesser extent wind power, meant that decisions based on data even one or two years old can significantly overestimated the costs of renewables. To fill this gap, and ensure that robust policy can be made on accurate, timely data, IRENA has developed a database of around 15,000 utility-scale renewable power generation projects and close to three-quarters of a million small-scale solar PV systems.[7] The trends emerging from this data show not only the success of deployment policies to drive down costs but that the cost-competitiveness of renewable power generation has reached historic levels. Biomass for power, hydropower, geothermal and onshore wind can all now provide electricity competitively compared to fossil fuel-fired power generation where good resources and cost structures exist (see figure below).

[7] The majority of the utility-scale project data in the IRENA Renewable Costing Database are in non-OECD countries. This is driven by the fact that many of these projects benefit from development support or lending from development banks or multi-lateral lending agencies and high level data is in the public domain. More commercial markets, such as those predominate in the OECD, are characterized by much more stringent confidentiality issues and data is therefore more difficult to obtain. In all cases, the project-level data by country and technology is compared to or supplemented by averages from trusted secondary sources.

Figure 13. Levelized Cost of Electricity from Utility-Scale Renewable Power Generation Projects Compared to Fossil-Fuel Fired Electricity, 2010 and 2014



Note: The size of the diameter of the circle represents the size of the project. The center of each circle is the value for the cost of each project on the Y axis. Real weighted average cost of capital is 7.5% in OECD countries and China; 10% in the rest of the world.
Source: IRENA

In the past 4 years, the global weighted LCOE of utility-scale solar PV has been cut in half

Between 2010 and 2014 the global weighted average levelized cost of electricity (LCOE) of utility-scale solar PV fell by half. The most competitive utility-scale solar PV projects are now regularly delivering electricity for just $0.08 per kilowatt-hour (kWh) without financial support, compared to a range of $0.045 to $0.14/kWh for fossil fuel power. But even lower costs are being contracted for 2017 and beyond. The recent tender in Dubai of $0.06/kWh ably demonstrates this shift, even in a region with abundant fossil fuels. Other tenders in Jordan, Chile, Brazil and South Africa have all highlighted that solar PV can be competitive.

Onshore wind is now one of the most competitive electricity sources

Onshore wind is now one of the most competitive sources of electricity available. Technology improvements, occurring at the same time as installed costs have continued to decline, mean that the cost of onshore wind is now within the same cost range, or even lower, than for fossil fuels. Wind projects around the world are consistently delivering electricity for $0.05 to $0.09/kWh without financial support, with the best projects costing $0.04/kWh.

CSP and onshore wind still typically cost more than fossil fuel generation, but are in their infancy in terms of deployment

The electricity from concentrating solar power (CSP) and offshore wind still typically costs more than fossil fuel-fired power generation options today, with the exception of offshore wind in tidal flats. But these technologies are in their infancy in terms of deployment.[8] Both represent important renewable power sources that will play an increasing role in the future energy mix as their costs will continue to come down.

More mature renewable tech (biomass, geothermal, hydropower) has been stable

Costs for the more mature renewable power generation technologies – biomass for power, geothermal and hydropower – have been broadly stable since 2010. However, where untapped economic resources remain, these mature technologies can provide some of the cheapest electricity of any source.

[8] The cumulative deployment of CSP reached 4.3 GW at the end of 2014, while that of offshore wind reach 8.8 GW (IRENA, 2015).

Solar PV and Wind Power: The Rapidly Maturing Newcomers

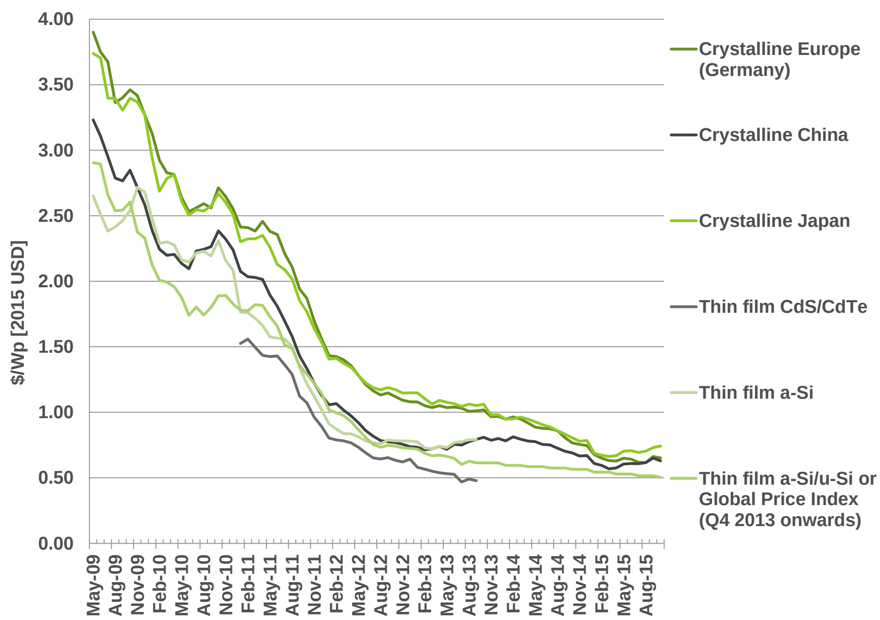
Technology improvements and cost reductions in solar PV and wind have been significant

It is remarkable to think that in the year 2000, just 800 MW of solar PV capacity was installed worldwide and 17 GW of wind power. Both of these “new” renewable power generation technologies are now mature, commercially proven technologies which are increasingly competing directly with the alternatives on economic grounds alone, without taking into account the value from their reducing local and global pollutant emissions. In both cases, the technology improvements and cost reductions have been significant.

Solar PV Costs

For solar PV, growing economies of scale, efficiency improvements and reductions in material inputs and prices have driven down costs dramatically. Solar PV module prices in October 2015 were 78% to 81% lower than their levels in October 2009 (See Figure 14), and the estimated learning rate for solar PV modules was between 18% and 22%. At the same time, the balance of system costs has also been driven lower. The end result is that solar PV installed costs have also fallen rapidly.

Figure 14. Solar PV Module Prices in Europe, 2009 and 2015



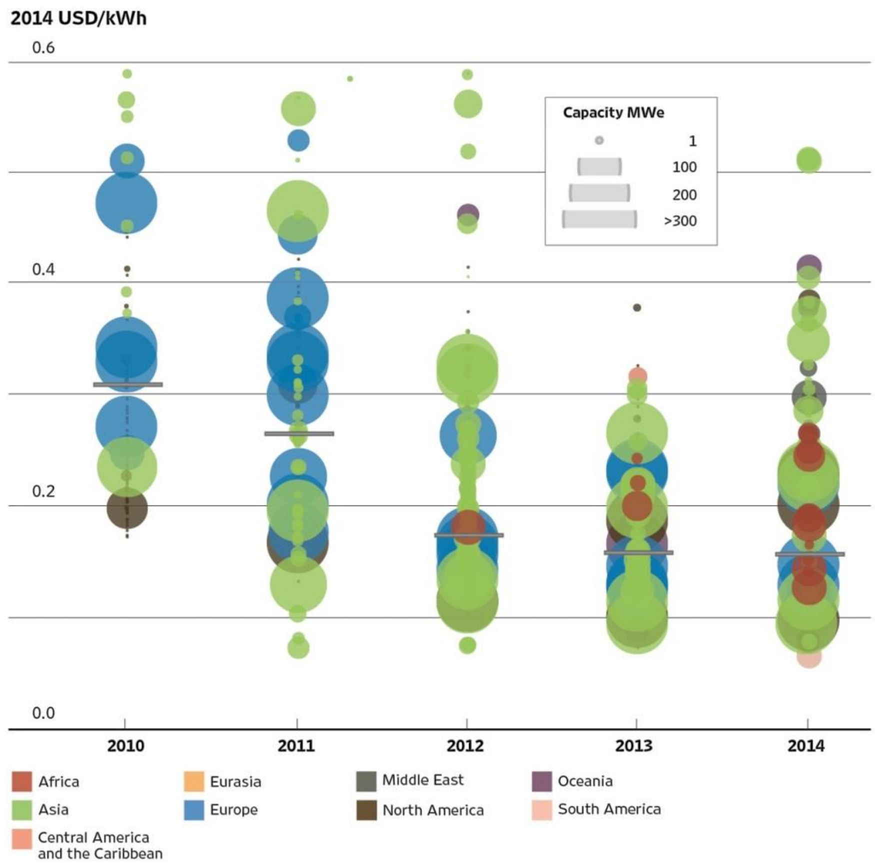
Source: IRENA

Most competitive utility-scale solar PV projects have continuously reduced costs

Between 2011 and 2014, the most competitive utility-scale projects have continuously reduced costs – from lows of around $3,200/kW for small-scale projects and $2,200/kW for large-scale projects in 2011, to lows of around $1,300 for both size groups in 2014. This is a decline of 65% for smaller utility-scale projects (1-5 MW) and 41% for larger (>5 MW) projects in just three years. Cost reductions mean that the LCOEs of the latest utility-scale projects in 2014 are increasingly competitive. Figure 15 below presents the LCOE ranges and capacity-weighted averages for utility-scale PV projects between 2010 and 2014. The range of the LCOE has declined from between $0.18 and $0.61/kWh in 2010 to between

$0.08 and $0.50/kWh in 2014.[9] The ranges remain wide, but there has been a rapid reduction in the global weighted average LCOE of utility-scale solar and projects being contracted for today for delivery two years hence have LCOEs as low as $0.058/kWh in the case of the Dubai Electricity and Water Authority's recent contract with ACWA Power. This may be today's most competitive project, but by 2017 it will be the new norm for solar PV in sunny regions with access to low cost finance.

Figure 15. The Levelized Cost of Electricity from Utility-Scale Solar PV Projects, 2010 and 2014



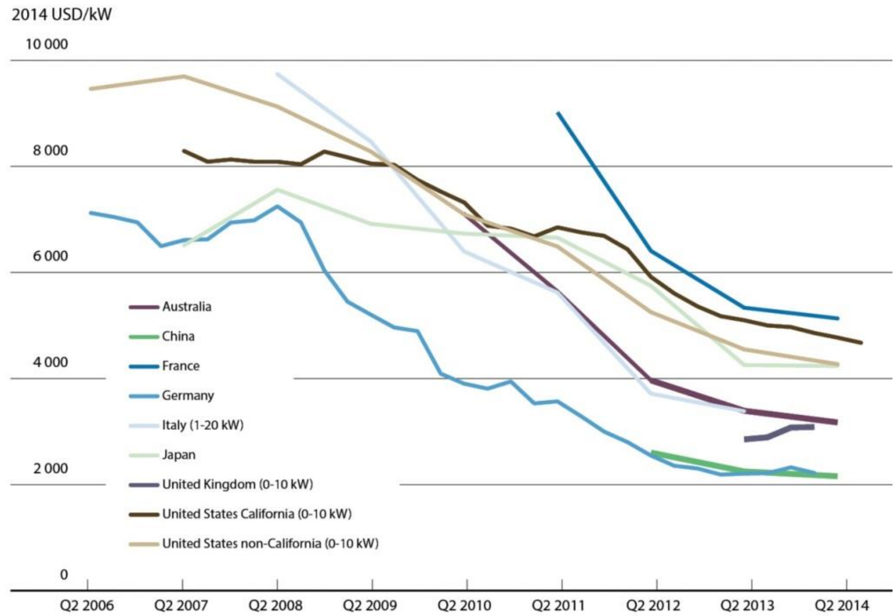
Source: IRENA

Rooftop solar PV costs have fallen rapidly, in line with solar PV module price reductions

Rooftop solar PV costs have fallen rapidly in line with solar PV module price reductions, but also as a result of reductions in balance of system costs (See Figure 16). Germany and China have, on average, the most competitive small-scale residential rooftop systems in the world. Germany's residential system costs have fallen from just over $7,200/kW in the first quarter of 2008 to $2,200/kW in the first quarter of 2014. They have continued to fall, albeit at a slower rate in 2015, and have averaged just $1,550/kW in 2Q 2015 (EUPD data). Rooftop solar PV is typically more expensive than a utility-scale project in a country, but this is not necessarily true between countries, as there is a very wide cost variation between countries. For instance, despite the gap narrowing residential-scale projects in Germany were still estimated to have lower average installed costs than utility-scale projects in the United States in 2014.

[9] The upper end of this range represents utility-scale projects in remote locations that are typically offsetting expensive diesel-fired generation.

Figure 16. The Levelized Cost of Electricity from Utility-Scale Solar PV Projects, 2010 and 2014



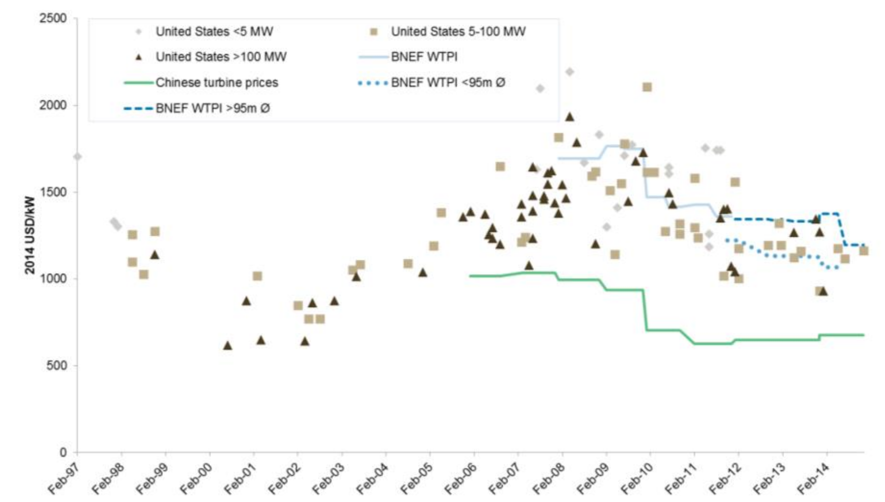
Note: Annual data for Australia, China and Italy; quarterly data for the remaining countries.
Source: IRENA

Wind power costs

Technology improvements and increasing capacity factors have increased the competitiveness of onshore wind

Wind power is a more mature than solar PV, with around 393 GW installed at the end of June 2015[10], yet wind turbine costs are continuing to edge lower at the same time as technology improvements (e.g. taller turbines, with larger swept areas) are increasing capacity factors for a given resource compared to older wind turbine models. The combined result is that onshore wind in particular is now very competitive where good cost structures and/or wind resources exist.

Figure 17. Wind Turbine Price Evolution by Market, 1997 to 2015



Source: IRENA

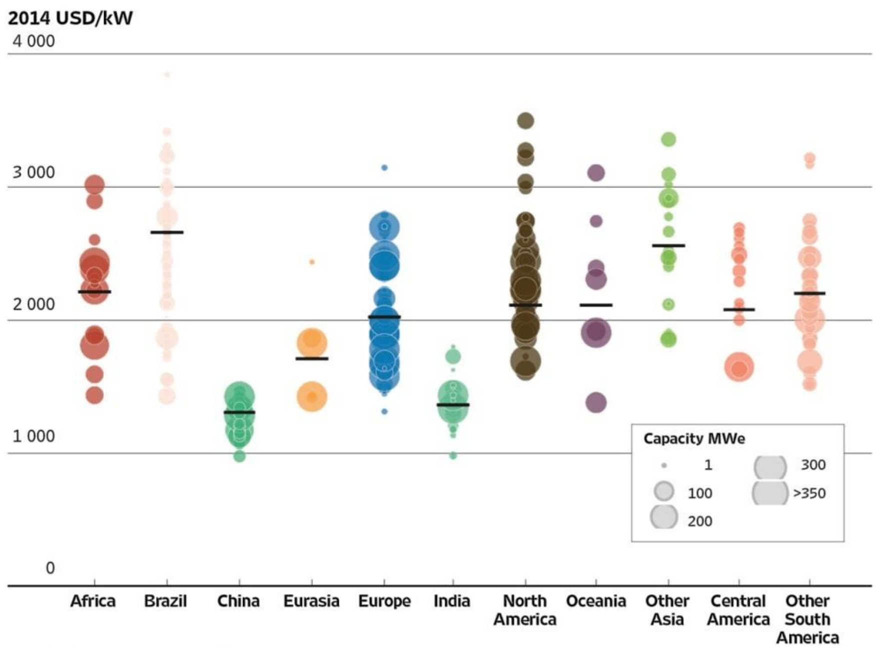
[10] According to World Wind Energy Association (WWEA).

The wind turbine is the largest single cost item of the total installed cost of a wind farm. Wind turbine prices have fluctuated with economic cycles and with the price of commodities such as copper and steel, which can make up a sizeable part of the final cost of a wind turbine. The average turbine price in the United States for projects larger than 100 MW was $755/kW for projects delivered between 2000 and 2002 (Wiser and Bollinger, 2014). In 2009, the cost of wind turbines peaked in the United States at $1,728/kW and in Europe at around $1,890/kW. Since the peak of 2009 wind turbine prices have fallen by around 30% (See Figure 17).

Wind project installed costs have declined, especially in the US but by varying amounts geographically

As a result total installed costs have also declined, for instance from around $2,300/kW in the United States in 2009 to $1,710/kW in 2014, with expectations that little change will occur in 2015. However, similar to solar PV, there exists a wide variation in installed costs by country (See Figure 18). This reflects differences in the maturity of the local market, the extent and competiveness of the local supply chain, as well as structural factors (e.g. labor rates, local commodity prices, etc.).

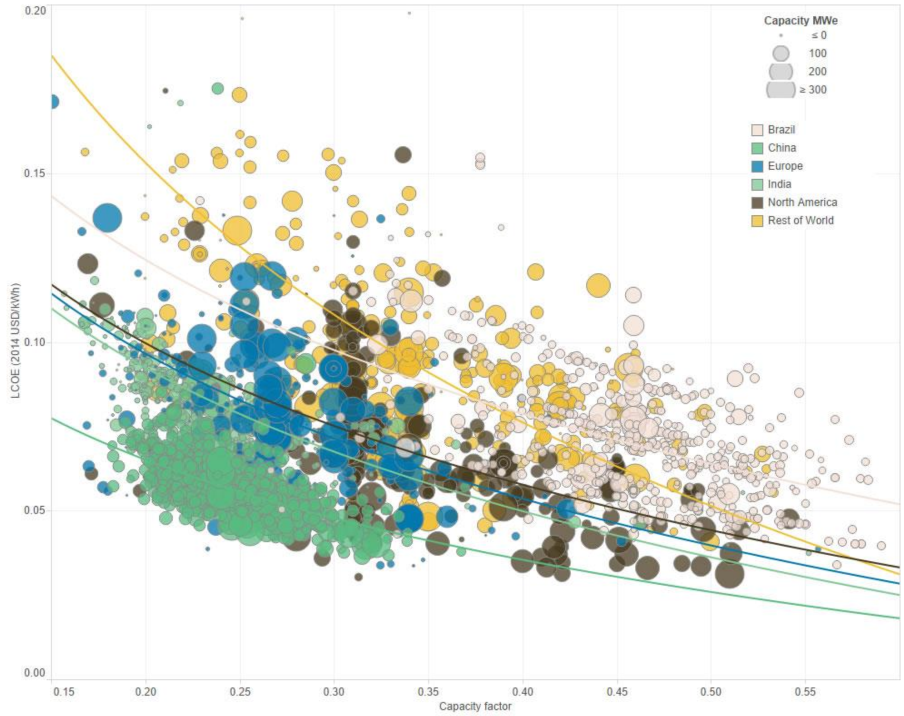
Figure 18. Wind Project Installed Costs by Country or Region and Project Size, 2013/2014



Source: IRENA

What is interesting for onshore wind power is that the magnitude of this variation in installed costs is not translated into the LCOE. Competitive pressures mean that countries with poorer wind resources work much harder to drive down costs to ensure wind is competitive, while those with excellent resources can bear higher installed costs (e.g. through higher grid connection costs) in order to access the best resources. The end result is that onshore wind can deliver competitive electricity across a range of wind resource qualities (See Figure 19).

Figure 19. Wind Project LCOE Compared to Capacity Factor by Country/Region and Project Size



Source: IRENA

Energy 2030: Commodities Analysis

(5) A Global Power Struggle: The Face-off between Renewables, Coal and Gas

Anthony Yuen
Ed Morse
Seth Kleinman
Adriana Knatchbull-Hugessen
Commodities Research Team

Fossil fuel prices could stay lower for longer, but renewable energy costs have also gotten more competitive over time: which will win out? Understanding the true competitiveness of fossil fuels vs. renewables is crucial to seeing where regional and global energy balances could be heading. Though policy support will be another key driver of renewable adoption, in a world where many governments have limited fiscal capacity to subsidize costly renewable projects, competitive dynamics will play an increasingly important role. Here, reducing financing costs may be the next frontier.

Competitive dynamics among fossil fuel will be critical to reaching emission targets

Competitive dynamics among fossil fuel technologies will also be critical to reaching emission targets. Conventional wisdom dictates that natural gas, a cleaner-burning fossil fuel, could enter its golden age, and coal, the dirtier fuel, should lose market share. However, conventional wisdom could be wrong: alternative outcomes could see coal less of a loser and gas less of a winner, with dramatic impacts on carbon emissions.

In the following section, we discuss the face-off between fossil fuels and renewables and the role financing costs could play in shaping its outcome.

In a Low Fuel Price Environment, Financing Costs Could Be the Differentiator between Fossil and Renewables

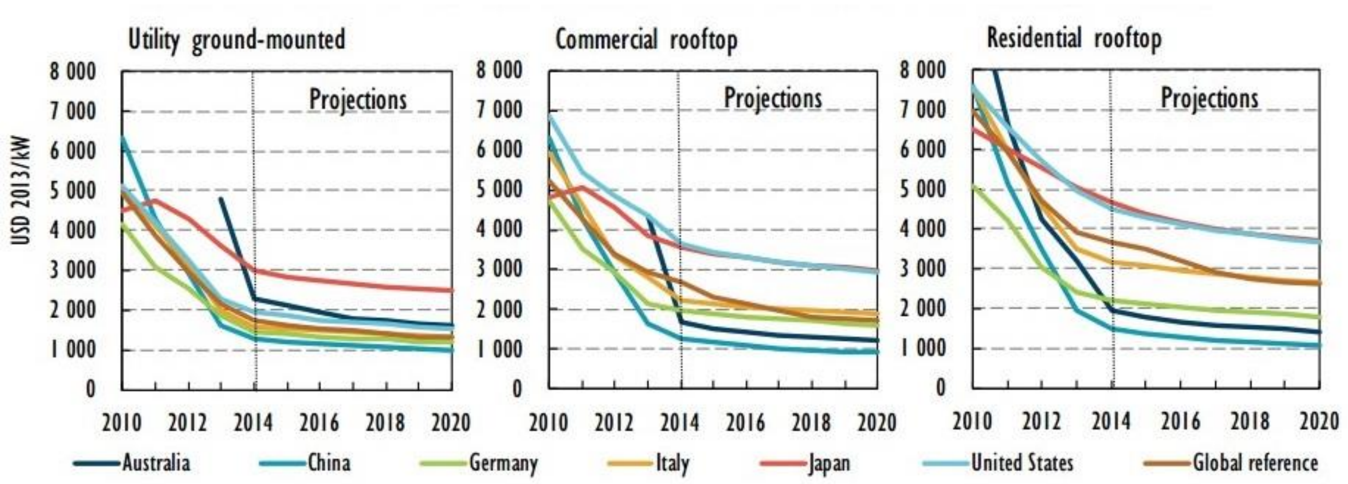
Renewable energy has accounted for more than 50% of all new power sector capacity additions globally since 2011

In the power sector, the momentum behind renewable energy is strong and building: since 2011, renewable energy has accounted for more than half of all new capacity additions globally. Citi expects that share to increase going forward. But the new reality of cheaper fossil fuels alters competitive dynamics in important ways that can shape investment in the coming decade. Financing costs need to play an increasingly important role in determining how the battle between fossil fuels and renewable alternatives plays out.

Capital costs for renewables have seen dramatic declines helped by the technological revolution

As the technological revolution in renewable energy has progressed capital costs for renewables have seen dramatic declines while efficiencies have improved; certain technologies such as onshore wind have become economic in some regions even absent any policy support. But this very maturation of renewable technology inevitably leads to a slower pace of capital cost reduction as efficiency gains and cost declines approach technical asymptotes. As technologies mature, the cost declines associated with additional capacity growth diminish, a phenomenon typically captured in models by a logarithmic relationship between installed capacity and costs. Wind and solar are increasingly becoming mature technologies with many agencies expecting slower cost declines going forward.

Figure 20. IEA Historical and Forecasted Solar PV Investment Costs Show Diminishing Rates of Cost Reduction



Source: IEA Medium-Term Renewable Energy Outlook

Further cost declines in renewables will be necessary for them to remain competitive with cheap fossil fuels and incentivize deployment

But in a world awash in cheap fossil fuels, further cost declines in renewables will be necessary to incentivize deployment, creating a need to pursue other avenues of cost reduction to reach sustainable energy goals. Reducing financing costs is the next phase in improving the competitiveness of renewable energy. For capital intensive renewable projects, financing costs can make up nearly half of the total cost of a project. This is particularly true in developing nations, where the cost of capital can be much higher and access to capital markets much more restricted. This is also where the majority of new generating capacity is being deployed, making reducing financing costs for renewable energy projects pertinent in the global effort to combat climate change.

Analyzing fossil fuel and renewable competitiveness out to 2030— laying out our assumptions

In this report we analyze the economic competiveness of coal, gas, wind and solar power generation to 2030 in key global markets, considering:

- Detailed Citi forecasts for lower oil, gas and coal prices globally.
- Comprehensive global data from IRENA on actual installed costs for renewable energy in important regions of the world and the latest data on installed costs from the IEA for coal and gas plants in various countries.[11]
- The latest technological learning assumptions from the US National Renewable Energy Laboratory based on the DOE's Wind and Solar Vision reports for renewables and the Annual Energy Outlook for coal and gas.[12]

[11] Two general approaches to analyzing renewable energy costs are often used: observed costs and modeled costs. Because regional differences in equipment costs, labor, permitting and other local factors and be critically important, using actual, observed comprehensive statistics for a large sample of global projects that have actually been installed yields more relevant results than a modeled approach. Hence we rely on an empirical rather than hypothetical cost approach.

[12] Bolinger, Mark and Joachim Seel. "Utility-scale solar 2014: an empirical analysis of project cost, performance and pricing trends in the United States" Lawrence Berkley National Laboratory. 2015; and Wiser, Ryan and Mark Bolinger. "2014 Wind Technologies Market Report" Lawrence Berkley National Laboratory. 2015.

- Financial modeling of power plant economics based on Citi's adaptation and enhancement of US Department of Energy's power plant models.[13]
- Citi's analysis of global capital market conditions, renewable energy finance and capital costs.
- Our analysis assumes a 10% investment tax (ITC) credit for solar in the US, but no other government subsidies or tax credits.

We assume the US long-term gas price to average $3.50/MMBtu in 2015 dollars, with a soft ceiling in the low-$4 range and soft floor around $3. Production growth continues even in places where prices have fallen to the $1/MMBtu range.[14] See "The New American (Gas) Century II: Disruptive and Durable" for further discussion of long-term US natural gas pricing. We also assume the use of ultra-supercritical technology for coal (in all locations except the US) in our competitive generation economic analysis between coal, gas and renewables. Hence, cuts in public financing, as announced by the OECD, have no impact on our analysis.

Over the next half-decade when new US LNG terminals come online, we assume that the price of US natural gas delivered could fall to around $4.50 to $5.50 for Europe and $6 to $7 for East Asia, compared with over $20/MMBtu in Asia just two years ago.[15],[16]

Costs in the power sector can vary significantly across countries and even within countries. We attempt to capture some of this variation by considering five representative regions: the United States, OECD Asia, Developing Asia, Europe and Latin America. Each region is differentiated by capital costs and technological efficiency, based on data from IRENA, the International Energy Agency (IEA), and the US Energy Information Administration (EIA). Financing costs are differentiated by region according to three main categories: developed world, low-cost financing developing world and high-cost financing developing world. In the developing world (United States, OECD Asia, and Europe), we use a 9% nominal (7% real) weighted average cost of capital (WACC), while in the high-cost financing developing world (Latin America) we use a 17% nominal (10% real) WACC. In developing Asia, some financial institutions are flushed with money thereby driving the cost of capital, below even the prevailing rates in the developed world. In this region, we use a 7% nominal (5% real) WACC. These assumptions were based on the average WACC of equity indices in different countries, such as the US, China and Brazil, as well as conversations with professionals in capital markets.

[13] Adapted from the Annual Technology Baseline (ATB) model from the US National Renewable Energy Laboratory, 2015.
[14] Although this price level does not appear to be sustainable long term (as it may only cover variable costs in some locations), considerably lower price ranges due to cost reduction, productivity gains and exploitation of large gas fields seem likely, with far-reaching consequences.
[15] This assumes capacity charges, which covers the capital costs of US LNG terminals as sunk, a $3.50/MMBtu Henry Hub gas long term, in addition to a transport cost of ~$0.9 from the US Gulf Coast (USGC) to Europe and ~$2.7 from USGC to Asia.
[16] If certain costs are viewed as sunk, this could take delivered costs of US LNG down further to ~$4 to $4.50 for Europe and ~$5 to $6 for Asia. Some offtakers of US LNG may consider dayrates of an LNG vessel sunk if they own or have signed long term contracts.

This analysis is a comparison of the current state and projected competitive dynamics, not a forecast of the likely future of power markets

Though we attempt to make realistic cost estimates and projections by differentiating by region and using current data on actual installed costs, there are still many limitations to cost modelling that should be noted here. These include: limited data on costs particularly outside the US, variability in resource efficiency between locations, the high sensitivity of forecasts to assumptions on technological innovation, grid integration costs and the feedback effect on power pricing from renewables (discussed below). **As such, we intend this analysis principally as a comparison of the current state of and projected competitive dynamics and particularly what factors could influence this evolution, rather than a forecast of the likely future of the power market**.

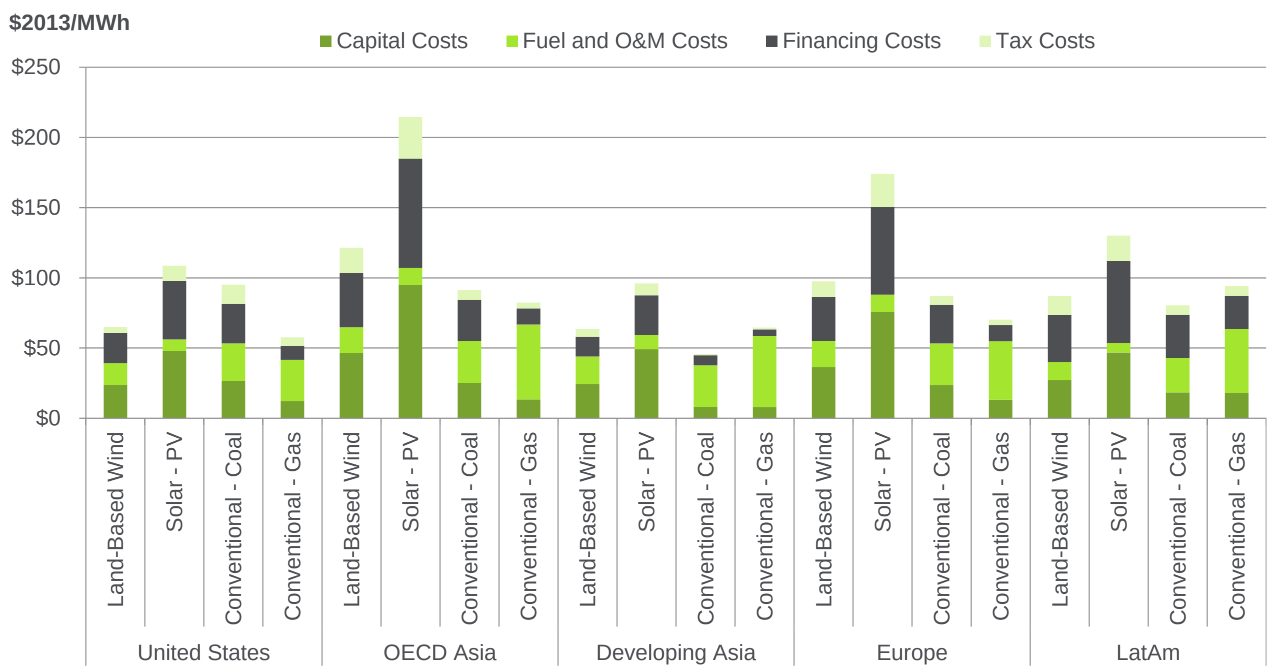
The Current State of Competitive Dynamics

Falling capital costs have increased the competitiveness of renewables vs. fossil fuels on an economic basis

As the capital costs of renewables have come down, these technologies have increasingly been able to compete with fossil fuels on an economic basis. But competitive dynamics vary significantly in different parts of the world, due to regional differences in capital costs, fuel costs and access to cheap capital. Note the year specified in our work is the year of investment, rather than the online year.

The cost of building and operating a power plant consists of several key factors. First are the capital costs related to the sourcing and construction of a power plant, operating and maintenance (O&M) costs involved in running the power plant, fuel costs in the case of fossil generation and the financing costs associated with raising debt and equity capital for the project. Then come other costs that relate to tax structure and government incentives.

Figure 21. The Breakdown (Capital, O&M, Financing and Tax) in 2015 of Power Plant Costs (New) Across Regions and Technologies Shows that Financing Costs Can Be a Significant Portion of Overall Costs for Renewables, Particularly in Developing Countries with High Cost of Capital



Source: NREL, IRENA, IEA, EIA, Citi Research

The relative importance of power plant costs varies amongst technologies…

The relative importance of these costs varies significantly amongst technologies. Variable costs (including fuel and O&M) make up a larger portion of the overall cost of fossil fuel generation than renewable generation, due to the absence of fuel costs in the latter case – though this has become less of a differentiator with the substantial decline in fossil fuel pricing over the last year. However, renewable projects and particularly utility-scale solar PV, tend to be more capital-intensive than fossil fuel generation because the upfront costs of building the plants tend to be higher as compared to gas and coal. Renewables are also affected by low capacity factors as compared to fossil fuels (the percentage of time a plant is actually able to produce electricity) due to the variability in wind and solar resources throughout the day and year. This raises not only the capital costs of renewable projects, but also their financing costs.

...and across regions

The distribution across cost categories also varies regionally. In the developing world with high-cost financing, such as Latin America, financing costs for capital intensive renewables projects can indeed constitute the largest component of overall costs. On the other hand, in developing Asia, with low-cost financing and low labor and construction costs, both capital costs and the cost of financing are diminished, making fuel costs a principal driver of overall economics.

Fuel costs also differ considerably across regions

Regionally, fuel costs can differ considerably. In the US where an abundance of natural gas from shale production has brought on a new era of low-cost natural gas pricing, variable costs for gas generation are nearly on par with coal on a country-wide average basis and are lower than coal in certain regions. But in other parts of the world, where higher-cost LNG dominates, coal remains the least cost alternative on an operational cost basis, and in developing Asia, coal is the lowest total cost technology due to the large impact of relatively high natural gas prices. Indeed natural gas may be less of a winner than many market players have previously anticipated as we discuss in detail below.

Current competitive dynamics are driven by these regional and technological differences

These regional and technological differences play important roles in current competitive dynamics, differentiating the least-cost technologies across the world. In the US, natural gas generation is the most economic technology on a total basis, though onshore wind is nearly as cheap. Coal and solar-PV are relatively expensive in the US. In OECD Asia, both onshore wind and solar PV remain relatively expensive compared to fossil generation due to high capital costs. Gas is slightly cheaper than coal in a total cost basis, though on a variable cost basis, coal is the winner. In developing Asia, cheap coal and low capital costs continue to make coal the lowest cost technology. Wind's competitiveness is hampered by low capacity factors; there is a huge opportunity for greater competitiveness if capacity factors can be improved. While fossil generation remains the most competitive in Europe, aggressive policies for renewable energy drive economics there. Hence investment will be more tied to Feed-in-Tariff (FiT) policy than competitiveness. Finally, in Latin America wind is already the lowest cost technology (we exclude coal due to negligible generating capacity for coal-fired plants in Latin America) due to relatively expensive fuel prices in this region.

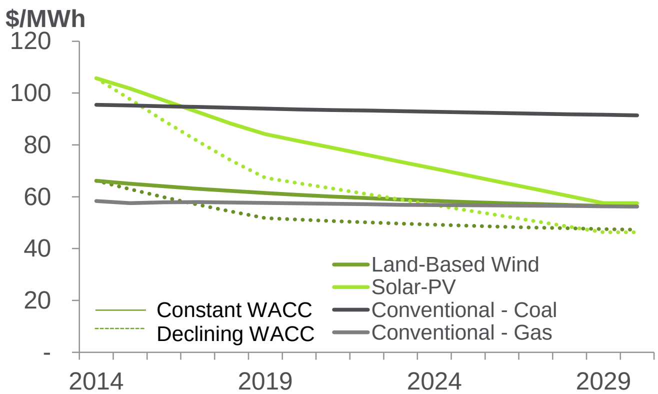
One thing that is consistent across regions: financing costs are significant in overall spend for a renewables projects. Indeed, it is clear that financing costs will be an important driver of relative economics between renewables and fossil fuels going forward, particularly if capital cost reductions slow. To what degree could financing costs influence competitive dynamics?

Can Financing Costs become the Differentiator?

Analyzing new power plant costs to 2030 under two financing scenarios

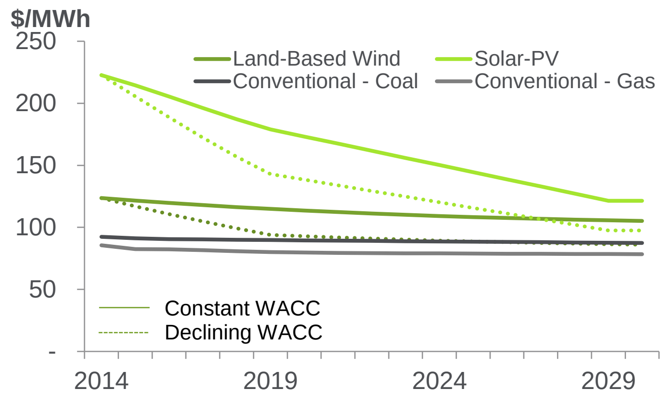
To investigate how innovations in renewable energy finance and policy support for green finance could alter the competitive dynamics of renewables vs. fossil fuels, we consider total costs of new power plants forecasted to 2030 under two financing cost scenarios for renewables.

Figure 22. US: Results Show that Onshore Wind Is Already Nearly Competitive with Natural Gas Generation (Country-wide Average, May Vary Regionally). Solar Would Become Competitive with Gas in the Mid-2020s Under the Cheaper Financing Scenario



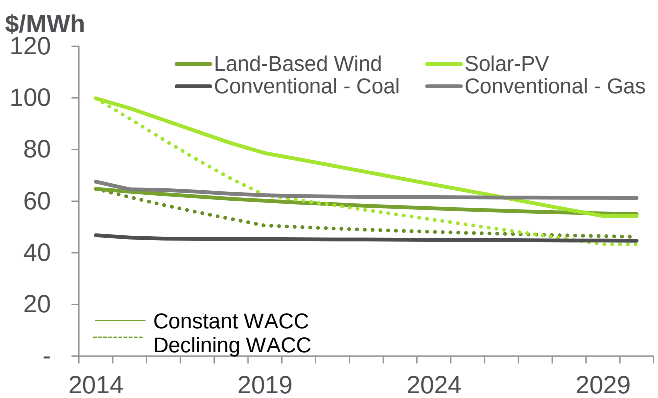
Source: NREL, IRENA, IEA, EIA, Citi Research

Figure 23. OECD Asia: Although Coal and Gas Remain the Cheapest Technologies (Total Cost) Throughout the Forecasting Period, Under Cheaper Financing, Wind Would Become Competitive by 2020 and Solar Would Be Nearly Competitive by 2030



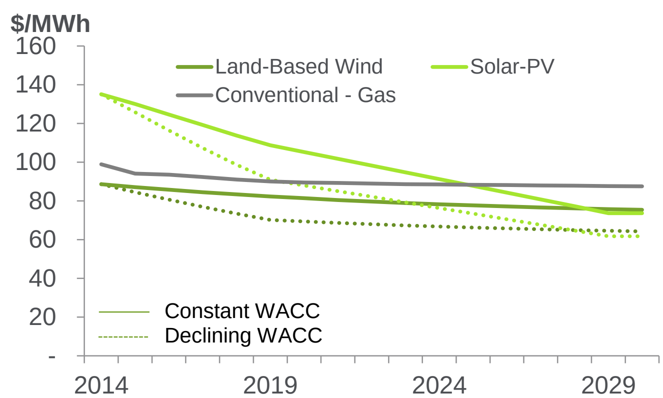
Source: NREL, IRENA, IEA, EIA, Citi Research

Figure 24. Developing Asia: Cheap Coal Is Hard to Dislodge in Developing Asia, but Cheaper Financing Would Make Both Solar and Wind Competitive by the End of the Forecasting Period



Source: NREL, IRENA, IEA, EIA, Citi Research

Figure 25. LatAm: Wind Is Already Nearly the Lowest Cost Technology. Cheaper Financing Could Bring Down Solar Costs to Competitive Levels by the Early 2020s



Source: NREL, IRENA, IEA, EIA, Citi Research

We look at both a "high" and a "low" financing cost scenario

The first scenario ("high") uses the financing costs as indicated earlier constant over the forecasting period, while the second scenario ("low") considers a 250pbs reduction by 2020 in real WACC, a hypothetical scenario of possible financing cost reductions. We incorporate cost declines and efficiency improvements in our projections based on the assumptions of the National Renewable Energy Laboratory (NREL) as a base case for cost declines in various technologies.

Reduced financing costs for renewables can accelerate the competitive "threshold" of wind and solar vs. fossil

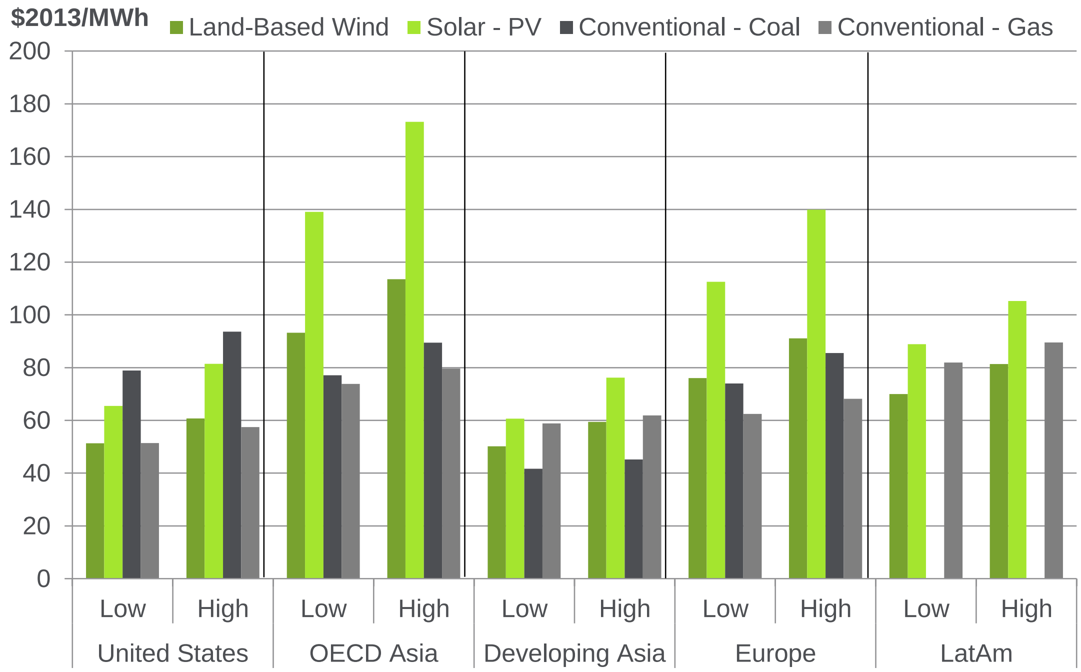
Reduced financing costs for renewables can greatly accelerate the competitive "threshold" of wind and solar vs. fossil. In some cases, cheaper financing is the differentiator between a future in which renewable technologies eventual compete with coal and gas and one where fossil fuels remain the cheapest alternative throughout our forecasting period.

- **US:** In the US, solar is nearly competitive with coal and should surpass coal under both scenarios by the end of the decade. Wind is nearly on par with low cost natural gas generation. To be sure, gas prices vary regionally in the US, as do wind capacity factors, which could impact wind's competitiveness in certain regions. But under a cheaper financing scenario, both wind and solar become clear winners over our forecasting period with wind surpassing gas within the next few years and solar by the late-2020s.
- **OECD Asia:** Coal and gas remain the most competitive throughout the forecasting period in the baseline case. With cheaper cost of capital, wind becomes competitive with fossil fuels in the early 2020s and solar in the late 2020s.
- **Developing Asia:** Cheap coal will be difficult to dethrone in developing Asia, but under a reduced cost of capital scenario, both wind and solar would be competitive in the 2020s. Solar would become competitive with gas by the late 2020s in our base case and by the early 2020s under lower cost financing.
- **Europe (not shown):** Power markets in Europe are driven more by policy than competitive dynamics. Gas and coal are the cheapest technologies into the mid-2020s under our base case, but heavy subsidization of renewables has supported rapid penetration there.
- **Latin America:** Wind is already competitive with gas. Solar would become competitive with wind and gas in the early 2020s under cheaper financing versus the late 2020s in our baseline scenario.

Competitive dynamics could be altered even if cost of capital declines across all technologies

Such differentiated declines in the cost of capital for renewables vs. fossil fuels would likely necessitate policy intervention or targeted financial products for renewable technologies. Competitive dynamics could be altered even if the cost of capital declines across all technologies. This may be particularly important in the developing world, where there is significant space for reducing institutional risk.

Figure 26. 2020 LCOE of Various Technologies under High and Low Financing Cost Scenarios Show that Lower Cost Financing Significantly Narrows the Gap between Renewable and Fossil Fuel Projects Costs



Source: NREL, IRENA, IEA, EIA, Citi Research

In a lower financing cost scenario, all technologies indicate that competitive economics of renewables improve significantly

Indeed, projected costs in 2020 applying the "high" and "low" financing cost scenarios to *all technologies* indicate that the competitive economics of renewables improve significantly under a lower cost financing scenario. Because financing costs disproportionately affect high capital cost renewable projects, reductions in financing costs disproportionately benefit these projects. Innovation in financing could thus reduce the "gap" that technological innovation must cover in order to bring renewables into an era of cost competitiveness with fossil fuels. This could be particularly important for solar projects, which largely remain above competitive cost levels in our forecasts.

Other factors affect capital costs and could affect renewable energy economics…

To be sure capital cost declines may progress faster or slower than our projections, potentially changing ultimate competitive dynamics. Key variables could improve renewable energy economics vs. these results: (1) faster technological innovation could lead to both lower equipment costs and better capacity factors; (2) capacity factor optimization from improved project siting or better grid connectivity (less curtailment); and (3) lower costs of capital. On the other hand, coal and gas technologies could likewise see more aggressive cost declines if fuel prices continue to fall or technological innovation in this space exceeds expectations.

...but financing costs still matter

But regardless of how the actual progression of capital cost declines and efficiency improvements across fossil and renewable technologies manifests, financing costs will matter. Cheaper renewables financing can greatly accelerate the timeline for renewables to become more competitive than fossil generation on a widespread basis. Even cheaper financing across all technologies would improve the competitive landscape for renewables, narrowing the gap between total costs of fossil and renewables, bearing some of the burden for cost reduction.

Even so, several concluding caveats need to be noted:

(a) In power markets, competitive dynamics don't always drive investment

Competition is not always straightforward in energy markets

Competition is not always straightforward in energy markets. Many of the power markets in emerging Asian economies are not competitive; they are state-controlled or in various states of gradual reform.[17] India, China and much of Asia fall into this category, although China is set to open up its power market to more competition. In sum, economics still matter in developing economies, but are heavily distorted by government and policy objectives.

(b) Impacts of intermittency and grid integration costs are externalities of high renewable penetration that are not captured by plant costs

Intermittency and grid integration costs are important economic factors for renewables

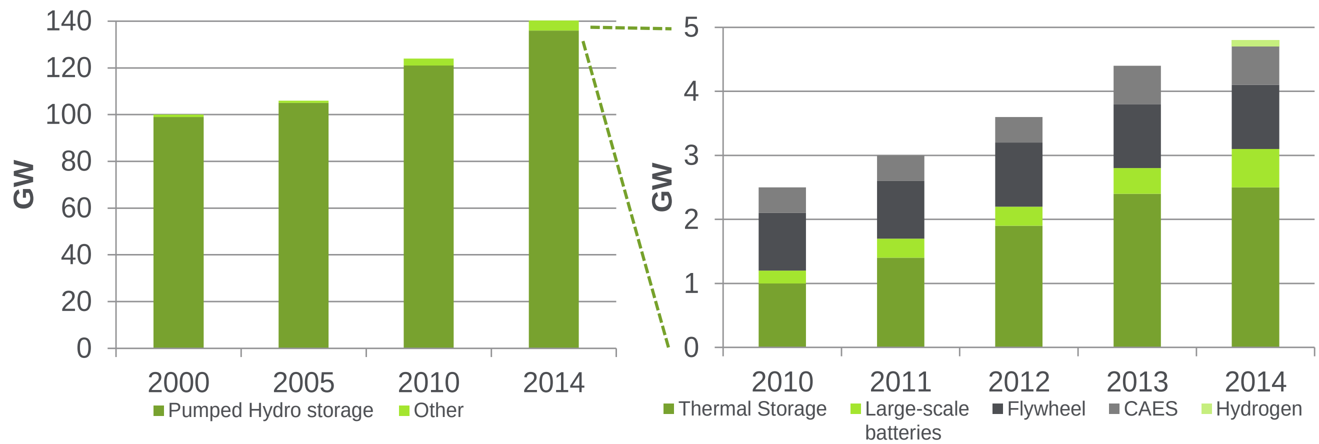
Another important economic factor is the role of intermittency and grid integration costs. Examining asset-level competitiveness does not fully capture the effect on the entire electrical grid, which should also be taken into account.[18] Some renewables can be baseload, "dispatchable" power: hydro, biomass and geothermal. Others, such as wind and solar, depend on weather conditions and are interruptible by nature and therefore variable (henceforth VRE, or variable renewable energy).

The integration of a substantial share of renewable energy into the power grid will require large investments and changes in operation. They include: (1) accommodating two-way power flows, blurring the generation-load divide, because homes themselves could generate electricity through distributed generation resources, such as solar; (2) improving ancillary services to balance the grid and accommodate the intermittency of renewables, as electricity supply and demand have to be balanced instantly; (3) wider adoption of demand-side management measures that can change demand patterns throughout the day; (4) integrating multiple distributed generation resources for greater balancing and resiliency; and (5) incorporating energy storage to balance the electricity network.

[17] For a detailed analysis of the political economy of developing country power sectors, see Victor, David and Heller, Thomas. "The Political Economy of Power Sector Reform; The Experiences of Five Major Developing Countries". Cambridge University Press. Cambridge. 2009.

[18] For a more detailed assessment of this issue, see Renenewable Energy Integration in Power Grids. IRENA. 2015.

Figure 27. Global Energy Storage Capacity from Pumped Hydro, Large-scale Batteries and Other Sources

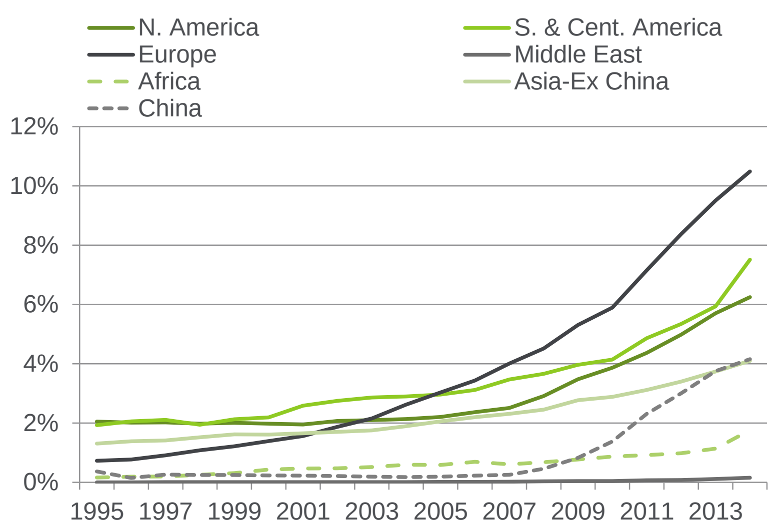


Source: IEA, Citi Research

Storage could be a key factor going forward but is currently inadequate to back up intermittent power systems globally

Storage could be a key technology going forward, but for the moment, its scale is unfortunately inadequate to back up intermittent power systems globally. The total electricity generated globally in 2014 was 2,687GW in utilized capacity terms, of which ~100-GW came from solar and wind. Although the latest IEA report put storage capacity at just under 140-GW, seemingly sufficient to back up renewables, nearly all of that capacity is pumped-storage (i.e. water on high ground or tanks). These pumped-storage facilities are often not in the same area as where solar and wind are expanding, while the non-pumped part of storage is still less than 5-GW, of which battery is less than 1-GW. Even at rapid growth rates, it would take years for batteries to be able to back up solar and wind. In addition, currently the growth of solar and wind appears to be faster in absolute terms than non-pumped storage. Finally, the cost of large-scale batteries is still very high making the full system cost of renewables supported by battery storage much higher than if renewables were standalone resources able to produce a smooth generation profile like fossil, nuclear or hydro.

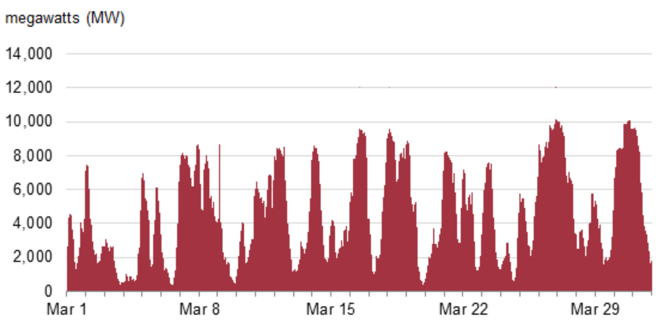
Figure 28. Penetration of Renewables (% Renewable Consumption to Total Electricity Generation) in Major Regions



Source: BP, Citi Research

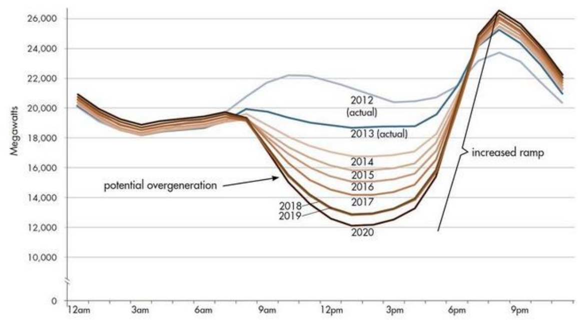
The cost and level of investment required will be a function of renewable energy penetration levels. Integration costs can be considered in two categories: grid infrastructure and system operations costs. IRENA estimates that grid upgrading costs for a power system with 20-30% variable renewable energy, subject to grid and interconnection capabilities could be in the range of $0.5-3.5/MWh.[19] These costs can be phased in over time as renewable energy penetration increases. For system operation costs, the single largest cost is anticipated to be reduced plant utilization of baseload assets. At penetration rates of 30-40%, this would account for half of system operations costs on the level of $16-28/MWh.

Figure 29. For Wind Generation, There Are Still Kinks that Require Smoothing (ERCOT Hourly Wind Generation in March 2014)



Source: EIA, Citi Research

Figure 30. "Duck" Curve Representing the Sharp Drop in Mid-day Electricity Demand but the Sharp Ramp-up of Evening Demand (Net Load Curve for California from 2012 to 2020)



Source: LBNL, Citi Research

(c) Greater renewable energy penetration will have feedback effects on power prices and generation revenue

Costs aren't the only consideration for renewables, the revenue side matters as well

The revenue side of the economic calculation is equally as important as the cost side, where much of the discussion so far has focused on the fuel, capital and financing cost of power assets.

Greater penetration of renewables pushes down power prices and impacts the value of all generation assets. Higher shares of renewables and more generation from sources with near-zero marginal costs (e.g. nuclear) should keep off-peak prices low. Regions with large shares of low-cost variable generation at times see near zero or even negative electricity prices because generation from renewable energy exceeds demand or transmission capacity. Developers are concerned about these shrinking margins, which impedes the motivation to sponsor renewable energy projects. Hence, as margin falls, the solar and wind install economics will have to rely more on continued cost declines to stay economic.

Renewables power prices could become move volatile at certain times of the day due to a surge in mid-day generation

Power prices could also be more volatile during certain times of the day. High penetration rates of renewables also create another problem manifested in a so-called "Duck" curve. The surge in solar generation mid-day sharply lowers mid-day electricity demand and severely depresses prices. But the evening ramp-up in electricity demand after sunset requires either more fossil generation or sufficient energy release from storage facilities. Therefore, markets for ancillary services and capacity become necessary to financially support electricity supply from fossil or storage, as energy prices (i.e., electricity prices) are expected to keep falling.

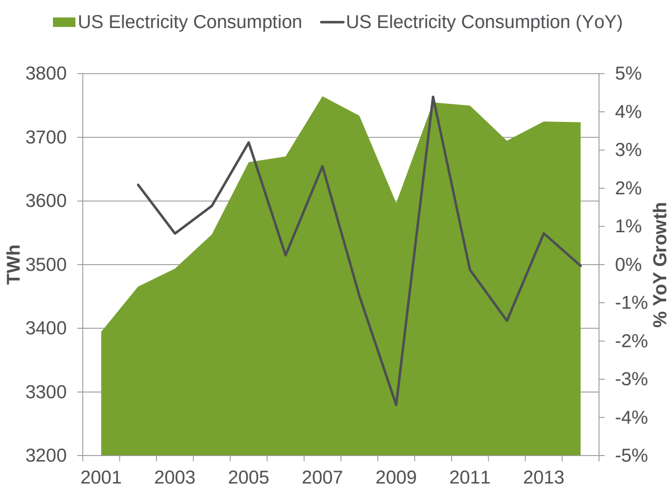
[19] Renewable Energy Integration in Power Grids. IRENA. 2015. See report for detailed discussion.

(d) The role of power demand growth and energy efficiency

The pace of energy demand growth relative to economic growth is an important factor

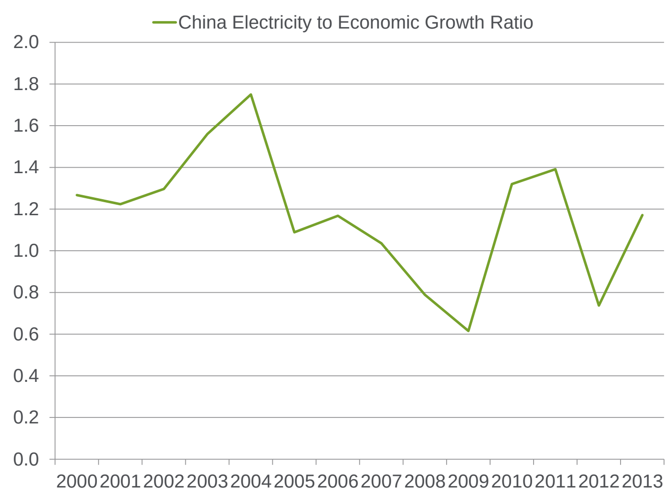
Given the competitive dynamics shown above, the pace of electricity demand growth relative to economic growth is an important factor in how much renewable energy would be required to meet emissions constraints. Historically, electricity demand growth was generally correlated with changes in economic activities. But over the last few years, electricity demand growth has shown a weaker correlation to GDP growth. The impact of load energy efficiency, off-grid and distributed generation, demand response, and behavioral changes has become more significant.[20] Indeed in recent years, Europe, Japan and the US have seen positive GDP growth, but flat to negative power demand growth. In emerging markets, power demand growth, although still largely positive, may not necessarily keep pace with GDP growth: the ratio of year-over-year electricity demand growth to year-over-year GDP growth in China has fell from over 1.2 in the 2000s to below 0.2 in 2015.

Figure 31. US Power Demand Growth Has Flat-lined in Recent Years



Source: EIA, Citi Research

Figure 32. China % YoY Change in Electricity Consumption to %YoY Change in GDP Shows that the Energy Intensity of Growth Is Declining



Source: Bloomberg, NBSC, Citi Research

If there is lower power demand growth, power market fossil fuel allocation could increase while still meeting emission constraints

In a scenario with lower power demand growth, the power market could allocate a greater share of total generation to fossil fuel while still meeting emission constraints. This lower demand growth scenario means less total generation required, and it becomes easier to meet emission targets. This leaves more room for coal to compete with gas as coal and gas can take a larger "share of the pie" while still meeting emissions constraints. Citi's recent analysis on the US Clean Power Plan highlights how low power demand, despite the implementation of an emission cap, could help support coal-fired generation.

[20] The US, Europe and Japan have all seen declines in power demand (weather-adjusted), likely reflective of a gradual decoupling of electricity demand and economic growth rates. China's YTD power load growth of less than 1% y/y relatively robust official GDP growth figures may also signal some form of decoupling between electricity and economic growth.

Cheap Oil and the Rise of the Alternative Vehicle

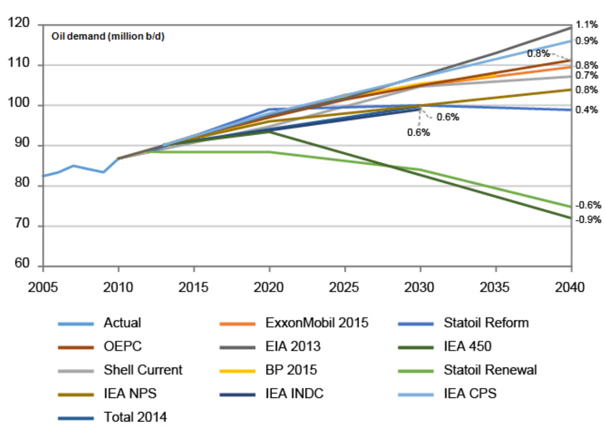
Oil's impacts on renewable energy most often come through (a) the alternative transport sector and (b) wind and solar in certain electricity generation systems. Low oil prices could slow the growth of electric vehicles (EVs), thereby cutting the power load growth assumptions embedded in some projections. As discussed above, lower power demand growth appears to favor coal over gas as a power generation fuel in some locations.

Structural factors — rising energy efficiencies and energy substitution — remain in play and will continue to weigh on oil demand growth. US consumers may be buying SUVs again, but fuel economy mandates mean that a model year 2016 model is a very different technological animal to a model year 2005 model. The drop in diesel pricing has slowed the momentum towards compressed natural gas (CNG)/liquefied natural gas (LNG) trucks in the US, but the collapse in oil-inked LNG prices, and the massive ramp up in LNG supplies just underway in Asia means that gas prices have fallen even more than oil prices, keeping the momentum in place in that crucial demand region. Furthermore the collapse in LNG prices will effectively trap large amounts of gas in various countries around the world; a portion of the gas that was expected to be exported into global LNG markets could instead be repurposed.

Even as lower oil prices potentially slow the direct oil-to-gas transportation switch near-term, an increasing focus on emissions standards ahead of Paris and in the wake of VW's clean diesel scandal, along with continued renewables growth and a sluggish (and less oil intensive) global economy will keep eroding oil demand growth. Figure 33 below shows a comparison of global oil demand forecasts with even the most bullish seeing just a 1% compound annual growth rate out to 2040. In fact, a recent study by Carbon Tracker challenged the assumptions of population growth, GDP growth, energy intensity and renewables growth used by the bulk of forecasters to paint a starkly different (and much lower) scenario. The key question is clearly becoming how quickly will oil demand peak, not if it will.

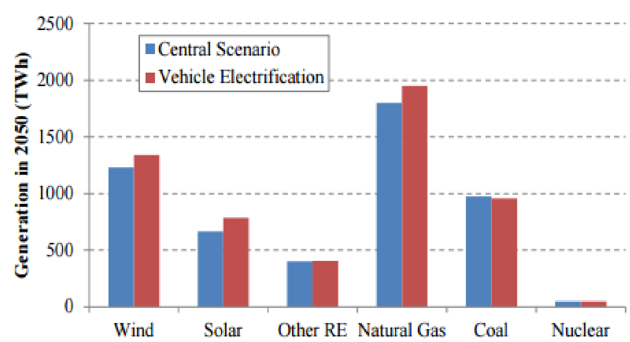
For personal transportation, the drive for less polluting vehicles continues globally, with China, the world's largest auto consumer, now driving early adoption of efficiency mandates. After a sluggish adoption of China-4 (equivalent to EU-4) fuel standards, the move to China-5 standards has accelerated with provinces such as Shandong and Hainan enforcing earlier adoption targets than the broader government requirements. Globally the drive for a reduction in carbon emissions from passenger vehicles is unaffected by the lower oil price, with government commitments to increasing fuel efficiency not waning. And this is helping drive growth in alternative fuel vehicles such as hydrogen fuel cells and PHEV/EV's, an area where China saw staggering growth last year of over 300% last year (see Figure 36 below).

Figure 33. Future Oil Demand Forecasts (m b/d)



Source: Carbon Tracker Initiative

Figure 34. Electricity Generation by Generator Type in 2050 for the High PHEV Adoption Scenario. The Additional PHEV Demand Is Met Primarily by Wind, Solar, and Natural Gas Generators.

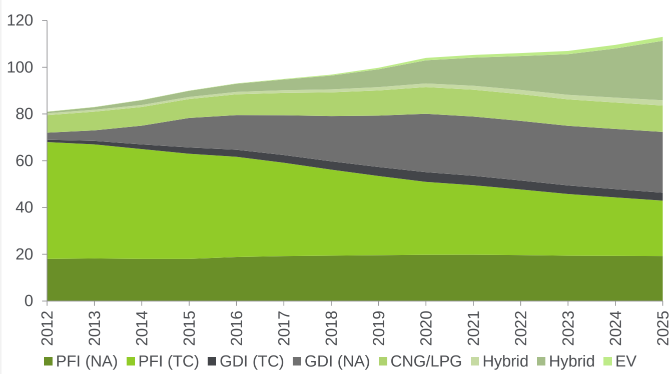


Source: US National Renewable Energy Laboratory

Citi published its latest in the Car of the Future series earlier this year (see Citi GPS: Car of the Future v2.0) which lays out a roadmap for what could be propelling future vehicles, with electric vehicles and hybrids expected to see impressive growth in the years ahead. This potentially key area for passenger vehicle growth is seeing a raft of electrified vehicles brought to market, with the likes of BMW and Volvo adding to Tesla, Toyota and several others. And regional players in China, India and Japan are also increasing the range of alternative fuel vehicles available. It is still early stage, and switching costs remain high, such as in Europe where a Toyota Prius has a 19-year pay-off compared to a petrol-powered Volkswagen Golf, but this gap is closing, and growth rates such as those in China are impressive. The effect on oil demand would clearly be negative, but if vehicle electrification surpasses expectations, then this will provide a boost to power fuels according to a recent study by the US NREL. An increase in electricity demand under an "advanced electrification" scenario would boost both natural gas and solar by non-negligible amounts.

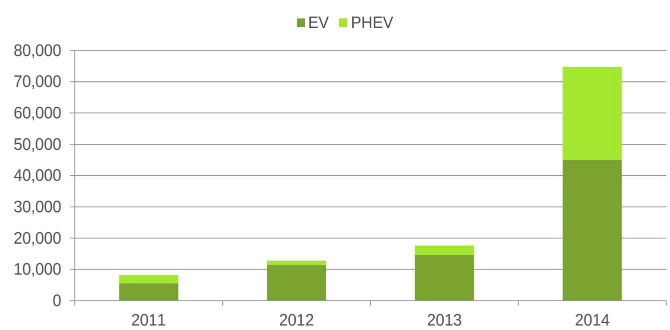
Also joining the fray is hydrogen-powered vehicles, which could actually prove advantageous to current energy producers given hydrogen can be derived from natural gas, though the gas demand for this should be small relative to total demand for all uses. Additionally, energy companies currently involved in retail distribution can benefit given refueling is essentially the same practices as currently for gasoline/diesel. Shell is leading the way in Germany and along with co-operation from other sources is aiming to have 400 hydrogen refueling stations by 2023. In Japan, government plans are for 100 refueling stations to be installed by the end of this fiscal year. This commitment to infrastructure build-out goes somewhere to overcome one of the biggest impediments of new fuelled vehicles.

Figure 35. Global Engine Penetration Roadmap to 2025



Source: IHS, Continental and Citi Research estimates

Figure 36. China – Pure EV & PHEV Sales (Passenger Vehicles)



Source: CAAM, Citi Research

The blowback from the Volkswagen clean diesel scandal has brought vehicle emissions and testing under heavy scrutiny, and in Europe this could pave the way for increased hybrid/electric vehicle adoption longer-term. Current emissions standards and attitudes in Europe act as an impediment to all fuel types. A 27% mandated decrease in new-car carbon emissions between 2015 and 2021 due to Euro VI and VIII standards makes petrol cars unviable. On-road testing, which should come in 2017, will likely prove difficult for current diesel cars to meet the 80g/km of nitrous oxide (NOx) allowable level. A recent EU commission proposal to raise this by 60% out to 2017 is being met with region-wide opposition, with member countries wanting even greater reductions and for a more prolonged period. The technology is there for diesel, but it comes at a cost, such as the BMW X5, which is installed with two NOx-trapping technologies, but this has increased the cost per vehicle by over $1,000 according to the International Council on Clean Transportation (ICCT). A similar issue arises for current hybrid/electric vehicles, with high switching costs vs. gasoline/diesel engines to achieve the greater efficiency and lower emissions. It will come down to the debate between cost vs. emission levels, and if stricter emissions standards are pursued this will likely foster a beneficial environment to hybrids/EV's given costs of diesel units will have to increase.

(6) Policies: Crucial Roles but Unintended Consequences

Policy support is critical to outcomes, despite improving costs of renewables. Global momentum to enact climate policy is building, with the Paris COP21 as the main event, garnering more optimism than any conference of parties (COP) since Copenhagen.

Any agreement could be undermined by the "free-rider" problem

However, the "free-rider problem" where some countries free-ride on others who implement more stringent policies, and low fossil fuel prices could get in the way of carrying out a forceful, comprehensive global agreement. For now, terms such as "acknowledge", "recognize" and "shall" seen in the draft text of the Paris agreement, instead of terms with more binding meaning, could give countries more leeway post-Paris, if those looser terms stay in the final agreement. More broadly, the transparency and review mechanisms on what and how countries pursue climate change goals, if widely adopted, could help countries and civil societies focus their actions on parties who are "non-compliant."

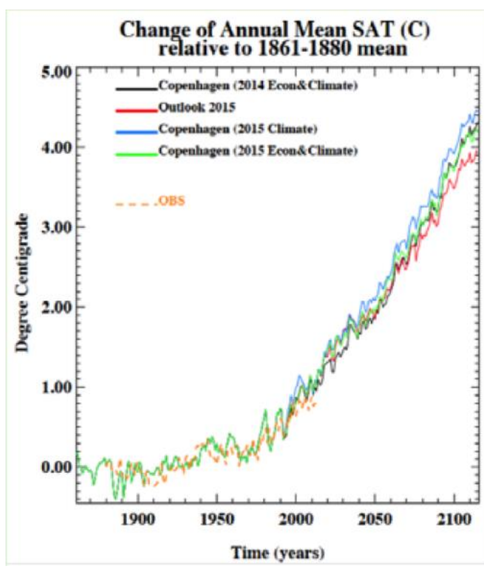
Local and national policies matter more than global agreements

The COP21 meeting in Paris matters, but bottom up, local and national policies matter more. In December, the global community will gather in Paris to seek a global climate accord (see Citi GPS report Energy Darwinism II). But as students of climate policy know, a rich body of research addresses why the UN negotiation process is designed in such a way as to make meaningful global agreement extremely difficult (see Global Warming Gridlock).[21]

Bottom up assessments of what countries can actually do will also have a greater impact than a global agreement

What is likely to have a greater impact are bottom up assessments of what countries can actually do based on their own political economy (as opposed to top down, negotiated caps). COP21 and a new "bottom up" approach emphasizing Intended Nationally Determined Contributions (INDc) submitted by individual countries provides momentum towards countries making those commitments that can reduce emissions in their own economies using national policies.

Figure 37. Current INDCs Submitted (red line) Only Reduce Warming in 2100 Very Little



Source: MIT

[21] David G. Victor.

It is unlikely that many nations would self-impose high carbon prices in their bottom-up approaches

Although this bottom-up approach looks promising, it is unlikely that many nations would self-impose high carbon prices. In the lead-up to COP21 in Paris, many countries have put out their emission goals and these goals aggregate up to the global level, which is different form the past when goals were more top-down and countries were allocated to achieve certain emission levels. However, in using this approach, countries may hesitate to voluntarily put in stringent policies on carbon. In general, putting a high price on carbon incrementally reduces a country's competitive edge by raising production costs, unless most other countries impose high carbon prices. This is despite in the long-run having a carbon price is good for the world. This is the opposite case of competitive currency devaluation, for example, where a quick devaluation may boost a country's exports incrementally in the short-run, even though in the long-run countries tend to suffer if everyone devalues. Hence, countries may opt to pursue policies that increase welfare in the short-run and avoid policies that reduce welfare in the immediate future. With a looser cap on carbon, coal may have more breathing room.

In the US, President Obama's Clean Power Plan that was announced in August 2015, has the *potential* to remake the power sector in a cleaner image. Yet the plan faces a gauntlet of legal, political, and implementation risk between now and its 2022 start date that could impact its existence or eventual design, creating large uncertainties. For full detail, see Citi's report Clean Power Plan: Focus on the Big Risks (Aug'15)

The "Mission Innovation" and "Breakthrough Energy Coalition" initiatives, as announced at the start of COP21 in Paris, are much-needed steps to drive the next wave of research, development and innovation in clean energy.[22] Driving innovation in clean energy may not see as immediate a return as software, as the speed of replication and commercialization is much faster for the latter thereby attracting substantial amounts of venture capital investments. In addition, investing in traditional forms or energy is still appealing because, from some investors' view including Bill Gates, there could potentially be a higher degree of "uncertainty" regarding clean energy. These initiatives aim to drive the focus back to clean energy. Indeed, private sector involvement and public-private partnerships are critical: the $100 billion per year of commitment in clean energy investment from developed countries to developing countries, as committed to in Copenhagen in 2009, would only be achieved if funding comes not just from the public sector and multi-lateral development banks (MBDs), but also from leveraging the private sector, as previously analyzed by the World Resource Institute.[23] In all, decarbonizing the global economy in a low fossil fuel price environment requires a further reduction in the costs of clean energy; R&D is key but reducing risk and financing costs are crucial in compressing clean energy costs.

But policy isn't all pointing in one direction: important tax incentives for wind and solar are being phased out in the US by 2017 unless Congress renews them. Whether Congress extends renewable energy support policies should have a large impact on the pace of renewable energy expansion before 2022 in the US.

[22] The "Mission Innovation" initiative, as announced at the start of the Paris conference, is a key example of public sector involvement, as 20 countries have signed on pledging to double their investments in clean energy R&D in the next five years. Meanwhile, Bill Gates is leading a parallel initiative called "Breakthrough Energy Coalition" – a private-sector push bringing early-stage energy programs into the marketplace.

[23] http://.www.wri.org/publication/getting-100-billion-climate-finance-scenarios-and-projrctions-2020

Unintended Consequences of Policies – Stranded Assets of an Unexpected Kind

Battles between fossil fuel generation and renewables is as important as the battle between coal and gas to dominate the global power mix

The battle between fossil fuel generation and renewables is only part of the story in the global effort to mitigate climate change. The battle between coal and gas to dominate the fossil fuel share of the global power mix will be equally critical. Indeed, natural gas produces about half of the carbon dioxide emission per unit of generation versus coal (when both fuels are burned),[24] so even a seemingly minor shift in the coal to gas ratio of generation capacity could be meaningful.

Conventional wisdom dictates that coal should be the biggest loser in this battle while gas should emerge victorious, entering the 'Golden Age of Natural Gas'. The simple argument has been that, with natural gas being a cleaner-burning fossil fuel and gas production surging due to shale and other discoveries, thereby driving down gas prices, coal would be pressured on economic, environmental and regulatory basis. Getting coal out of the system is often the implicit policy goal of many environmental regulations.

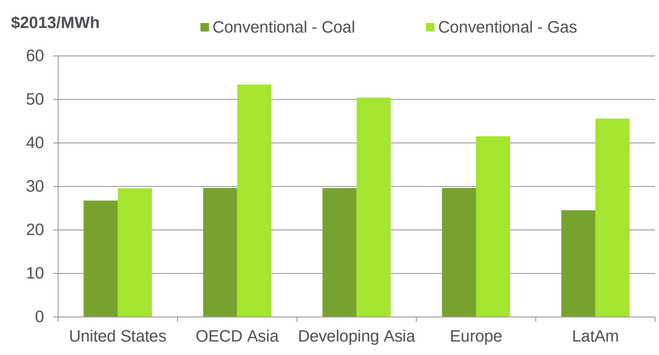
Coal may be less of a loser than previously anticipated for multiple reasons

But dethroning King Coal may not be so straight-forward. There are three main reasons why coal may be less of a loser than previously anticipated, and gas less of a winner: (1) coal is cheaper on the variable cost level in most regions globally; (2) coal is cheaper on the total cost level in some regions globally; and (3) a rotation from coal to gas may not be necessary to satisfy emission requirements.

Coal Can Be More Competitive vs. Gas on a Variable Cost Basis

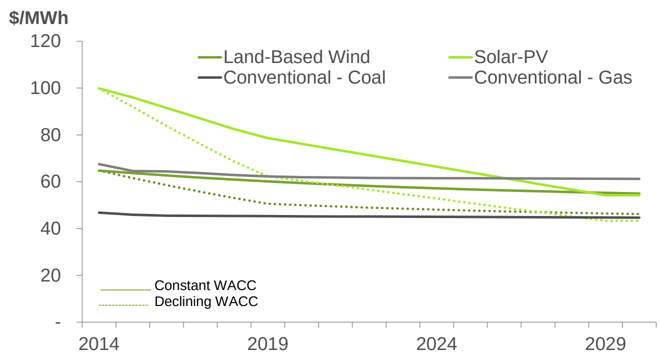
On a variable cost basis, coal remains significantly cheaper than gas in most regions. These economics should support continued coal burn at existing plants.

Figure 38. Estimated Variable (Fuel + O&M Costs) in 2015 by Region and Technology*



Source: NREL, IRENA, IEA, EIA, Citi Research, *These represent costs based on average fuel prices. Fuel prices may vary substantially by location within regions

Figure 39. Coal Is Still King in Developing Asia, and Looks Likely to Remain Strong in this Key Region of Generation Capacity Growth



Source: NREL, IRENA, IEA, EIA, Citi Research

In regions where power demand is flat or declining, like North America and Europe, variable economics may be more important than total costs. Cheaper operational costs would keep coal plants running, potentially at higher rates than higher cost gas plants.

[24] Based on US EIA's calculations: http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11

Coal Is Still Competitive on a Total Cost Basis in Critical Growth Areas

Coal is likely to remain the cheapest alternative in Developing Asia but looks slightly more expensive in the US and OECD Asia

In Developing Asia, coal looks likely to remain the cheapest alternative, although coal looks slightly more expensive on a total cost basis in most regions, including the US and OECD Asia (by a small margin). Indeed, in our base case financing scenario, neither gas nor renewables reaches competitive levels with coal throughout our forecasting period. Despite the possibility of coal demand peaking in China in the near future, (see Citi's report "The Unimaginable: Peak Coal in China" (Sept '13) for details) as air pollution concerns drive a shift towards cleaner technologies and a macro economic slowdown reduces overall power demand, other countries in the region including India and Indonesia, are poised to see significant power demand growth. Much of this growth could be satisfied by coal given its competitive advantage in this region.

Figure 40. In regions with falling coal demand, gas may not substitute coal 1-for-1; in regions with growing power demand coal often wins vs. gas

Country/region	2014 demand (mtoe)	Cumulative demand (mtoe)	Share of total world demand	Growth mode	Comment
China	1.96	1.96	51%	No	Coal demand peaked, but gas use minimal and likely only partially substituting coal-fired power generation
North America	0.49	2.45	63%	No	Coal demand peaked, but possible for coal's share in power generation to stay above gas as renewables partially take shares
India	0.36	2.81	72%	Yes	Coal - a less expensive generation fuel for wide-spread electrification vs. gas
EU	0.28	3.10	80%	No	Coal demand more resilient than gas due to pricing
Japan	0.13	3.22	83%	No	Nuclear restarts backing out oil, then gas, with government's plan looking for both coal and gas to have similar generation shares
South Africa	0.09	3.31	85%	Yes	Major coal producing country
Russian Federation	0.09	3.40	88%	Yes	Major gas and coal producing country
South Korea	0.08	3.48	90%	Yes	Previous government plans (the 6th and 7th Basic Plans) looked to ramp up coal-fired generation capacity (6th Basic Plan PDF)
Indonesia	0.06	3.54	91%	Yes	Major coal producing country building new coal power plants
Australia	0.04	3.59	92%	Yes	Major coal and gas producing country; the country's Bureau of Resources and Energy Economics still expects coal demand to grow, particularly in the power sector

Source: BP, Citi Research

In regions where power demand is growing, coal is generally cheaper than gas on a total cost basis

Looking at the top 10 regions of coal consumption reveals that there may be less room for gas to take market share than many analysts expect. In regions where power demand is growing, such as South Africa, Indonesia, India and Australia, coal is generally cheaper than gas on a total cost basis, which should support new coal plant builds over new gas plant builds absent strict emission caps. However, in regions where growth is not expected, such as Europe, North America, Japan and China, coal is being substituted more so by renewables and nuclear than by natural gas while variable cost economics largely continue to favor coal.

Some think that low North American gas prices could help gas-fired generation gain market share in power generation. But, similar to what's happening in China with coal, having more capacity does not necessarily mean higher consumption. In the US, electricity demand growth is flat to negative, while generation from renewable energy is rising and nuclear is relatively stable. This puts a squeeze on fossil fuel power generation, particularly on coal at first glance. However, there are regions where the variable generation costs of coal power plants are cheaper than gas plants. In this case, then coal could stay resilient. Even if there is a carbon price, which should disadvantage coal, if the carbon price is not high enough to lift the variable generation cost of coal to equal that of gas, then coal power generation in that location could stay favored. This is currently the case in Europe, where the carbon price is too low to support gas-fired power generation.

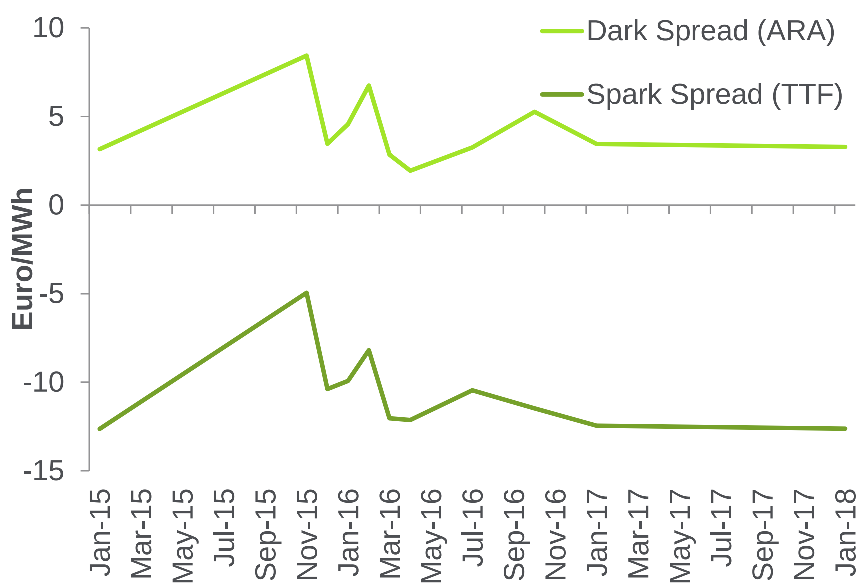
Even with Emission Reduction Policies, Coal Could Remain Resilient

Emission requirements could be met by a slight change in power demands vs. a rotation from coal to gas

A rotation from coal into gas may not be necessary to satisfy emission requirements. A slight change in power demand or emission caps could tilt the balance toward more coal burn. Regulatory caps on carbon emissions, if not adjusted for changes in total electricity demand, could instead favor coal over gas in some cases. A low power demand scenario requires less power generation, so that coal-fired generation may be enough to help meet demand while satisfying the emission cap. A high power demand scenario requires more power generation, so that keeping too large a presence of coal-fired generation could breach the emission cap. In this case, coal-fired generation has to ramp down and gas or other cleaner energy sources ramp up.

- **Europe:** This exact story has largely played out already. Indeed, the power market there sees more robust generation from coal than gas, although gas is supposed to be the cleaner fossil fuel. But gas prices have stayed relatively high, while emission permit prices have not been high enough to tilt the generation balance from coal to gas. Europe has had robust support for renewable energy, leading to a surge in wind and solar installation. This has kept power prices low, making utilities even more reliant on lowest cost variable generation – which is still coal. Coupled with falling power demand, there is sufficient power generation, including coal, to both meet demand and the emission cap.

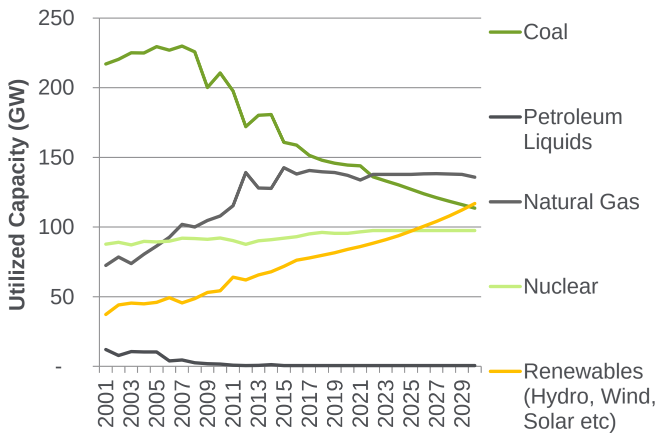
Figure 41. Despite carbon pricing, German power sector economics still favor coal over gas (forward dark spreads for coal and spark spreads for natural gas)



Source: Bloomberg, Citi Research. Note: Assumes ARA coal and TTF gas.

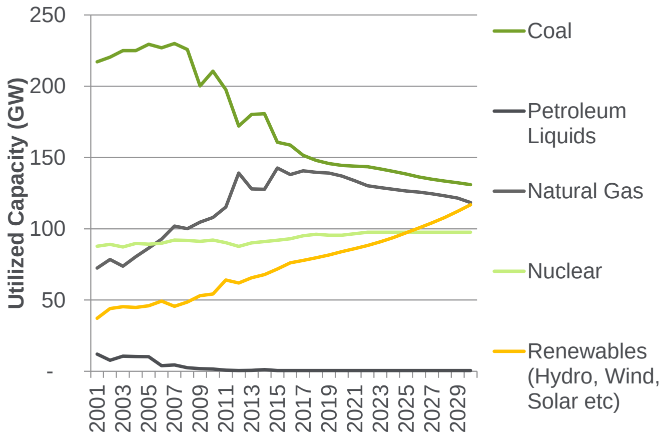
- **United States:** A similar result with coal staying resilient *could* also happen. Although our base case assumes the implementation of the Clean Power Plan, where coal's share in total generation would fall from the mid-30s% in 2015 to ~30% in 2022 and 25% in 2030, below gas, it is not a foregone conclusion that coal could not maintain its market share. An alternative scenario under a slightly looser emission cap by 2030 could mean lower gas burn for power generation. See Citi's report on the Clean Power Plan (Aug'15) for details.

Figure 42. Base case – coal's share continues to fall while gas' share stays flat in the US due to President Obama's Clean Power Plan



Source: EIA, Citi Research

Figure 43. A slight loosening of the US emission cap in 2030 could theoretically keep coal's generation share above that of gas



Source: EIA, Citi Research

- **Rest of World:** Elsewhere globally, without policies that target coal, the relative generation economics generally still favor coal over gas**.** Hence, those areas that could choose between coal and gas-fired generation may opt for more coal-fired generation. It is at first glance a purely economic decision, but it is more of an unintended consequence of policy choices and market design.

Externalities Increasingly Captured in "Shadow Carbon Prices"

National policies to create clean energy still contain risk and uncertainty

Globally, the trend is towards stronger national policies to penalize GHG emissions and promote clean energy, but the risk and uncertainties are still large. This trend is creating a "shadow price" of carbon because national polities are increasingly capturing the externalities – negative and positive – associated with fossil fuel and renewable energy. These policies create tangible incentives and costs, which alter the competitive landscape, even if they do not explicitly price CO_2.

Some important externalities, increasingly captured in "shadow carbon prices" and driving national policies, are:

- **Energy security:** For many of the energy-short economies of Asia, renewable energy provides an important hedging and diversification value. Economies like China, Japan, Korea, and Taiwan are hugely exposed to global fossil fuel prices and availability; greater use of renewable energy reduces this exposure. Policy makers are acutely aware of this in many cases and may express that awareness in the form of policy targets, FiTs, or other incentive programs for renewable energy.

- **Local pollution:** In China, aggressive regulation of coal plants has been underway for years. But it wasn't initially motivated by climate concerns; it was motivated by local pollution, which has immediate health impacts. A typical coal plant emits sulfur oxides, nitrogen oxides and particulate matters etc., which cause acid rain, smog and other adverse environmental effects. These effects have substantial negative impacts on the environment and public health, such as shortening the lifespan of surrounding populations.

- **Costs of Climate Adaptation:** Governments are increasingly aware of the risks to economies and agricultural systems, such as on rice, water etc. The prospect of environmental stress in China could create public unrest – something that the government monitors closely.

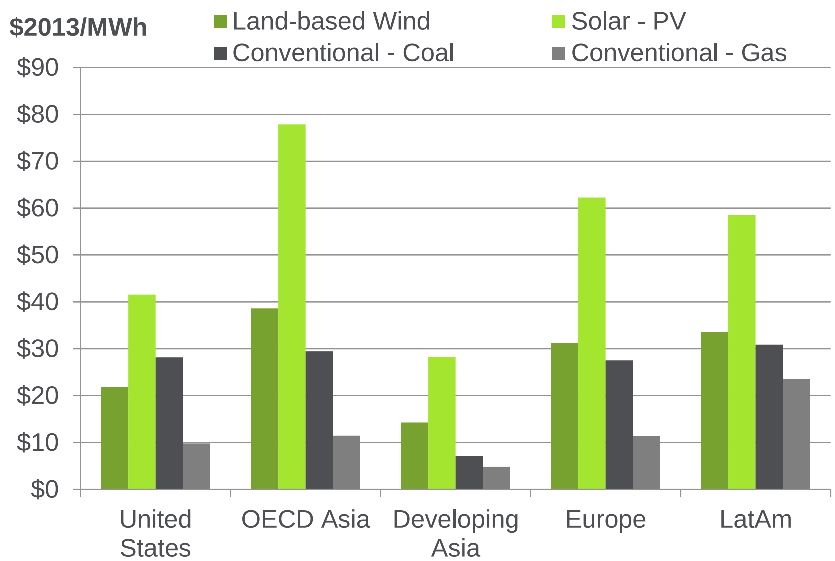
Part A Conclusion

- Fossil fuel pricing, from oil to coal to natural gas, looks poised to stay lower for longer as oversupply and slowing demand keep markets loose.
- But fossil fuels aren't the only thing getting cheaper. Solar and wind technologies have undergone rapid technological advances in the last decade that have brought costs down to increasingly competitive levels.
- These two forces are leading to a global power struggle between renewable energy and fossil fuels described in section 5.
- In the interim, when the cost of renewable energy could still be higher than fossil fuel technologies, even as renewable energy costs continue to fall, policy support remains crucial to steer investments into renewables. But policy isn't all pointing one direction. In the US, for example, important tax incentives for wind and solar are being phased out by 2017 unless Congress renews them. Whether Congress extends renewable energy support policies should have a large impact on the pace of renewable energy expansion before 2022 in the US.
- While technology has thus far been the nexus of innovation in this area and will continue to play a major role, finance looks poised to be at the frontier of cost reduction going forward. Innovative financial products and technology cost declines on the private side, combined with supportive policies on the public side could bring about a new age of renewables growth.

Part B: The Future of New Energy Financing

With the high upfront capital costs of renewables, lowering financing costs is critical and can potentially be achieved through financial innovations and public sector de-risking measures. Financial innovations can help to lower the cost of capital, match risk profiles in particular parts of a project to more appropriate sets of investors and facilitate more effective recycling of capital. The public sector could also help de-risk projects in ways that could sharply lower the cost of capital and expand the size of private financing into renewable projects. In the US, policy support, tax credits, tax equity treatment and subsidies have been instrumental. More broadly in the global context, local power market design, policy orientation, public acceptance as well as political, economic and financing conditions all imply different types of risks that need to be priced in. Public sector measures could help mitigate these factors.

Figure 44. Financing Costs in 2015 by Region and Technology



Source: NREL, IRENA, IEA, EIA, Citi Research

Green finance includes a broad spectrum of financial instruments and institutions globally; sophisticated project finance is instrumental in pushing the field forward

Green finance includes a broad spectrum of financial instruments and institutions, applicable globally in many cases. Sophisticated project finance could help steer investments into green projects beyond traditional bank lending. The public equity market through examples such as YieldCos, could provide an effective way for project developers to recycle capital at the right valuation, although the sector has suffered recently due to over-valuation and some companies having over-expanded. Instead, private placement to private equity, large institutional investors or strategic players, particularly in times of poor equity market performance, could be another way of recycling capital for project developers to sell stakes or exit. Strategic players, such as utilities or independent power producers (IPPs), have been traditional buyers of projects. “Strategics” often have lower costs of capital given the nature of their business, where regulated entities can rate-base their costs to their consumers. Private equity is also active in the space. Many have raised substantial amounts of funds to enter in the space, with leverage. Some large institutional investors, who used to gain exposure via public equity and debt, are buying at the asset level.

Green bond issuance was $36.6 billion in 2014 and numbers are increasing in 2015

Another development is green bonds. Green bonds are somewhat different from other fixed income instruments, as they specify the use of proceeds to green activities. By some measures, $36.6 billion of green bonds were issued in 2014, driven by both new and refinancing activities. However, what defines 'green' and the certification process can be rather involved causing some companies to shy away from pursuing. The Green Bond Principles (GBP) are "voluntary process guidelines that recommend transparency and disclosure and promote integrity in the development of the Green Bond market by clarifying the approach for issuance of a Green Bond. The GBPs are intended for broad use by the market as: (1) they provide issuers guidance on the key components involved in launching a credible Green Bond; (2) they aid investors by ensuring availability of information necessary to evaluate the environmental impact of their Green Bond investments; and (3) they assist underwriters by moving the market towards standard disclosures, which will facilitate transactions."[25] Eighty-nine institutions, ranging from investors, issuers and underwriters, have joined GBP as members and forty-five organizations have observer status as of May 2015. Separately, the Climate Bonds Standard, which grew out of the Climate Bonds Initiatives, is a "multi-sector standard that is certified by a third party verifier…[and] consists of a certification process, pre-issuance requirements, post-issuance requirements and a suite of sector-specific eligibility and guidance documents."

The stringency of the 'green' definition could either help the credibility or discourage issuance of green bonds

On the one hand, qualifying what is green would help establish the credibility of a green bond and the green bond market as a whole. On the other hand, requirements being too stringent at this nascent stage of green bond development could discourage issuance. There is a natural tension between issuers, who may like to have the green label to attract investors without undergoing a very stringent set of qualifications, and investors, who may like to have a higher certainty that a green bond indeed finances meaningful green activities. The green bond market is still evolving.

Green banks, green funds and green loans are also public-sector sponsored entities or initiatives that aim to provide financing, engage in public-private partnership, transfer risk from the private sector to the public sector (e.g. through loan guarantees) to attract private capital. The "Mission Innovation" initiative, as announced at the start of the Paris conference, is a key example of public sector involvement, as 20 countries have signed on pledging to double their investments in clean energy R&D in the next five years. Meanwhile Bill Gates is leading a parallel initiative called the "Breakthrough Energy Coalition" — a private-sector push bringing early-stage energy programs into the marketplace. Together they could form a potent public-private partnership in accelerating research and commercialization.

Beyond these, we highlight in the report the following areas of development: innovations in alternative energy finance, securitization, more complex hedging, international project financing and the foreign exchange on financing projects internationally.

[25] http://www.icmagroup.org/Regulatory-Policy-and-Market-Practice/green-bonds/green-bond-principles

Energy 2030: Financing Analysis

Innovations in Alternative Energy Finance

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Director, Alternative Energy Finance Group, Citi
Richard Morse
Associate, Alternative Energy Finance Group, Citi

Financial innovation is now central to the growth and profitability of renewable energy, as rapid market growth requires commensurate amounts of capital and financing costs can contribute to as much as half the total cost of renewable energy. Delivering growth in renewable energy therefore requires delivering the lowest cost of capital with minimum amount of risk.

The competitiveness of renewable energy vs. fossil fuels depends on it. While technologies like gas or coal-fired power can be cheaper in terms of upfront capital invested, expensive and variable fuel procurement raises total costs.

Financing renewable energy growth requires meeting different challenges in different regions. As we discuss below, in many parts of the world, project finance is the leading method of developing renewable energy projects. Yet it is important to note that alternative energy finance is not a "one size fits all" solution; the nature of power markets, capital markets, and government incentives can vary significantly, requiring adaptive approaches. For example, in Europe Feed-in-Tariffs were extensively utilized to promote renewable energy, whereas in the USA, federal government incentives relied heavily on tax credits to promote renewable energy. The different government incentive programs lend themselves to different types of financial solutions.

Many such issues are discussed in this section, including: the role of currency risk in emerging markets, participation of Development Finance Institutions, securitization of distributed energy production, hedging strategies for project finance, and public sector de-risking measures. Additionally, new capital markets instruments such as green bonds, green loans, and "green IPOs" might soon play a larger role in both developed and developing economies. The solutions discussed here are not exhaustive, but do offer insight into some of the most important and promising strategies currently being used.

The section below explores the core alternative energy project finance strategies which are critically important in many regions. In the sections that follow, the authors drill down to present detailed analysis of key components of broader financing strategies.

The Central Role of Project Finance

Non-recourse project finance is a strategy for sourcing and delivery capital to clean energy projects

Non-recourse project finance is one of the most important strategies for sourcing and delivering capital to clean energy projects. This area of finance focuses on developing long-lived infrastructure through innovative structures that enable funding of projects that might otherwise be too risky for single investors. As capital intensive, long-lived infrastructure assets, most renewable energy falls into this category. Citi has a long history in project finance – having famously financed the Panama Canal – and is actively engaged in financing infrastructure of all types around the globe.

The set of renewable technologies that have benefited from project finance strategies is broad and growing

The set of "renewable" technologies that that have benefited from project finance strategies is broad and growing, having also benefitted from precipitous declines in technology costs. Technology types that Citi and other financial institutions have financed include (but are not limited to): 1) wind power; 2) utility scale solar; 3) distributed and residential rooftop solar; 4) geothermal energy; 5) energy efficiency; and, 6) renewable fuels and biofuels.

These structures are now developed to finance multiple sectors including wholesale power generation, commercial and industrial applications, residential energy, the building sector, and other types of infrastructure. But the opportunity is not limited to these areas – any segment of the global economy that consumes energy is a potential market.

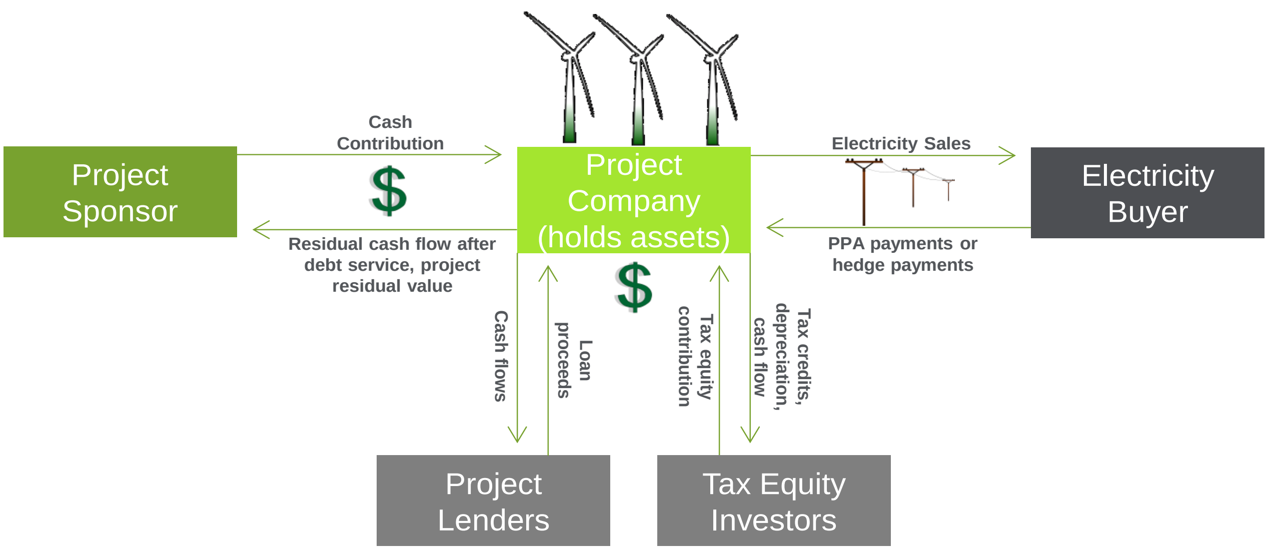
Good project finance is about integrating the full range of financial solutions

Fundamentally, good project finance is about integrating the full range of financial solutions to bring complex projects to life that might not otherwise happen, often due to complex risks and different investor objectives. A critical element is finding a long-term offtaker that will contract to purchase the energy produced by the project. The non-recourse construct has two benefits: 1) it allows project sponsors to construct with little or no risk back to the sponsor; and, 2) it allows investors to invest into the project based on the contracted cash flows that are then used to service the debt.

Tailored allocation of risk is an important characteristic of project finance

One important characteristic of project finance is the tailored allocation of risk. Through creation of bankruptcy-remote project companies, a sponsor can remove itself from risks it is not prepared to take and share those risks with other investors that are better prepared to manage them. For example, many corporate sponsors/developers may not be willing to construct large energy projects if the associated liability can have recourse to the parent over a 20 to 40 year project life. But by creating bankruptcy remote project companies where the risks are shared by project-company investors only, financing becomes possible where risk to the sponsor/developer was otherwise prohibitive.

Figure 45. Simplified Project Finance Structure



Source: Citi Alternative Energy Finance Group

Similarly, project finance allows for the optimal allocation of returns. Project finance can structure investments in renewable energy such that different investors can leverage their unique advantages and capture returns consistent with their risk tolerance. Offering the capability for customization brings more investors and more capital to the renewable energy market. Tax equity investments in the US are a good example. By using project company structures that allow investors with tax appetite to claim tax benefits, while allowing project sponsors (renewable energy companies) to claim cash and recycle their capital, projects achieve a lower cost of capital and the industry can access a much deeper pool of finance across all projects.

Delivering the optimal balance of risk and return through project finance means lowering the cost of capital for renewable energy.

Citi Alternative Energy Finance

Financing renewable energy projects requires specialized skills in multiple areas of finance – and the ability to successfully integrate them as a project requires.

Organized to find solutions for financing all types of alternative energy at the cheapest cost of capital, Citi AEF has three principle roles in the market:

1. Integrating Citi's wide array of existing financing solutions and tailoring them for alternative energy.

2. Offering unique tax equity investment structures that enable the wind and solar industries to tap cheaper capital and faster growth.

3. Developing new strategies and solutions for the rapidly evolving alternative energy sector.

There are several fundamental components of Citi's strategy for financing new and growing markets in renewable energy and energy efficiency. A common thread across all of these components is the ability to creatively adapt and combine elements of traditional finance, and the notion of "stretching" across a number of transaction attributes. "New" finance typically does not come out of the gate optimally sized, from established market players, or with standardized executions. Attaining these attributes is an important goal in developing a liquid and efficient financing environment. Each key component is described below, along with an illustrative example.

Application of Multiple Solutions

A host of financing, advisory and hedging strategies and services are needed to manage risk and maximize return

To help foster the development of the renewable energy and energy efficiency markets, a host of financing, advisory and hedging strategies and services are needed to manage risk and maximize return.

In some cases these will be existing strategies; in other cases the development of new products is required. The ability to draw on a wide set of strategies and approaches is critical for delivering efficient and cost effective financing solutions. The following strategies and instruments can be utilized to finance large projects and pools of small projects around the globe:

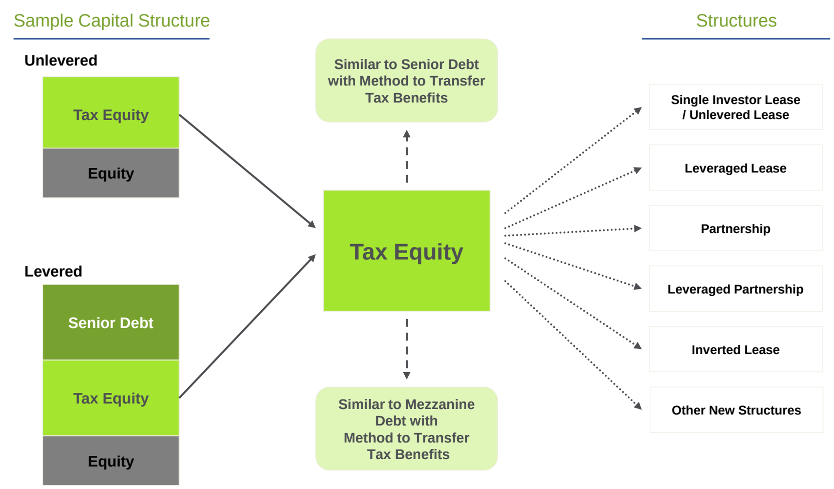
- Construction Financing
- Term Debt Financing (Bank Term Loans and Project Bonds (144A & 4(2) Private Placements)
- Mezzanine Financing (Mezzanine Debt, Leasing, Tax Equity)
- Pool financing (Tax Equity: Inverted Leases, Debt: Asset-Backed Securities, and Equity: REIT, MLP, YieldCo)
- Derivatives Hedging (Interest Rate, FX, Commodities, Power)
- Equity Financing (IPOs, follow-ons)

Tax equity is a strong example of financing innovation in the US markets

Tax Equity is a strong example of a financing innovation in US markets – one that is often provided in combination with other products on utility scale wind and solar projects. By providing optimal ways for renewable energy developers and capital providers to allocate risk and monetize federal and state tax incentives, tax equity structures can deliver a lower cost of capital. Benefits of tax equity to the investor include:

- Attractive risk-adjusted after-tax returns
- More efficient use of tax ownership benefits (Production Tax Credits, Investment Tax Credits, Modified Accelerated Cost Recovery System depreciation (MACRs))
- Flexibility in structuring for different project conditions and investor objectives
- Long-term control remains with the Sponsor (often a renewable energy company) as opposed to the tax investor

Figure 46. Sample Tax Equity Capital Structure



Source: Citi Alternative Energy Finance Group

Figure 47. Detailed Common Tax Equity Structures

	Lease	"Flip" Partnership
Structure	• The Lease Equity Investor will purchase the project from the Lessee with equity contributions and lease the project back to the Lessee on the Lease commencement date	• Prior to commercial operation, the Sponsor will establish a special purpose LLC to be the owner of the project • On the commercial operation date, the LLC will fund a portion of the acquisition cost of the project, and Tax Equity Investors will purchase membership interests in the LLC
Equity Returns	• The Lease Equity Investor receives free cash and all the tax attributes as the owner • Lessor cash is scheduled much like debt service, that is amount certain and date certain • As the rent in lease structures is sized to achieve investment grade rating, the Lessor economics are stable and predictable	• The Sponsor and Tax Equity Investors receive their respective share of cash distributions and allocation of net taxable income/loss in accordance with the terms of the LLC agreement • Accordingly, both sponsor and Tax Equity Investor cash distributions are tied to production levels
Debt Service	• The Debt Investors (only applicable in a levered lease) receive debt service payments secured by: – Lessee's unconditional obligation to make rent payments under the lease agreement – Sponsor's pledge of the ownership interests in the Lessee – Collateral assignment of the PPA – A first mortgage on the project assets	• The Debt Investors (only applicable in a levered partnership) receive debt service payments secured by: – A first mortgage on the Project assets – Collateral assignment of the PPA

Source: Citi Alternative Energy Finance Group

The Shannon Wind Project illustrates the importance and value of an integrated strategy that includes tax equity

The Shannon Wind Project, a 204 MW wind project in Texas sponsored by Alterra Power Corporation and Starwood Energy Group illustrates the importance and value of an integrated strategy that includes Tax Equity. In this case, Citi provided a comprehensive solution for the Shannon Wind Project, combining a 13-year physical power hedge (which provided revenue certainty to enable financing), construction loan and letter of credit facilities (which provided cost effective construction finance), and an unlevered tax equity partnership investment (which structures an optimal risk/return profile for all parties involved).

Figure 48. Key Facts: Shannon Wind

Summary Terms

Project:	Shannon Wind
Sponsors:	Alterra Power Corp. and Starwood Energy Group
Technology:	119 General Electric 1.7-103 Wind Turbines
Location:	Clay County, Texas
Capacity:	204 MW
Revenue Structure:	Physical power hedge with Citigroup Energy Inc.
O&M Agreement:	Alterra Management Services LLC
Closing Date:	June 30, 2015
Expected COD:	December 2015
Total Project Costs:	$338MM
Financing:	• $287MM Construction Loan and L/C Facilities • $219MM Tax Equity Investment jointly provided by Citi and Berkshire Hathaway Energy
Tenor / Flip Date:	• Construction Loan and L/C Facilities: ~10-months • Energy Hedge: 13 years • Tax Equity Investment: 9.5 year target flip date
Tax Equity Structure:	Unlevered "flip" partnership (PTCs)
citi Roles:	• Sole Energy Hedge Provider • Tax Equity Investor • Joint Bookrunner and Mandated Lead Arranger • Administrative Agent, Collateral Agent and Depositary Bank

Transaction Highlights

- ✓ Citi provided a comprehensive solution for the Shannon Wind Project, combining a 13-year physical power hedge, construction loan and L/C facilities and an unlevered tax equity partnership investment
- ✓ The $219MM Tax Equity financing provided by Citi and Berkshire Hathaway Energy allows Shannon to maximize financing proceeds by monetizing PTCs
- ✓ The Shannon wind transaction is the third Citi-led financing solution for Starwood over the past 18 months, building on the successful Stephens Ranch I and II wind financings

Project Overview

- The Shannon Wind Project is a 204 MW utility-scale wind energy facility located in Clay County, Texas
- The Project will consist of 119 General Electric 1.7-103 wind turbines for a total capacity of 204.1 MW and is being constructed by Mortenson Construction
- The Project has entered into a physical power hedge with Citigroup Energy Inc. for a term of 13 years under which the Project will receive a fixed power price
- Shannon Wind is located in the ERCOT North region and will interconnect through the Oncor Cobb substation
- Construction has commenced and expected COD is December 2015

Financing Components

- Construction Loan and L/C Facilities: $212MM construction loan to be repaid upon COD via the tax equity investment and $75MM of L/C facilities
- Tax Equity Investment: $219MM tax equity commitment, providing the Project with attractively-priced, long-term financing
- Energy Hedge: 13 year, fixed-price physical power hedge, providing the project with predictable contracted revenues which facilitate the debt and tax equity financings

Source: Citi Alternative Energy Finance Group

These structures can enable utility scale renewable energy development that might not otherwise be possible. Several components of these kinds of transactions are essential for delivering cheaper capital:

- **Optimal monetization of tax benefits:** In the US market, two primary forms of credits can be utilized by investors – Production Tax Credits (PTC) and Investment Tax Credits (ITC), and Modified Accelerated Cost Recovery System (MACRs) depreciation. Monetizing these benefits requires an investor with large amounts of taxable income; many renewable energy developers are not able to do this. Tax equity structures therefore are carefully crafted to allocate benefits to each investor in a project such that the cost of capital is as low as possible. This enables more projects to be financed at more competitive costs.

- **Revenue certainty through hedging:** Where more traditional power purchase agreements (PPAs) are not available, hedges provide revenue certainty – and therefore the ability to finance a project. Hedges can therefore greatly expand the growth potential for key US wind and solar markets.

- **Addressing inter-creditor conflicts:** Integrating construction loans, tax equity, and hedging under one roof allows Citi to address potential inter-creditor conflicts that might otherwise prevent a project from being financed. For instance, there is often a conflict between the construction lender and hedge provider; both want first liens on the assets. This can block financing where two parties cannot agree on how to solve this issue. Citi has strategized to solve this problem in multiple transactions by providing both construction finance and hedge, thereby navigating through the conflict and allowing projects to be financed.

Connecting New Markets to Capital Markets: Market Segmentation and Prioritization

Lack of clear precedents for financing can impede access to capital market even if there are attractive opportunities and returns

New markets typically lack clear precedents for financing, and this can impede access to capital markets even where there appear to be attractive opportunities and returns. Energy efficiency is a prime example.

In the aggregate, and on many power point slides over the last decade, energy efficiency is lauded a huge opportunity. McKinsey, in its 2009 report, “Unlocking Energy Efficiency in the US Economy” indicates, “the potential to reduce annual non-transportation energy consumption by roughly 23 percent by 2020, eliminating more than $1.2 trillion in waste—well beyond the $520 billion upfront investment (not including program costs) that would be required”.

Market fragmentation has made unlocking energy efficiency challenging

However, tapping this opportunity has until recently proved challenging due to a high degree of market fragmentation across a number of dimensions. Those include: different possible property improvement measures and types and lack of simple, easily available project implementation and financing tools for property owners that can be standardized for investors. Potential measures to realize the $1.2 trillion in energy savings include everything from insulation and more efficient appliances in single family homes to new lighting technologies in school systems to heating and ventilating systems for large commercial and industrial facilities. Property types and their respective underlying ownership structures also vary widely. Taken together, these characteristics do not lend themselves to standardization and aggregation in ways required for scalable, capital markets finance solutions; solutions that have been widely available in markets such as auto loans or credit card receivables. Innovative finance is therefore critical to unlocking the energy efficiency opportunity.

The Energy Efficiency Finance Framework helps to break down and access the overarching energy efficiency opportunity

To address this issue and help the market to break down and access the overarching energy efficiency opportunity, Citi developed an Energy Efficiency Finance Framework. The Framework breaks the market down by finance product/solution and property type (underlying owners and “credits”), the intersections of which are color-coded and tagged by an estimation of “doability”. Solutions include unsecured and a number of secured forms of lending, including Property Assessed Clean Energy (PACE), where loans are repaid on the property tax bill and secured by a lien on the property, and Utility On-Bill Repayment (OBR), where loans are repaid on the utility bill and secured by remedies available to the utility.

Citi uses this tool to help develop and disseminate market knowledge among public, non-profit and private sector market actors in a way that can help develop more mature markets. Successive iterations of the framework have been presented over the last four years at the annual Citi-Environmental Defense Fund (EDF) energy efficiency finance conference; the last of which was held on October 22, 2015 in New York.

This tool also helps segment the huge potential for energy efficiency investment into a more accessible opportunity, and the makings of a new asset class that can be more easily financed by a wide investor base. The warehouse for energy efficiency loans (WHEEL), a Single Family, Pooled Asset Deal, was identified as a market-making opportunity given the existence of a pipeline of efficiency activity, historical performance data, and the availability of FICO scores to measure credit risk (unique to this property type). Recent transactions demonstrate the potential.

Citi and Renew Financial, the WHEEL Administrator, completed the first securitization from WHEEL on June 18, 2015; which represented a first-to-market energy efficiency asset-backed security (ABS). With a now established and scalable financing model, a much deeper pool of capital can be brought to bear on the immense opportunity that is energy efficiency investment.

Figure 49. Energy Efficiency Financing Solutions

Product / Solution	MUSH	Federal/DOD	Single Family	Multifamily	Commercial	Corporate
Large Single Project	Yes	Yes	N/A	Yes	Yes	Yes
Pooled Asset Deal	Yes	Yes	Yes	Difficult	Difficult	Yes
ESCO/ESA Two Factor	Yes	Yes	N/A	Difficult	Difficult	Yes
PACE	Yes	N/A	N/A	Yes	Yes	Yes
On-Bill (OBR)	Yes	N/A	Yes	Yes	Yes	Yes
Stranded Cost Tariff	Yes	N/A	Yes	Yes	Yes	Yes
Green Bond	Yes	N/A	N/A	N/A	N/A	Yes
Sustainable Energy Utility	Yes	N/A	N/A	N/A	N/A	N/A
Microfinance	N/A	N/A	Yes	N/A	Yes	N/A

Source: Citi Alternative Energy Finance Group

Win-Win Finance: Public Private Partnerships

PPP represent opportunities for public entities to catalyze or complement private market actors

Public Private Partnerships (PPP) represent opportunities for public entities to catalyze or complement private market actors where objectives are aligned. Public entities can help fill critical gaps in transactions that otherwise would not get done without their participation. In successful cases the PPP is structured in such a way so that the public role can be supplanted by private.

For renewable energy and energy efficiency markets, public entities can play an important role by promoting policies and standards, providing indirect or direct financial support, and establishing programs. All of these activities help leverage private capital for important public objectives.

WHEEL is an excellent example of a PPP that has helped leverage private capital for important public objectives

WHEEL is an excellent example of a PPP that has performed in this way. Actually, WHEEL is more than a PPP given the involvement of philanthropies and non-profits that helped create and develop WHEEL in advance of the participation of both public and private players. Philanthropies such as Rockefeller Foundation, non-profits such as the Energy Programs Consortium, and governments such as the State of Pennsylvania were instrumental in conceiving and developing WHEEL. Public entities were engaged in WHEEL in the following roles:

- State of Pennsylvania Treasury: Pennsylvania's Keystone HELP program, a state energy efficiency program, provides the essential pipeline of loans and historical data that was used to "prime the pump" of WHEEL. Pennsylvania Treasury roles, with respect to Keystone HELP, included provision of funds, program design and implementation. State of Pennsylvania Treasury was also a co-investor with Citi in the warehouse facility.
- Kentucky Home Performance: provides pipeline of loans
- Greater Cincinnati Energy Alliance HELP: provides pipeline of loans
- U.S. Department of Energy (DOE): through the provision of funds from the American Recovery and Reinvestment Act (ARRA), DOE has supported the establishment of energy efficiency programs across the U.S., as well as approval for states to use ARRA funds in support of their participation in WHEEL.

WHEEL is just one example of the importance of collaboration between public and private entities for supporting new market development in renewable energy and energy efficiency, through PPPs and other mechanisms, such as loan guarantees and tax benefits as illustrated in the aforementioned example of tax equity.

Conclusion

Innovative financing that provides enhanced opportunities for alternative energy investments to deliver attractive returns at lower risks is a critical lynchpin

Technology, economics, and policy are converging around a future that will demand a greater deployment of alternative energy solutions. Innovative finance that provides enhanced opportunities for alternative energy investments to deliver attractive returns at lower risks is now a critical lynchpin for delivering that future.

But there is no "one size fits all" solution for the rapidly changing alternative energy landscape in the US and internationally. Fully capturing the opportunity at hand will require innovative finance to continually bring new tools and transactions to the market in pursuit of the most efficient solutions.

Based on Citi's experience across transaction types, results are clear and meaningful: greater access to capital for clean energy, cheaper capital for clean investments, optimal structuring of risk and returns, a deepening investor base, and the delivery of cleaner energy at scale in markets comprised of projects from household to utility scale. And while the contribution of innovative finance to clean energy development has already been significant, we are likely seeing the beginnings of new markets and the benefits that can be delivered. This section has outlined key frameworks and elements of innovative renewable energy finance. In the sections that follow, the authors dig deeper into important transaction types that are fundamental parts of many renewable energy finance strategies.

Energy 2030: ABS Analysis

Securitization Solutions for a Greener Planet

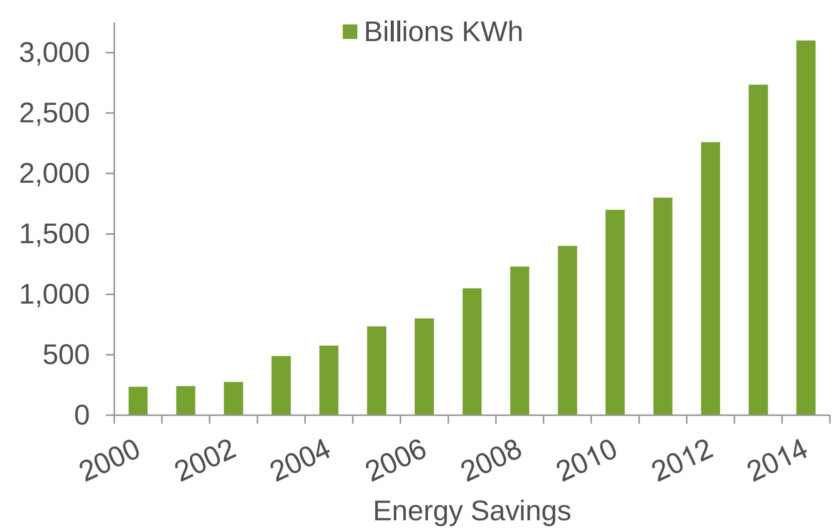
Mother Earth = Mother Lode Energy Savings

Mary Kane
Head of Global Securitized Products Research, Citi

Eugene Belostotsky
US Consumer ABS Strategy, Citi

Clean energy is not only good for Mother Earth but it is fostering significant commercial opportunity and is expected to be a source of rapid economic growth in the years ahead. Whole new industries have sprung up in the new Millennium, like solar and wind, while biomass, clean water and geothermal have been around for decades. Americans purchased more than 320 million ENERGY STAR-certified products in 2014 across more than 70 product categories for a cumulative total exceeding 5.2 billion products since 1992[26]. ENERGY STAR is a key Environmental Protection Agency (EPA) initiative to develop national programs, policies, and regulations for reducing US air pollution. In 2014, the EPA estimates that US consumers and businesses reduced utility bills by $34 billion and reduced greenhouse gas emissions by 300 million metric tons[27]. Investments in energy-efficient technologies and practices will continue to provide cost savings for years to come. For details, please see the report "Securitization Solutions for a Greener Planet" (Nov'15)

Figure 50. ENERGY STAR Program Benefits Have Doubled in the Last Five Years



Source: US Environmental Protection Agency. ENERGY STAR 2014 List of Achievements

When the ITC expires at the end of 2016, will probably position securitization as a more attractive financing solution than lease or other financing.

The securitization market has played a small role in green energy capital formation thus far, and could play an even more prominent role in the years ahead, given appropriate structures and other terms and conditions. In order for this to happen, however, we think the asset-backed security (ABS) market can best contribute to the goal of reducing the cost of financing green energy for consumers and businesses by adopting a simple and standardized structure. Of the "green" securitizations done to date, we think structures based on the WHEEL program have the most potential to conform to this standard and gain wide market

[26] www.energystar.gov; "2014 Overview of Accomplishments".
[27] Ibid.

acceptance.[28][29] Expiration of the ITC in 2016 will also have a bearing on future green ABS economics. We discuss the WHEEL program in more detail and the structure of the inaugural 2015 securitization (RF 2015-1/ RenewFund Receivables Trust) based on WHEEL and also comment on what we see as the limitations of some alternative green energy securitization structures (such as solar lease and PACE liens) in the report.

Why WHEEL Represents the Future

WHEEL is an effective structure for financing sustainable energy and represents the future of the ABS market.

WHEEL is an effective structure for financing sustainable energy and represents the future of the ABS market, in our view, for the following reasons:

- **Simple and transparent.** WHEEL loans are simple fixed-rate closed-end unsecured installment loans to high-credit-quality residential homeowners that meet stringent income ratio and other conservative underwriting measures established by the participating state.
- **No "security" delusion.** Unsecured loans avoid the trap of over-relying on the value that collateral adds to the loan.
  - **Solar lessors** typically do not repossess the collateral as solar panels have experienced quality, technological obsolescence and other problems historically, and the collateral value is uncertain. There is also some evidence that solar leases depreciate the property value and make it more difficult to sell because buyers are reluctant to take on long-term leases. These long-term leases are sometimes off-market because the equipment cost often drops from the initial lease date.
  - **PACE liens** are thorny: the Federal Housing Finance Agency (FHFA) opposes super-priority liens in front of the first mortgage provider and stated in December 2014 that it would aggressively initiate actions toward this end. The FHFA has directed the government-sponsored enterprises (GSEs) not to buy mortgages on properties with PACE liens and there is evidence that homes with PACE liens are more difficult to sell[30]. However:
    - **PACE more inclusive / California (CA) reserve fund.** Contractors would like to have multiple financing solutions for jobs they quote and PACE is a possible solution for consumers who do not qualify for unsecured financing. This makes the PACE program more inclusive for "green" consumers. The State of California set up a reserve fund to defray lenders' PACE lien risk on foreclosed properties.
- **Standardization.** The WHEEL underwriting standards are conservative and well-documented on the lender's website. The program guidelines and use of proceeds are tightly supervised and the receivables are written using standardized documentation.

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[28] Toyota has structured and priced several "green" securitizations which represent securitizations for hybrid and other energy efficient vehicles. This asset class is already an on-the-run ABS and benefits from document standardization, long collateral history and extensive disclosure. These standard ABS programs dressed up as "green" have been highly successful and are outside the scope of this report, which examines more esoteric assets.
[29] Securitizations of LEED-certified commercial buildings, commercial real estate retro-fitting and other commercial "green" projects are also outside the scope of this report.
[30] "Green Financing Has Hobbled Home Sales in California", by Nichola Groom, Reuters, October 19, 2015.

- **Collateral history.** WHEEL is derived from Pennsylvania's Keystone HELP program, which began in 2006. WHEEL launched in 2014 and has adopted the underwriting, eligibility and contractor standards used in Keystone HELP.

Green Energy ABS Supply: Past and Future

$500–536 Million during Last Two Years

Green new issue supply priced in the term ABS capital markets was about $500-$536 million for the past two years

The amount of esoteric green new issue supply that priced in the term ABS capital markets amounts to roughly $500–$536 million a year for the last two years, consisting of a handful of small 144A deals. The total renewable energy ABS supply in 2014 amounted to slightly more than $500 million from two shelves. The HERO shelf, which is collateralized by PACE liens, priced two 144A transactions in 2014 and 2015, ranging in size from roughly $100–$240 million. Kroll is the sole rating agency for the 2015 transaction and rates the class A double-A. Renewable Funding (RF) brought a small ($12 million) prototype inaugural WHEEL deal in June 2015 as a 144A. Fitch rated the senior class single-A.

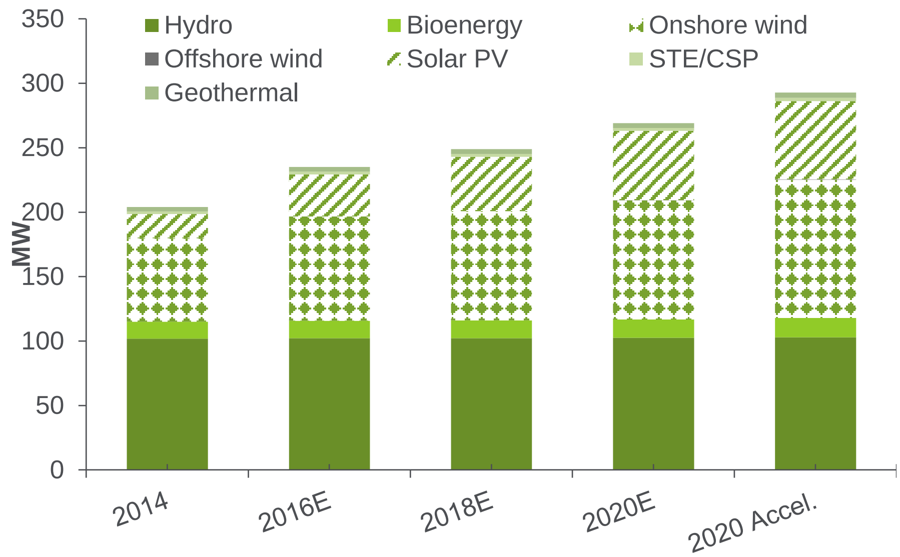
In general, the presence of only one rating agency, below-triple-A rating, and 144A market on each of these shelves limits the potential size of the investor base. Each of these structures has its own unique structural and collateral risks limiting the top rating. We discuss these constraints separately.

ITC Loss in 2016 Could Initially Shrink Consumer Loan Demand …

- The 30% federal tax credit for residential energy efficiency equipment expires on December 31, 2016,[31] and the loss of the subsidy may initially shrink the amount of "green" consumer loan demand. But in the longer term, the costs of various energy-friendly projects are shrinking as the costs of conventional energy forms are mixed.[32] Part of the conventional energy cost gains derives from electric utilities' need to conform to increasingly stringent state-level emission requirements and also the scheduled retirement of nuclear and coal-fired plants over the next decade. The International Energy Agency projects the growth rate of total US renewable energy sources to slow from 2016–2020 (particularly hydro, which accounts for just over half of total renewable sources). However, it projects solar PV and onshore wind to continue to grow at a fast pace, with 64% and 14% growth rates, respectively, from 2016E–2020E (Figure 51).

[31] The Energy Policy Act of 2005 established a 30% residential renewable energy tax credit.
[32] The cost of fossil fuels has been shrinking in the last year or two, but has risen over the longer run.

Figure 51. US Renewable Energy Capacity (2014–2020E)



Source: International Energy Agency

… But the Emerald City Lies Ahead

There's been a shift from consumer rebates to consumer energy financing programs.

The level of "green" ABS priced in capital markets to date is de Minimis when measured against the significant level of the US energy-related home improvement market business. The sales of windows, doors, insulation, HVAC, roofing and appliances account for more than $40 billion annually. Until the last few years, states and municipalities largely emphasized consumer rebates, but more recently have shifted to support energy efficiency finance programs. According to a 2013 report by the Lawrence Berkeley National Laboratory (LBNL), customer-funded energy efficiency spending amounted to $4.8 billion in 2010, having doubled from $2 billion in 2006.[33] The company also projects annual spending on these programs to again double by 2025 – to $9.5 billion.[34] The article cites possible consumer demand that could impact the need for future securitization supply:

- **$600 billion.** Pennsylvania estimates the size of the US residential retrofit economy at potentially $600 billion.
- **$40 billion**. Size of annual energy improvement market residential sales resulting from replacement of boilers, roofs, windows, doors, air conditioning and the like.

Energy Loans for Consumer Retrofitting

- **$250 million** in residential PACE programs in California.
- **$100 million** in Pennsylvania Keystone HELP program energy efficiency loans made under state-subsidies. WHEEL offers loans in New York, Kentucky, Virginia, Indiana and Florida and can potentially accommodate state sponsors nationally.

[33] "Energy Efficiency Finance Demand Isn't the Problem, Design Is", by Cisco DeVries, CEO of Renewable Funding, *State & Local Energy Report*, February 2015.
[34] Ibid.

How WHEEL Works: Kickoff ABS Deal

After growing its energy efficiency loan portfolio to $45 billion from 2006–2010, the state of Pennsylvania's Keystone Home Energy Loan Program (HELP) realized it would deplete its available public funds and sought private capital to form a partnership funded by foundation, private and public funds:

- The Ford, Rockefeller, Surdna, and Energy Foundations, and the DOE provided the initial WHEEL funding.
- Several banks provide warehouse financing for the energy efficiency consumer loan originations.
- WHEEL launched in 2014 with Pennsylvania and Kentucky as the first state sponsors providing capital to support the program. WHEEL bundles the loans into diversified pools to collateralize rated term asset-backed securities.

A Secondary Market for Energy Efficiency Lending

PA, KY and FL joined in 2014. NY, IN, VA and others are also members and several more states are examining the program.

The goal of the Warehouse for Energy Efficiency Lending (WHEEL) is to create a secondary market for residential clean energy loans in order to source lower-cost capital for state and local energy loan programs. WHEEL purchases unsecured residential energy efficiency loans from participating programs such as Keystone HELP and Kentucky's Home Performance loan program and packages the loans into diversified pools to collateralize ABS. A $100 million line of credit from a bank and the Pennsylvania Treasury officially launched the program in April 2014.[35] Kentucky joined in October 2014 with $20 million of loans. In addition to the State of Pennsylvania (PA), the State of New York (NY), the Commonwealth of Kentucky (KY), the State of Indiana (IN), the State of Florida (FL), the Commonwealth of Virginia (VA) and the Greater Cincinnati Energy Alliance have all joined the WHEEL program, and additional states are expected to join soon.

Benefits of the WHEEL Program

- **Access to national scale, low-cost financing**. The purchase and aggregation of personal installment loans for energy efficiency via bank conduit facilities should provide access to funds at a low cost to consumers. Some of the program guidelines are as follows:
  - Fixed-rate (contemplated to be <10%)
  - 5-, 7- and 10-year (10YR) terms
  - 640+ FICO scores

[35] Ibid.

Renewable Funding (RF): Principal Parties

AFC First Financial Corp: RF Servicer / Wells Fargo Bank: Backup Servicer

AFC is a non-bank Pennsylvania consumer energy lender, founded in 1947 and was recently acquired by Renew Financial of Oakland, California (see below). AFC has specialized exclusively in residential energy efficiency lending since 1999. It is a leader in residential energy-efficiency and renewable lending and rebate programs. It operates nationally in partnership with states, utilities, manufacturers and municipalities. It offers programs through 4,000 approved contractors which sell, install and service high efficiency heating, air conditioning, weatherization and other renewable energy projects. Contractors have a tremendous influence on a customer's decision on how they will pay for an energy efficiency upgrade. The lender trains contractors how to effectively make affordability of energy efficiency a key part of every sales proposal and evaluation.

AFC originates loans in all 50 states and Washington D.C. AFC's "EnergyLoan" program is for homeowners who meet the program's eligibility guidelines. These customers can get a low cost, low payment loan for qualified improvements including: high efficiency heating, air conditioning, air sealing, insulation, windows, and "whole house" improvements. Special loan terms can help save significant costs over the life of the loan, enhancing the positive financial impact of energy savings and minimizing out of pocket costs. EnergyLoan's interest rate is fixed and the loan maturity terms are longer than what is typically available at a bank. AFC's website discloses some of the following attributes for these loans:

Figure 52. Selected Attributes of Renewable Energy Loans Made by AFC

Eligible Projects	Some Origination Standards
Heating & Cooling Systems	Loan amounts from $1,000 to $25,000
Water Heaters	100% financing
Windows & Doors	Unsecured
Insulation - All Types	Low fixed-rate, fixed monthly payments
Roofing & Siding	No lien filing on the residence
Solar PV & Solar Thermal	No home equity required: new homeowners OK
Geothermal Heat Pumps	No points, fees or closing costs
Lighting & Controls	Repayment up to 10 years — no prepay penalty
Electrical & Plumbing	Work must be done by approved contractor
Heated Sunrooms	Primary residence (1–2 unit) or vacation home on permanent foundation
Most other Energy-Related Improvements	

Source: Company Reports

Renewable Funding Group, Inc., Oakland, CA

Renewable Funding Group, Inc. (RFG) was founded in 2009 to develop innovative financing and technology solutions for the US transformation to clean energy. Its affiliate, Renew Financial, acquired Pennsylvania-based AFC First Financial Corporation, one of the nation's premier lenders specializing in the energy efficiency home improvement market in early October. It did not disclose the terms of the transaction. RFG is the master servicer for the RF shelf.

Renew's founder, Cisco DeVries, invented the PACE lien program for local and state governments while serving as the chief of staff for the mayor of Berkeley, CA. *Scientific American* magazine termed the PACE program solution as one of the top 20 "world changing" ideas in 2009. Several private equity funds rank among the company's principal investors, including Apollo Investment Corporation, Angeleno Group, NGEN Partners and Claremont Creek Ventures. Renew Financial operates in 10 states and 150 communities. It also operates in Melbourne, Australia. The states include: Maryland, California, Colorado, Washington DC, Oregon, Louisiana, New Mexico, Florida and Illinois.

RF Structure and Credit Enhancement

We would expect future securitizations to closely mirror the inaugural RF deal and as more states add assets to the program, the collateral mix will likely have greater geographical diversity and transaction sizes would have more scale. The kickoff RF deal structure consists of one senior class A rated single-A by Fitch. Credit enhancement consists of overcollateralization, a yield supplement account (YSOC), a reserve fund and excess spread. The senior class has an expected 2.3YR WAL and is optionally callable when the receivables balance is equal to 20% of the cutoff pool balance. Figure 53 shows the initial capitalization of the trust at the closing date.

Figure 53. Renewable Funding Receivables Trust, Initial Capitalization at Closing

	Amount	WAL (YRS)	% of Pool	Credit Enh (%).
Class A	12,580,000.00	2.28	79.7	21.3
Overcollateralization	3,208,381.50		20.3	
Pool balance	15,788,381.50		100.0	
YSOC	2,411,369.72		15.3	
Reserve fund	157,883.82		1.0	

Source: Prospectus

- **Overcollateralization**. The initial overcollateralization (OC) amounts to approximately 20.3% of the cutoff pool balance. Going forward, any excess cash flow will be available to build and maintain the target OC. The target OC will equal the lesser of:
  - (i) the sum of (a) 10.0% of the pool balance as of the last day of the related collection period and (b) 13.0% of the cutoff date pool balance and
  - (ii) the pool balance as of the last day of the related collection period.

Collateral Risks & Mitigants

4. Origination Network / Contractor Qualification Standards

The origination channel for any consumer loan is typically a point of potential vulnerability — WHEEL uses a network of over 7,000 pre-approved and managed contractors to deploy its financing. Contractors must be approved to access WHEEL financing for their customers. Contractor approval requirements include:

- Minimum time in business;
- History of financial stability;
- Minimum net worth criteria;
- Satisfactory company and personal credit histories;
- Satisfactory Better Business Bureau rating; and
- Satisfactory customer and trade references.

WHEEL actively monitors its approved contractors and takes remedial action when required, terminating contractors for poor performance or failure to maintain the minimum WHEEL contractor requirements. These standards mirror the Pennsylvania Keystone HELP program which has been in existence since 2006.

5. New Asset Class / Lack of Historical Data / Mirrors 2006 Program

The Pennsylvania State Treasury launched Keystone HELP in 2006, with AFC as the loan originator and servicer and the WHEEL program adopted the identical underwriting, eligibility and contractor standards as those used in Keystone HELP. AFC continues as the originator and servicer for energy efficiency loans originated under the WHEEL program.

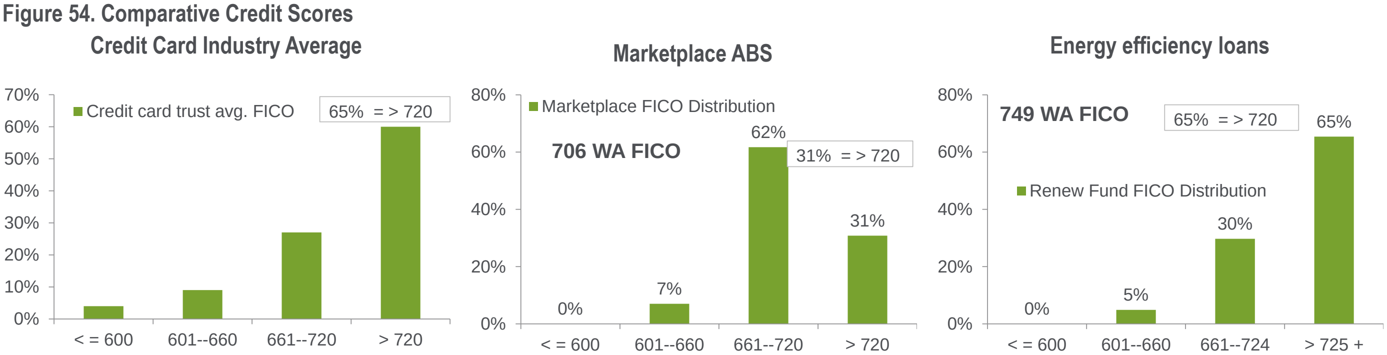
6. Unsecured Lending but High-FICO Obligors with Motivation to Pay

While the energy efficiency loans are unsecured, the obligor credit characteristics compare favorably to marketplace loans and credit card trusts in terms of average FICO distribution, loan amount and loan purpose.

- **Motivated payers**. We think consumers would be more motivated to pay energy efficiency loans than general purpose installment loans because it saves them money on their utility bills and the discount equips them with cash flow for debt service. There is also an argument that environmentally conscious consumers are better educated and motivated to do the right thing.

- **Strong credit quality**. Two-thirds of the inaugural deal had a FICO score of 725 or better and the weighted average FICO was 749 (right-hand panel of Figure 54). These metrics compare very favorable to typical marketplace securitizations that have come to the ABS market (middle panel) and to the credit card industry (left-hand panel). The purpose of the vast majority of marketplace loans is to consolidate credit card debt, which would not rank very highly as a debt priority through a full credit cycle, in our view.

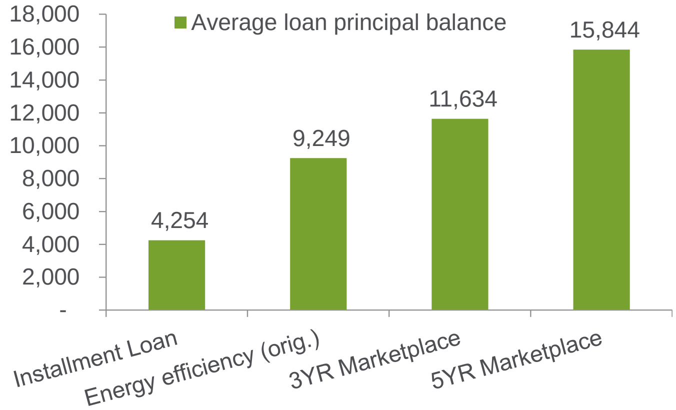
Figure 54. Comparative Credit Scores



Source: Prospectuses Source: Prospectuses Source: Prospectuses

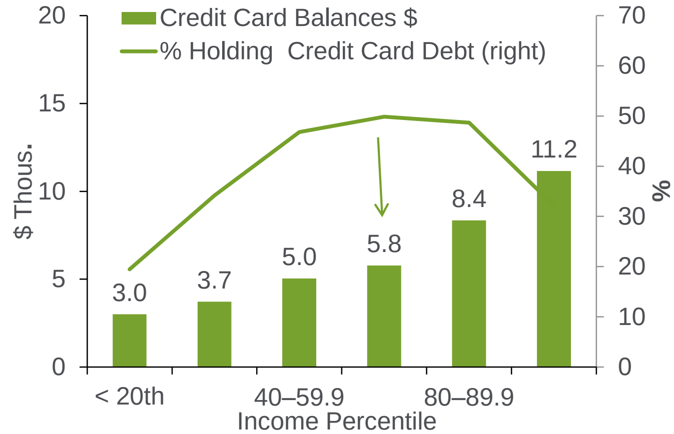
- **Loan amount**. The energy efficiency loan balances compare favorably to average marketplace loan balances (Figure 55) and are more in line with average credit card balances (Figure 56) for consumers which run a balance. While the average borrower income for energy efficiency loan is not disclosed, we would expect it to be comparable to marketplace loans, which ranks in the 60–89.9th income percentiles. Lower balances and favorable interest rates imply that energy efficiency borrowers are less leveraged than marketplace borrowers.

Figure 55. Average Principal Balances for Subprime, Energy Efficiency and Marketplace Installment Loans, in $



Source: Prospectuses

Figure 56. Average Credit Card Balances by Income Percentile for Households with Credit Card Debt, in $



Source: Federal Reserve Bank, Survey of Consumer Finances 2013

7. Other Safeguards

The underwriting standards are well-thought out and establish conservative credit, income and ability-to-pay criteria, documentation and standards. All borrowers remit their payments electronically or by mail to a lockbox. Wells Fargo Bank functions as a backup servicer receives monthly pool data, confirms certain data on the monthly servicer reports and becomes successor servicer if the master servicer or servicer is terminated for any reason.

Solar Lease & PACE Lien ABS Limitations

Solar Lease

There have been at least four small transactions since 2013. Some of the challenges these transactions face include: (1) short performance history, (2) long length of assets and unpredictable cash flows, (3) rapidly changing technology, (4) potentially off-market contracts because costs are dropping rapidly and (5) lack of contract standardization. Some investors have expressed negative opinions about some of the document provisions, including liberal default and cure rights.

PACE Liens

In qualifying states or localities, residential or commercial property owners may take out a loan to improve the energy efficiency of a dwelling on the property. A PACE lien is similar to a tax lien, as it confers a super senior lien on the financed real estate, which is also superior to the first mortgage loan. Prior to 2009, only California and Colorado had enacted PACE loan legislation. Since that time, 32 states and the District of Columbia have authorized local governments to create PACE financing programs. Most states confer a super-senior priority lien status on PACE loans, similar to a tax lien. But in recognition of the FHFA's opposition to the super-senior lien, a few states have enacted legislation that grants PACE loans a subordinate lien instead. Oklahoma, Maine and Vermont downgraded the lien status to subordinate, for instance (Figure 57).

Figure 57. US States Offering PACE Loan Incentives for Renewable Energy and Energy Efficiency as of Jan 2014

State	Lien status	State	Lien status	State	Lien status
AR	Super-senior	MD	Super-senior	OH	
CA	Super-senior	**ME**	Subordinate	**OK**	Subordinate
CO	Super-senior	MI	Super-senior	OK	Super-senior
CT	Super-senior	MN	Super-senior	OR	Super-senior
DC	Super-senior	MO	Super-senior	RI	
FL	Super-senior	NC	Super-senior	TX	Super-senior
GA	Super-senior	NH	Super-senior	UT	
HI	Super-senior	NJ	Super-senior	VA	Super-senior
IL	Super-senior	NM	Super-senior	**VT**	Subordinate
LA	Super-senior	NV	Super-senior	WI	Super-senior
MA	Super-senior	NY	Super-senior	WY	Super-senior

Source: US Department of Energy and PACE Now.

Typical PACE Program Underwriting Standards[36]

1. Homes must have 15% or more positive equity
2. Residential Projects limited to 10% of home value
3. Energy audit and work performed by accredited professionals
4. Projects must show cash flow savings (positive Savings/Investment Ratio)

The PACE program assessment ranks pari pasu with tax liens (in all jurisdictions but Vermont), with a super-priority interest in the property that is senior to the first mortgage holder. Theoretically, the sale of the property would not trigger a required PACE loan prepayment, and the assessment is supposed to remain with the property until paid as scheduled. In practice, Agency lenders will not make new mortgage loans against PACE-lien properties and since the Agencies grant the vast majority of new mortgages today, the PACE lien must be satisfied prior to voluntary sale of the property. In foreclosure proceedings, the lien remains with the property, and only the amount in arrears needs to be brought current.

[36] Sonoma County Energy website.

Summary: ABS Offers Green Pastures for Energy Financing

We expect the ABS market to expand and believe the most likely source of significant deal flow is from the WHEEL program

All forms of renewable energy are expanding, and we expect the ABS market to play a part in its growth. The most likely source of significant deal flow is from the WHEEL program. This takes the form of making a direct unsecured personal loan to the consumer and is "cleaner" than other forms of financing for renewable energy program financing. More delinquency and default data is needed in the public domain, but we would expect the losses on these types of loans to be low, given the cost savings involved in the projects. It is difficult to project a firm supply number, but we would expect more term ABS financing to come to market in the year ahead.

Energy 2030: Financing Analysis

Renewable Energy Project Structuring and Hedging in the US

Roxana Popovici
Director, Commodity Structured Products Group, Citi

Mike Curry
Head of North American Commodities Structured Products Group, Citi

The presence of the production tax credit (PTC)[37] legislation and prevalence of corporate sustainability plans have led to significant renewable growth in the United States with a concentration of projects in regions such as Texas, the Mid Atlantic and the Southwest (ERCOT, PJM and SPP energy regions) in the wind space and in the West (WECC) in the solar space. While uncertainty around the expiration of PTCs[38] every two to three years has led to a boom-bust cycle in the development pipeline, corporate sustainability plans have recently served as a mitigant in that regard and have stimulated a baseline expansion of the pipeline.

The complexity of executing a renewable transaction has been a barrier to entry

The complexity associated with executing a renewable transaction has served as a barrier to entry since each one encompasses three and in some cases four components: (1) power purchase arrangement, (2) construction loan, (3) tax equity investment, and in some instances, (4) back-leverage. While the construction loan, tax equity investment and back-leverage are executed as club deals with a handful of participants, the power purchase arrangement is put in place with a single entity and is meant to support the other legs of the deal.

There are two types of power purchase arrangements — traditional and virtual

There are two types of power purchase arrangements that are pervasive in the market as it stands today: 1) Traditional Power Purchase Agreements ("PPAs") and 2) Physical or Financial Hedges, also known as virtual PPAs. Under both arrangements, the project agrees to sell either all or a portion of the power and / or renewable energy credits at a fixed price in order to support the associated financing.

Although both types of power purchase arrangements are acceptable to the set of investors coming into a deal either as lenders or tax equity investors or both, PPAs are preferred due to the favorable transfer of risks from the project to the buyer.

Traditional Power Purchase Arrangement Overview

Traditional PPAs are driven by utilities, corporates, municipalities and cooperatives

The traditional PPA market has been driven by utilities, corporates, municipalities and cooperatives in various degrees of participation derived from each group depending on the power market. In PJM for instance, wind project PPAs have stemmed primarily from engagement by corporate entities foraying into the renewable space. In ERCOT, the PPA market has emanated from a combination of participation from municipalities, cooperative and corporates. The past two years have seen a proliferation of corporate participants into the market feeding into the triple bottom line corporate governance approach. Names making headlines have included Amazon, IKEA, Hewlett-Packard, Google and many others.

[37] The federal renewable electricity production tax credit (PTC) is an inflation-adjusted per-kilowatt-hour (kWh) tax credit for electricity generated by qualified energy resources and sold by the taxpayer to an unrelated person during the taxable year.
[38] Originally enacted in 1992, the PTC has been renewed and expanded numerous times, most recently by the *American Recovery and Reinvestment Act of 2009* in February 2009, the *American Taxpayer Relief Act of 2012* in January 2013, and the *Tax Increase Prevention Act of 2014* in December 2014.

Risk in a traditional PPA is disproportionately allocated to the buyer

Traditional PPAs are favored by investors since under the typical structure risk is disproportionately allocated to the buyer. In its most basic form, a traditional PPA will provide for the buyer to purchase at a fixed price the power output from the project on an as produced basis at the node at which the project interconnects into the relevant power market. Minimum availability guaranties are set over extended time periods, typically in excess of one year, and capped liquidated damages (i.e. $10/MWh) are imposed if the project fails to deliver such minimum quantities.

The tenor of traditional PPAs is generally longer than hedges, credit requirements are less

While the tenor (maturity) of traditional PPAs is generally longer than that of hedges — some ranging from 15 to 25 years — credit requirements tend to be a fraction of what is required under a hedge. Credit is usually addressed via a relatively small letter of credit such that the asset is not encumbered, thus facilitating in some case more favorable debt and tax equity terms than under a hedge transaction.

The disproportionate risk allocation mentioned earlier is advantageous to the project, which receives a long-dated power purchase arrangement at a fixed price. In return, the buyer must capture the production risk with respect to the intermittent nature of the wind or solar resource, capped liquidated damages when the minimum availability guaranty is not met, basis risk with respect to the unhedgeable price delta between the node at which the power is purchased and the relevant, liquid hub and credit risk with respect to a single, ring-fenced asset to which the buyer is an unsecured creditor without recourse to the parent.

Virtual Power Purchase Arrangement Overview

Virtual PPAs emerged from the participation of financial investors with banks dominating the market

The virtual PPA market has emerged from the participation of financial investors, such as banks, and a handful of corporate or strategic players. Banks have dominated the virtual PPA market over the course of the past three to five years, bringing forth several advantages – speed of execution in a market grappling periodically with the cliff expiration of PTCs, good understanding via lending experience of the asset serving as collateral backstop and shared services through partaking in some or all prongs of the transaction such as tax equity, construction loan, and/or back-leverage.

In its simplest form, a virtual PPA entails a physical or financial sale from the project to the buyer of a portion of the power, shaped by month and time of day, at a fixed price for a tenor long enough to cover the term of the tax equity investment plus a buffer of two to three years. The hedge is generally sized at the one-year 99th percentile production level, which is determined through an assessment performed by one of several consultants recognized by and acceptable to investors. In mature markets, the virtual PPA may settle at the project node while in less established markets, it will settle at the more liquid hub or zone in which the project is located or even a hub or zone in an adjacent market to which a high degree of correlation exists. A virtual PPA provides for liquidated damages, which are uncapped and determined by market prices at the time the failure to deliver occurred.

Revenues are smoothed as a tracking account provides liquidity to the project

In addition, a tracking account, in the parlance of a virtual PPA, is used to smooth revenues by providing liquidity to the project in situations where its revenues are insufficient to cover obligations owed under the hedge. The tracking account is capped, but is customarily sized generously to give the project control over its operations during periods of prolonged stress on revenues.

Unlike a PPA that requires de minimis collateral requirements, a hedge entails significant but yet manageable collateral levels, which are bifurcated pre and post the commercial operation date.

Prior to the commercial operation date, the virtual PPA will rely primarily on a letter of credit provided by the lenders and a second lien on all project assets. After the commercial operation date, exposure from the project to the buyer is addressed via a first lien on the asset, thus eliminating the need for liquid collateral prevalent under traditional PPAs.

In virtual PPAs, inherent project risks are retained by the project

Unlike traditional PPAs where risks are disproportionately allocated to the buyer, in the case of virtual PPAs, inherent project risks, such as production shape risk and, in some instances, basis risk, are retained by the project. The end result for investors is more stringent due diligence around congestion, assessment, and availability under the tracking account.

Two developments have, at times, commanded certain variations around the basic structure of virtual PPAs, primarily through the use of options.

1. The decline in power prices and, more importantly, heat rates over the course of the past three years has led to sponsors looking to retain upside when possible.

2. Some buyers have become weary of concentration risk, especially with respect to illiquid tenor buckets.

The most common virtual PPA/option combo structure is one that entails a fixed-price power purchase for the first five to seven years and a put option establishing a floor for the remaining tenor, with the premium for the option embedded in the fixed-price transaction.

While this structure addresses the concerns of both equity investors and buyers, it becomes more challenging to implement as prices decline further due to additional reductions in the fixed price for the first five to seven years as a result of market conditions but also through the use of an option that is now less out of the money than previously and thus more expensive.

Outlook

If PTC's are not expected, future development in the renewable space is expected to stagnate

Future development in the renewable space is expected to stagnate if PTCs are not extended. The industry is counting on the sagacity of lawmakers to extend the legislation and allow for further development, particularly in light of the recently observed diversity of participants in the space.

It is unlikely that corporate sustainability goals or compliance entities are enough to compensate a project entirely for the loss of PTCs

Corporate sustainability goals may keep corporates from retreating, but they are not enough to support to the growth of the renewable energy market. If the program were to be abandoned entirely, corporate sustainability and compliance entities alone will have the ability to breathe air into the market via purchases above market levels. However, while corporates have displayed a proclivity to pay for meeting additionality goals and utilities have been willing to pay up to meet compliance targets, it's unlikely for either of them to compensate a project entirely for the loss of PTCs.

However, Renewable Energy Certificate markets could see an uplift in prices, although not enough to recompense projects for the loss of PTCs

One potential outcome associated with the elimination of PTCs is that most compliance Renewable Energy Certificate (REC) markets will see an uplift in prices, but not enough. However, the uplift is insufficient to recompense projects for the loss of PTCs. States will have to take a more aggressive stance with respect to complying with Renewable Portfolio Standard (RPS) levels, leading to a significant increase in the value of compliance RECs and thus keeping projects whole. Such action at the state-level, at a time when states are already burdened by carbon legislation, will take time and may dry up the development pipeline.

In the absence of a dramatic power price increase, regulatory action is critical to the survival of the industry

One potential fix would be to put in place a short-term PTC extension while mandating further federal guidelines for renewables and providing support to REC prices. In the absence of a dramatic power price increase, regulatory action is critical to the survival of the industry.

Financing Global Renewable Energy with Development Finance Institutions

Georges Romano
Regional Head of Export and Agency Finance Latin America, Citi

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The popularity of capital expenditures in renewable energy continues to grow unabated at a $200 billion[39] clip annually as new projects are deployed in virtually all corners of the world and across a vast array of green technologies. Accelerating improvements in efficiency and declining capital costs have allowed many solar and wind farms to become economically competitive vis-à-vis conventional power plants, becoming an energy solution of choice for governments and energy investors alike.

The imperatives posed by climate change, when combined with superior economic rationale for green projects, have prompted policy makers to enact sweeping energy reforms in almost all markets. Bold targets have been set for the deployment of renewable energy projects in many markets, including the US, China, Japan, India, Germany, Brazil, Chile, Mexico, South Africa, Morocco, Turkey, Egypt, and Pakistan. Among the many policy instruments available to promote capital investments in renewable energy, we would like to focus on financing programs provided by Export Credit Agencies (ECAs), Multilaterals (MLAs), and Development Finance Institutions (DFIs).

Export & Agency Finance for Renewable Projects

Export Credit Agencies (ECAs) exist for the purpose of promoting exports from their sponsoring countries

Export & Agency Finance is the general term for financing supported or provided by government-sponsored agencies, whereby such agencies provide funding based on their underlying purpose. Export Credit Agencies exist for the purpose of promoting exports from their sponsoring countries. Historically, ECAs were exclusively the tools of developed countries. However in recent years ECAs have also increasingly been promoted by emerging countries such as China, South Africa and India. Multilaterals and Development Finance Institutions, including well known institutions like the World Bank and lesser known lenders such as the Overseas Private Investment Corporation of the United States, exist for the purpose of promoting development in and investment into the emerging markets.

ECAs can provide financing with long tenors and lower cost than the private market

These types of agencies are typically able to provide financing with longer tenors and lower cost than within the private market. As a result, agencies often help to fill market gaps by mobilizing investments that would not otherwise have adequate financing solutions.

Official agencies fill the gap of capital availability

Even though improvements in technology in recent years have pushed the costs of renewable energy development downwards, investments face numerous barriers and potential risks. One of the primary barriers is capital availability and this gap is frequently filled by official agencies. The challenges inherent in financing renewable energy projects, including large upfront investments and drawn out repayment periods, make agencies a crucial source of financing for these types of projects. In this article, we attempt to identify the various agency programs that support investment in renewable energy projects, which can be used as a starting point to further engage with commercial banks and agencies for deal specific solutions.

[39] According to Advanced Energy Now 2015 Market Report

Export Credit Agencies

ECAs are a key source of debt funding

ECAs have been a key source of debt funding for renewable energy investments, particularly those covering exports by local industries. Many agencies express a desire to support such investments in order to meet their Corporate Social Responsibility objectives.

The structure of ECAs for renewables lessens the upfront burden of repayments

The OECD consensus, an agreement among the OECD countries that governs the terms of ECA credits, contains a specific "sector understanding" outlining how ECAs can provide support by the way of financing in the renewable energy sector. This flexibility allows ECAs to offer loans or loan guarantees for tenors up to 18 years, versus the standard term of 10 years for other types of exports, which enables the financing to match the frequently longer investment horizons of renewable energy projects. Also, whereas for ordinary exports ECAs require principal repayments to be in equal installments, for renewable projects ECAs allow interest payments to be combined with principal in calculating the equated installments, thus lessening the upfront burden of repayments.

Almost all ECA support is through credit lines tied to domestic exports or to investment made by local companies in the foreign geography

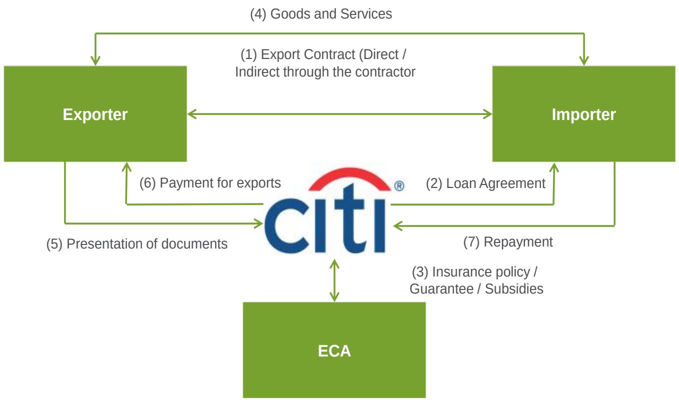
As mentioned above, many ECAs consider renewable energy as a focus area but almost all support is only through credit lines tied to domestic exports or to investments made by local companies in the foreign geography. Only the Japan Bank for International Cooperation (JBIC) and to some extent Nippon Export and Investment Insurance (NEXI) offer untied support to renewable energy projects by way of untied "Green" lending programs. Figure 58 includes a list of the ECAs that have been active in the renewable energy space. Some of the ECAs have special focus or specific programs for renewable energy.

Figure 58. List of ECAs Active in the Renewable Energy Sector

Country	Agency	Country	Agency
Australia	Export Finance and Insurance Co (EFIC)	**Japan**	Japan Bank for International Cooperation (JBIC)
Austria	Oesterreichische Kontrollbank (OeKB)	**Japan**	Nippon Export and Investment Insurance (NEXI)
Belgium	Office National du Decroire (ONDD)	**Korea**	Korea Trade Insurance Corporation (K-SURE)
Brazil	Brazilian Development Bank (BnDES)	**Korea**	Export-Import Bank of Korea (KEXIM)
Canada	Export Development Canada (EDC)	**Norway**	Norwegian Guarantee Institute for Export Credits (GEIK)
Denmark	Eksport Kreditfonden (EKF)	**Spain**	Compañía Española de Seguros de Crédito a la Exportación (CESCE)
Germany	Euler Hermes Kreditversicherungs-AG (Hermes)	**Sweden**	Exportkreditnämnden (EKN)
Italy	Servizi Assicurativi del Commercio Estero (SACE)	**US**	Export-Import Bank of the US (Ex-Im Bank)

Source: Citi TTS

Figure 59. Typical ECA Funding Structure



Source: Citi TTS

Multilaterals (MLAs) and Development Financial Institutions (DFIs)

MLAs and DFIs are driven by institution-specific mandates mainly to promote investment and development in emerging markets

Support from Multilaterals and DFIs for renewable energy projects is driven by institution-specific mandates, typically to promote investment and development in emerging markets. Most agencies have particular interest in renewable energy due to institutional or government mandates.

In recent years these institutions have supported large projects based on new technologies such as off-shore wind farms or geothermal power, which have some "demonstrative" effect to encourage additional private investment into the sector. They have also played a critical role in helping to deploy renewable technologies to address large generation deficits in regions such as Africa. Notably, the Power Africa initiative — a US government-launched initiative to bring together the private sector and governments to work in partnership to increase access to power in Africa — is being driven in large part by the involvement of DFIs from the US and other countries. The agencies' focus on renewables in these contexts has played a role in incentivizing the development of renewables over traditional technologies.

Agencies typically not engaged in lending activities have established programs focused on the renewables sector to carry out specific programs or mandates

In addition to the DFIs, in some cases, government agencies that do not typically engage in lending activities have nevertheless established programs focused on the renewable sector in order to carry out a specific program or mandate. The US Department of Energy has established a number of programs to provide loans and loan guarantees for renewable projects, and has successfully supported a number of large investments together with commercial banks like Citi.

Figure 60. List of Multilaterals and DFIs Active in the Renewable Energy Sector

Name	Name
European Investgment Bank (EIB)	Australian Renewable Energy Agency
Asian Development Bank (ABD)	International Finance Corporation
KfW/DEG	Central American Bank for Economic Integration (CABEI)
Inter-American Development Bank (IDB)	Netherlands Finance Development Co (FMO)
Oversease Private Investment Corp (OPIC)	Proparco
US Department of Energy (DoE)	European Bank for Reconstruction and Development (EBRD)

Source: Citi TTS

Agency Activity in Renewable Space

Over the past seven years there have been a total 83 agency deals in renewable energy worth $22.4 billion

According to data from league tables, during the past seven years (through 3Q 2015) agencies have supported a total of 83 deals in renewable energy with a value of $22.4 billion. Note that league tables understate the extent of the financing activities of official agencies because it only includes data on commercially-syndicated loans supported by ECAs, and typically does not include comprehensive data on multilateral and DFI loans, or direct or bilateral loans. However, the trends highlighted by the data can be demonstrative.

The majority of projects have been for wind in the EMEA region

Of the total agency support to renewable energy projects during this timeframe, wind projects contributed 67% of all volume and solar contributed 11%. Regionally, the Europe, Middle East and Africa region leads with 61% of all agency supported loan volume, followed by Asia Pacific with 29%. Perhaps more notably, according to Dealogic during the past 3 years only 2-4% of annual agency loan value is attributable to renewable projects, compared to 21-32% for oil and gas projects and 17-23% for transportation projects. This mainly reflects the difference in the scale of investment going into these sectors, but also suggests that despite the presence of many agencies willing to support renewable energy investments, there is room for agencies to significantly grow their support to the sector.

Key Takeaways

- Many ECAs have programs that support investments in renewable energy but almost all of these programs are linked to domestic exports or to investments by local companies in a foreign geography.
- The sector understanding under the OECD consensus provides flexibility to the ECAs to extend loans with tenors up to 18 years for project in renewable energy as against generally acceptable terms of 10 years. It also provides some flexibility in the terms of repayment.
- DFIs also have programs for renewable energy and have been actively seeking projects to support in the sector. An analysis of the historical deals suggests an inclination by these agencies to finance landmark projects in new technology sectors as proof of concept.

Energy 2030: Consultant Analysis

Innovation to Unlock Developing Economy Finance: Currency Risk Reduction

Barbara Buchner
Senior Director of Climate Policy Initiative

Tools to manage FX and interest rate risk are essential for increasing climate investment in developing countries

Investing in renewable energy and other forms of clean infrastructure is capital-intensive and requires long-term financing to match long operational lifetimes and payback periods. In countries with underdeveloped capital markets, oftentimes the only long-term financing available is in a hard currency – such as dollar or euro. Sub-Saharan Africa is a prominent example where, except for South Africa, local capital markets are not sufficiently deep to offer project finance in local currency or offer suitable hedges for currency risk (Donnelly, 2015[40]).

This creates a mismatch between local currency revenues and repayment obligations, creating the risk that foreign denominated debt cannot be paid back if the local currency loses value. Project investors will seek a higher return to compensate for the higher perceived risk and this can tip the balance of financial feasibility with the result of good projects not being pursued. An interlinked barrier is interest rate risk. Loans in developing countries are often only available with a floating interesting rate – meaning that debt repayments increase if interest rates rise. Inadequate currency and interest rate risk management can lead to greater project failures, adverse impacts on consumers and systemic risk on financial systems (Gray & Schuster, 1998[41]), (EU, 2011[42]).

An Innovative Instrument to Hedge FX and Interest Rate Risk

The TCX and the IFC have worked together developing a public-private instrument that would provide long-term foreign exchange and interest rate risk management to renewable energy projects

Over the past year, the Global Innovation Lab for Climate Finance[43] worked with The Currency Exchange Fund (TCX) and the International Finance Corporation (IFC) to develop a public-private instrument that would provide long-term FX and interest rate risk management to renewable energy and other climate-relevant projects. This concept was one of four finalists selected from over one hundred proposals based on their innovativeness, catalytic and transformative potential and actionability. By providing the tools to lock-in long term finance in local currency, the instrument will help make more projects viable and unlock new climate investment.

[40] Donnelly, D (2015). Financing Renewables Projects on Africa. In Clean Energy Guide. VB/Research Ltd.
[41] Gray, R David, Schuster, John 1998. "The East Asian Financial Crisis: Fallout for Private power Projects" World Bank, Washington, DC.
[42] EU (2011). Recommendation of the European Systemic Risk Board of 21 September 2011 on Lending in Foreign Currencies (ESRB/2011/1). Official Journal of the European Union (2011/C34).
[43] For more information see http://climatefinancelab.org/

About the Lab

The Global Innovation Lab for Climate Finance (The Lab) is a public-private initiative that identifies, develops, and supports delivery of cutting edge climate finance instruments. It aims to drive billions of dollars of private investment into climate change mitigation and adaptation in developing countries.

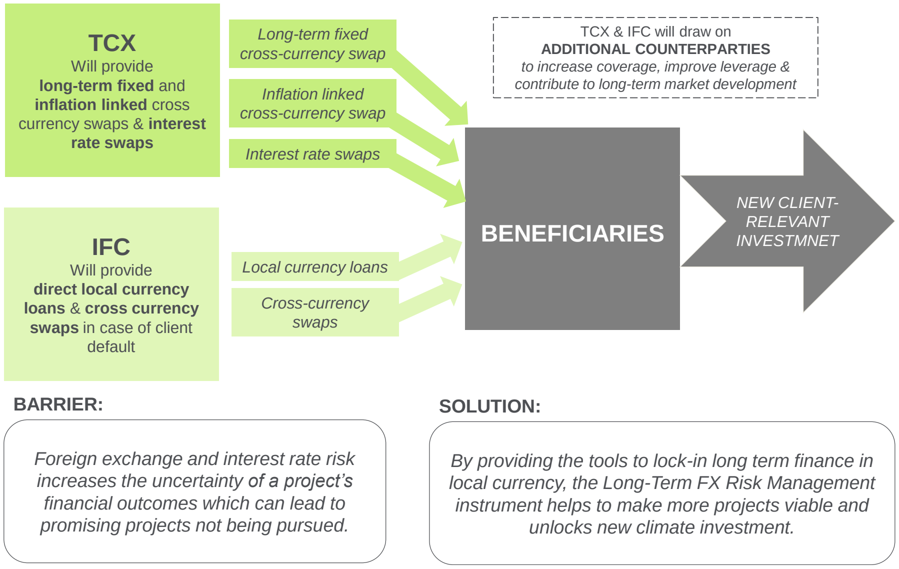
The Lab convenes a unique group of public and private actors, pooling political, technical, institutional, and financial resources to accelerate the development of innovative ideas from concepts through to implementation-ready projects that address investor and recipient country needs. It distinguishes itself from similar initiatives by quickly moving from talk to action, delivering effective pilots of Lab-tested financial instruments, and encouraging the replication of successful pilots at greater scale within reasonable timeframes. In addition to the Long-term Foreign Exchange Risk Management instrument, The Lab has delivered three other instruments, which include:

- Energy Savings Insurance, which insures the value of savings generated by energy efficiency investments. The instrument has a pilot in Mexico and it has secured further funding to replicate across Latin America.
- Climate Investor One, which will facilitate early-stage development, construction financing, and refinancing to fast-track renewable energy projects in developing countries, mobilizing at least $2 billion in private finance out to 2020.
- Agricultural Supply Chain and Adaptation Facility, which will partner with agribusiness corporations to provide farmers with technical and financial support for climate-resilient investments through the corporations' supply chains.

The instrument offers different types of cross-currency and interest rates swaps

The Long-term Foreign Exchange Risk Management instrument provides a suite of products that allow projects and entities to manage their foreign exchange (FX) and interest rate exposure[44]. The instrument would offer different types of cross-currency and interest rate swaps in countries not previously served by commercial markets including many countries in Sub-Saharan Africa. It would also offer a local currency lending product that bundles swaps with a US-dollar loan provided by the IFC to help clients who may not wish to enter into derivative contracts.

Figure 61. Long-Term FX Risk Management Facility Design



Source: Global Innovation Lab for Climate Finance

[44] More information and analysis related to this instrument is available at http://climatefinancelab.org/idea/long-term-currency-swap/

TCX and IFC will collaborate to develop a pipeline of projects

In a pilot of the instrument, TCX and IFC would collaborate to develop a pipeline of projects and enter into joint transactions where appropriate. Their roles are complementary and each would fill specific gaps in the market. TCX would focus on market risk while IFC on counterparty risk.

TSC has been hedging frontier market currencies since 2008. As part of this instrument, TCX will provide risk management instruments to firms, promoters and financiers that are undertaking climate relevant investment:

- **Long-term fixed foreign exchange (FX) swaps** offer clients fixed payments in a currency pair at tenors up to ten years to better match the operational lifetimes of renewable energy and clean infrastructure projects.
- **Inflation (CPI) linked FX swaps** decrease swap costs by indexing payments to inflation. This is ideal for a renewable energy project that can adjust revenues to inflation.
- **Interest rate swaps** will also be offered directly to clients as an additional benefit of the instrument. This allows clean investment projects to lock long term financing at a fixed rate.

Credit risk is lowered with IFC acting as an intermediate offering currency swaps to clients and also providing a local currency loan product

IFC would solve another key barrier – credit risk. Swap providers, including TCX cannot take credit risk which is present because a currency swap involves a stream of payments over time. They might require high collateral — as much as 25% of the value of the hedge up front. This is where IFC can come in. By accepting the credit risk and using their own AAA credit rating to act as the counterparty, they can make a transaction happen. IFC would be an intermediary offering currency swaps to clients and also providing a local currency loan product that combines a USD loan from IFC with a cross currency swap for clients who do not wish to enter into derivatives transactions. They would offer the following:

- **Local currency loans** which bundle a US-dollar-denominated loan with a cross-currency swap to directly offer a local currency loan to clients.
- **Cross currency swaps** directly to clients. The IFC would underwrite the swap and re-hedge its FX exposure with TCX or with commercial counterparties.

The Role of Public Finance

To start a pilot of this instrument, both organizations are seeking to raise risk capital from donor finance sources

To start a pilot of this instrument, both organizations are seeking to raise $250 million in risk capital from donor finance sources, which can leverage between three and four times more in additional finance. The funds would be used for:

- A proposed $200 million risk capital to back a portfolio of cross-currency swaps through TCX. These amounts are expected to support $600 million – $800 million worth of transactions.
- A proposed $50 million first loss tranche to partially guarantee a portfolio of local currency loans and cross currency swaps through IFC. IFC would also participate in the first loss tranche to ensure alignment of interest. This is expected to generate $300 million worth of financing extended by IFC to relevant projects over time.

There is public support for the FX instrument based on the environmental and economic benefits it provides

There is a case for public support for the FX instrument based on the environmental and economic benefits it provides. A simplified scenario was drawn that focused only on wind and solar projects to provide an estimate of potential impacts of a pilot. In this scenario, with $250 million in donor risk capital, the pilot could provide a total hedging capacity of $915 million. This could support $1.45 billion in total project value with potential GHG reductions of 1.7 $MtCO_2$ per year and a cumulative total of 39 $MtCO_2$ over the operational lifetime of the assets.

Ideas for Further Development

The instrument is versatile and can support multiple mitigation and adaptation projects

The Long Term Foreign Exchange Risk Management instrument is highly versatile and can also support clean energy, energy efficiency, public transport, water infrastructure, and other types of mitigation and adaptation projects. Post-pilot, the instrument is highly scalable and flexible in terms of geographic and sectoral reach and will also contribute to financial market development and transformational impacts, unlocking additional investment.

Energy 2030: Commodities Analysis

De-risking Through Public Sector Involvement

Anthony Yuen
Ed Morse
Seth Kleinman
Adriana Knatchbull-Hugessen
Citi Commodities Research

The public sector could help de-risk projects in ways that could sharply lower the cost of capital and expand the size of private financing into renewable projects. Unlike some developed markets that have strong renewable energy policies, institutional capacity, resource assessment, local expertise and grid connection, developing countries and even some developed markets are still forming their policies. Europe and California are deemed to be at the forefront of renewable energy integration but other markets are catching up. The United Nations Development Programme (UNDP) laid out a framework for de-risking that involves the following policy instruments:

- **Policy de-risking instruments** aim to remove underlying barriers that generate additional risks, such as grid access, permitting process, policies on the use of renewable energy, information, resource assessment, as well as institutional and individual capacity building.
- **Financial de-risking instruments** aim to transfer risk from the private to public sectors. They include loan guarantees and public equity co-investments.
- **Direct financial incentives** aim to reduce residual risks not eliminated by policy and financial de-risking. These incentives include subsidies, tax credits or explicit price premiums

Policy de-risking instruments help emerging markets address their policy gaps

Most emerging market countries need to address their policy gaps, which hinder the adoption of more renewable energy supply, through the use of policy de-risking instruments. However, some countries may need more direct financial incentives to lower the cost of renewable energy because other electricity generation sources are much more economically competitive: for example, coal-fired generation is often cheap in a coal producing country, so that support for renewable energy could help make renewables competitive vs. coal. Some countries may need financial de-risking instruments to lower the cost of capital, because sovereign and foreign exchange risks are high, or because of tight local financing markets: an example is Brazil with its high cost of capital. However, some local markets are so flush with money that their costs of capital tend to be low.

Policy de-risking could take years, however, as successful policy changes and capacity building efforts usually take time. Opening up and encouraging renewable energy penetration often goes against the entrenched interests of incumbents, firms along the existing value-chain or others that resist change. Developing local manufacturing and installation capability should also lower the cost of installing renewables and create green jobs. The investment and expertise brought in should raise foreign direct investments and improve local capacity building.

Reducing subsidies on fossil fuels should reduce the amount of direct financial incentives spent on renewable energy projects

Reducing subsidies on fossil fuels should help reduce the amount of direct financial incentives spent on renewable energy projects. While subsidies do distort the normal functioning of markets, if the objective is to promote renewables over fossil fuels, then why keep on subsidizing energy sources (i.e. fossil fuels) whose share in energy supply the government wants to reduce? Low-income consumers may need help to pay for their energy costs if subsidies for fossil fuels are taken away. Therefore, some other policy support should be in place to deal with the regressive nature of higher energy costs.

Designing and Applying Appropriate Instruments to De-Risk Projects

Designing and applying appropriate instruments to de-risk projects involves:

- **Identifying and quantifying risks** that contribute to entry barriers and higher costs of capital vs. similar projects in markets with best practices;
- **Formulating effective policy instruments** to break down key barriers and reduce risks, so that renewable energy projects become economically competitive enough vs. conventional energy projects;
- **Evaluating the effectiveness of these policy instruments** in lowering the cost of capital, boosting private investments, reducing consumer expenditure, and cutting emissions.

Risks identification

Project risks can include political, social, technical or financial risk

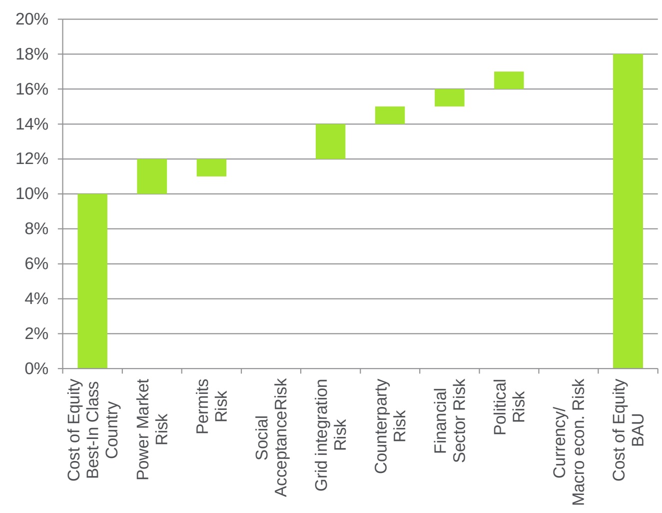
The types of risks that are typically identified include:

- **Political** risks include the direction of renewable energy policy, market access, permitting process and general uncertainty (e.g. stability of a government and its policies).
- **Social** risks include whether the public wants to have renewable energy. Even if people do support renewables, they may have a NIMBY (Not-In-My-Backyard) problem about the siting of renewables.
- **Technical** risks include the experience, expertise and adequacy of infrastructure in accommodating renewable energy, as well as data availability and resource assessment in helping project developers and financial partners evaluate projects.
- **Financial** risks include counterparty risk in making sure off-takers of the energy generated can pay, local funding conditions, macroeconomic risks including inflation and interest rates, as well as foreign exchange risks in relation to bringing in foreign capital or importing equipment and fuels.

Separate evaluations should be performed for equity and debt as their risk-return profiles are different

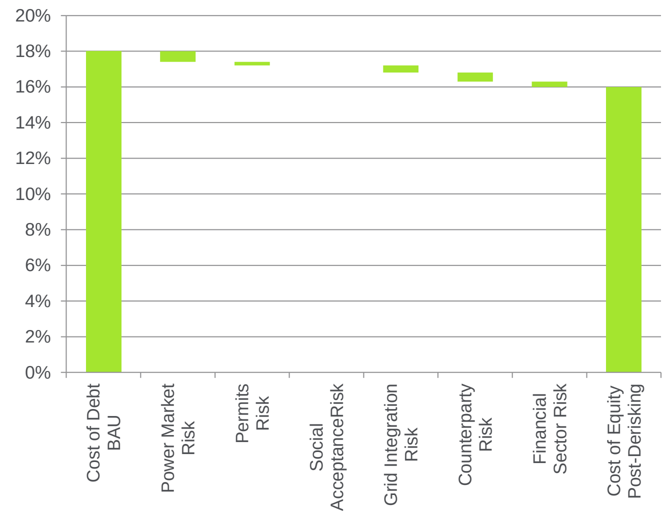
Industry comparables (e.g. sovereign ratings, local corporate or utility-specific WACC), existing deals, case studies in international and cross-sector experiences, as well as structured interviews should help quantify some of these risks. However some risks are qualitative in nature and hard to value. As the risk-return profiles of equity and debt are different, separate evaluations should be performed or these asset classes. The graphs below show illustrative cases of how the cost of capital could rise for a renewable energy project and how public policy measures could help de-risk projects.

Figure 62. Quantifying the Size of Risks Embedded in Higher Financing costs (equity)...



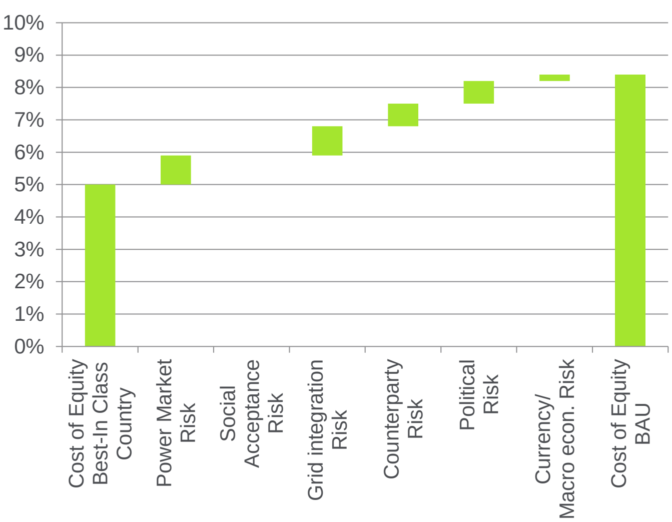
Source: UNDP, Citi Research

Figure 63. ...And how Public Policy Measures Could De-Risk Project



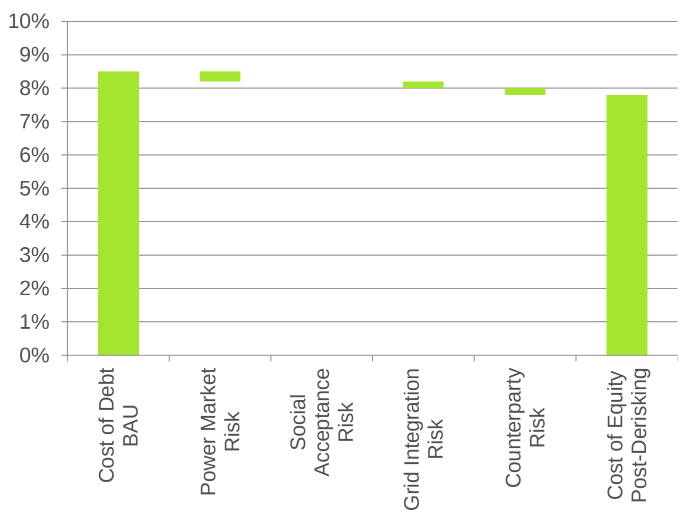
Source: UNDP, Citi Research

Figure 64. Quantifying the Size of Risks Embedded in Higher Financing Costs (debt)...



Source: UNDP, Citi Research

Figure 65. ...And How Public Policy Measures Could De-Risk Project



Source: UNDP, Citi Research

Costs and Implementation of Public Sector De-Risking Measures:

The costs for policy and financial de-risking must be evaluated

- For policy de-risking instruments, the core costs include the design, implementation, impact evaluations of instruments and the duration of these cost items. There are costs associated with funding permanent regulatory bodies and monitoring functions, but the streamlining of existing process and enhancing the new process could save money.
- For financial de-risking instruments, costs include the capital deployed or held in reserve for loan guarantees plus public equity co-investment etc. Sometimes there is no cost to the public because green banks or development banks make the loan but expect only a small profit. However, these policy banks could incur capital losses due to defaults on occasion. This is where risk evaluation is critical

to avoiding defaults as much as possible. Policy banks may leverage their paid-in capital and high credit ratings to raise private capital in order to lend to project developers. Some estimates suggest that institutions like the World Bank could leverage 3.5-times their paid-in capital. New development banks, most prominently the Asian Infrastructure Investment Bank (AIIB), are also looking to drive more public-private investments; the AIIB looks to target power, water and transport infrastructure investment in its initial phase of operation.

A cost comparison includes looking at financing, capital and variable costs

Next is the evaluation of the various costs of renewable energy vs. traditional energy sources. It is not just a simple total cost comparison that includes financing, capital and variable costs.

- For new renewable energy supply competing with *existing* fossil fuel power plants, the capital, financing and variable costs of the new renewable energy project should be compared with the fuel and variable (fuel + operating costs) costs of the fossil fuel plant, because no new fossil fuel plant is needed in this case.
- For building *new* power plants, the capital, fuel, variable and financing costs of both the renewable energy and fossil fuel project should be considered. A better baseline for comparison assumes no government support, such as subsidies for renewables or fossil fuels, then adds back the impacts of policies which aren't likely to be eliminated.

Evaluation of Policy Effectiveness

Evaluations of policy effectiveness involve (1) assessing how much more private capital has been raised vs. the amount of public capital put in; (2) how much consumers have saved and the affordability for consumers; and (3) how much emissions can be cut, which can be associated with lowering the health and environmental costs.

Part B Conclusion

- Technology, finance and policy are converging in the global effort to promote a greener future. Financial innovation is increasingly critical in this space as diverse solutions expand and evolve to facilitate the recycling of capital and to optimize the allocation of risk and funding of renewable energy projects globally. We highlight several influential financial solutions being developed and deployed today.

- Innovative financial solutions for "new" markets like renewable energy and energy efficiency are supported by several fundamental components: (1) tailoring adaptive solutions to specific projects by combining multiple financing strategies; (2) helping to connect new markets with capital markets by providing transparency and standardization in diverse and fragmented markets; and (3) leveraging public-private partnerships to fill critical gaps and mobilize projects that might otherwise not get done.

- Securitization solutions for residential green energy loans could help support greater and more diverse growth in residential purchases of green energy technologies. By pooling loans and slicing risk into different levels, securitization thereby expands access to capital by appealing to a broader range of investors with varying risk appetites. This has the potential to increase consumer access to low cost capital for funding household green energy purchases, thereby supporting the proliferation of these technologies. The WHEEL program in particular looks poised to be at the forefront of this effort.

- Different structures in power hedging, including PPAs and virtual PPAs could provide incentives for development in the US by allowing varying risk allocation between the buyer and seller.

- Development finance institutions and government-sponsored agencies provide a bridge between public and private solutions to promoting green energy, particularly in emerging markets. These institutions are able to provide lower cost and longer tenor financing to renewable projects than the private markets, helping to mobilize investments in the sector.

- In developing countries, where access to local capital markets is limited, foreign investment is often necessary to provide capital for renewable energy projects. However, foreign funding exposes investors to currency risk due to the mismatch between repayment obligations and local currency revenues. Mitigating this risk through innovative currency swap solutions could help lower the cost of capital for renewable energy in otherwise inaccessible markets, like Sub-Saharan Africa.

- The public sector could be a critical player in the effort to de-risk renewable investments and lower capital costs for projects. In this space, several solutions are available beside direct financial support, ranging from policy instruments that remove underlying barriers that generate risks, to financial instruments that transfer risks from the private to the public sector, such as loan guarantees for renewable energy projects.

Energy 2030: Macro Analysis

Part C: Will Fossil Fuels Be Stranded?

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"The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil" [45]

"Stranded assets" is a dramatic name for familiar concept: real (that is, physical) assets that have lost much or all of their value, or may even have become liabilities, as a result of unanticipated and sometimes discontinuous technological, social, political, economic and market developments which are perceived to be permanent. One can potentially think of stranded assets as assets that lose their value as a result of political and regulatory actions, and which absent those political and regulatory changes would still have material value. But in this report we stress that the issue is usually much more nuanced: technological, social, political, economic and market developments interact in determining the relative competitiveness of assets, technologies or resources and the relevant scenarios are not limited to the status quo and the world where an asset that has value today becomes stranded due to some political or regulatory action tomorrow.

Assets are risky and may become either worthless or a net drain on financial resources

It is hardly news that assets — both real and financial — are risky, that they may become worthless or turn into a net drain on financial resources. New environmental standards adopted in the US and a number of other countries hurt the financial performance of the mining sector by restricting the pollution of land, water or air and often prohibiting the release of toxic materials, notably the dumping of mine tailings in rivers, lakes and oceans. Mining companies are increasingly likely to be required to make full financial provision, in advance, to cover the cost of closing the mines and restoring the environment to an acceptable standard. The political momentum behind legislation like the Clean Water Act could prevent mining activities in protected areas or in areas with great non-economic (environmental, cultural or historical) value. An example is the decision by the EPA to invoke its powers under the Clean Water Act by reviewing the environmental impact of the proposed Pebble Mine in Bristol Bay, Alaska. This large open-pit gold, copper and molybdenum mining project has been shelved since 2013, but there is a legal challenge to the EPA's ruling.[46] If the legal challenge fails and the EPA's decision to impose restrictions based on Section 404 (C) of the Clean Water Act stands, this would effectively kill the project.[47] Asbestos is another classic example of a stranded

[45] Quote attributed by the Economist to Sheikh Ahmed Zaki Yamani, Saudi Arabia's Minister of Oil and Mineral Resources from 1962 to 1986. "The Future of Energy; The End of The Oil Age", *The Economist*, 23 October 2003, http://www.economist.com/node/2155717. A rival, but later attribution is to William McDonough: "The Stone Age did not end because humans ran out of stones. It ended because it was time for a re-think about how we live." As quoted in "Eco-designs on future cities" by BBC News (14 June 2005).
[46] See Michael J. Kowalski, "When Gold Isn't Worth the Price", New York Times, 7 November 2015, p. A23.
[47] "Section 404(c) authorizes EPA to prohibit, restrict, or deny the discharge of dredged or fill material at defined sites in waters of the United States (including wetlands) whenever it determines, after notice and opportunity for public hearing, that use of such sites for disposal would have an unacceptable adverse impact on one or more of various resources, including fisheries, wildlife, municipal water supplies, or recreational areas." EPA, Clean Water Act Section 404(c): Restriction of Disposal Sites, http://water.epa.gov/lawsregs/guidance/cwa/dredgdis/404c_index.cfm

asset killed by new knowledge about its health impact and by the laws, regulations and lawsuits triggered by this new knowledge.

Capital investment that makes sense during a price bubble might not make sense once the bubble is burst

Price bubbles in real reproducible assets can motivate capital investment that makes sense at the inflated bubble prices but not once the bubble has burst. During the Irish financial and construction boom preceding the Great Financial Crisis, a large amount of new residential construction took place in locations that were quite far off the beaten track. When the house price bubble burst, much of these speculative constructions became stranded assets. Unlikely ever to find buyers such properties stand empty and sometimes unfinished. In 2013 the Irish government demolished 40 unfinished 'ghost' housing estates. The costs were born by the site owners.[48]

The term 'stranded assets' is generally reserved for natural resources, though the logic can be applied to any real asset whose value can be drastically reduced or even wiped out by technological, social, political, economic, or market developments. The Irish ghost town example makes this clear.

The amount of any natural resource that can be profitably recovered is a function of its future price path

For most natural resources, the bulk of existing stock in the ground has never been a candidate for profitable extraction — these are not stranded assets as they never had a positive economic value

For any natural resource, the amount that can be profitably recovered, in a given time period or cumulatively between now and kingdom come, is an increasing function of its future price path: the marginal cost curve and, after a while, the average cost curve are upward-sloping with the volume of extraction in any given period and, unless technological progress comes to the rescue, with the cumulative extraction volume also. For most natural resources, the bulk of the existing stock 'in the ground' has never been a candidate for profitable extraction and likely will always remain unprofitable at any reasonably conceivable future path of prices and costs. Such resources are not stranded assets as we use the term, because they never had a positive economic value – they never were *assets*. Stranded assets are assets that once had positive economic value but no longer do, as it would not be profitable to extract them, now or in the future.

Total resources are the total amount of the resource that has been extracted plus an estimate of the amount that could be profitably recovered and produced

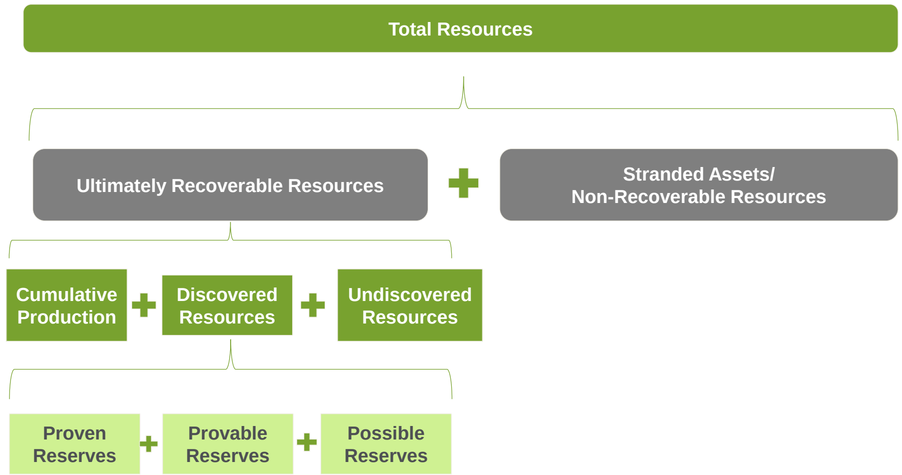
In the Figure 66, 'total resources' refers to the cumulative amount of the resource that has been extracted (profitably, presumably) plus an estimate of the amount that could be profitably recovered and produced (extracted, henceforth), using current technology and assumptions about future technology and geology plus an estimate of the amount that once could have been recovered profitably, but that because of unexpected developments is profitable no longer. The ultimately recoverable resources (URR) are an estimate of the cumulative total amount of the resource that will ever be profitably extracted. It is determined by geology, the laws of physics, technology, the prices of the inputs used in the extraction process, the price of the resource and the price of the other outputs of the extraction process. With the exception of the laws of physics, all these drivers of the URR will change over time. Technological change in the extractive industry itself will tend to raise the URR over time. New knowledge in general, however, need not have this effect, as the fate of asbestos illustrates.

[48] BBC News, "Ghost estates: 40 unfinished developments to be demolished", 28 November 2013, http://www.bbc.com/news/world-europe-25137410

A Classification of Recoverable Resources

As shown in the figure below, the ultimately recoverable resource is the sum of cumulative production, discovered reserves and undiscovered resources.

Figure 66. Decomposing the stock of available resources



Source: Citi Research

Cumulative production is the total amount extracted up to a given date

Cumulative production is the total amount extracted up to a given date. Discovered reserves are an estimate of the future cumulative profitable production from currently known reserves. Discovered reserves are the sum of proven, probable and possible reserves. Proven reserves are future cumulative profitable production that is recoverable with reasonable certainty (say at 90% probability or higher) from known reserves with current technology and current operating and market conditions. Probable reserves are reserves that are estimated to have a less than 90% but more than even (50% or higher) probability of being profitably extracted in the future, from known reserves with current technology and current operating and market conditions. Possible reserves are reserves that have a significant but less than 50% chance of being profitably extracted in the future, from known reserves with current technology and current operating and market conditions.

Undiscovered resources are resources yet-to-be discovered

Undiscovered resources are the unknown unknowns in the world of natural resources. These are resources yet-to-be discovered. A probabilistic assessment is made based on assumptions about future geological, technological, political, social and economic factors. This requires assumptions about the future price of the resource, about future technology, the future regulatory, legal and tax environment and other drivers of future costs of production and of the operational environment. The probability of being discovered may be low, but it is positive for undiscovered reserves.

To this standard decomposition of ultimately (profitably) recoverable resources, we add the category of resources that are (or are likely to be) technologically recoverable in the future, and once were expected to be profitably recoverable, but no longer are, given new assumptions about future prices, other market conditions and other drivers of the operational environment such as current and future taxes, regulations and technology. These Non-Recoverable Resources are the stranded assets that are making such a splash in the world of fossil fuels – principally coal, oil and natural gas. Total resources are the sum of ultimately recoverable resources and stranded assets.

The owners of the right to extract a resource in a given location value this asset in terms of the present discounted value of profits from exploiting the discovered reserves and the undiscovered resources; cumulative past production is a bygone. So are stranded assets, unless they turn into actual liabilities. The discount rate applied to the streams of future profits will rise as we move vertically in Figure 66. The value of the stranded assets is, by definition, zero.

Why the Interest in Stranded Assets Now?

The stranded asset debate is related to political and social debates about the negative externalities associated with their extraction and conversion into energy

Why is the stranded asset question mostly raised in the context of natural resource extraction? Resource extraction processes typically produce multiple outputs. The conversion of fossil fuels into energy likewise produces other outputs, such as greenhouse gas emissions. When one or more of these joint products are 'bads', like soil and water contamination or emissions of greenhouse gases, their price should be interpreted as the cost associated with handling these negative externalities. Historically, free disposal of the joint products created by the extraction process of fossil fuels and by their conversion into energy, has often been the rule. When knowledge accumulated about these negative externalities and was disseminated among those affected by them, the government would often respond with measures to force or incentivize the producers to limit these negative externalities. Taxes, quotas, tradable pollution permits, regulations that imposed costly restrictions on the extraction process and similar interventions often resulted. The debate about 'stranded assets' is therefore invariably related to the political and social debate about the 'bad' or the negative externality that is associated with their extraction and conversion into energy or other desirable products.

The costs imposed by negative externalities are referred to as energy subsidies

Sometimes the costs imposed by these externalities, to the extent that they are not internalized/borne by the mining companies, the electric power generators or the users of goods and services that have fossil fuels somewhere in their supply chain, are referred to as energy subsidies (see e.g. Coady, Parry, Sears and Shang (2015), Ebeke and Ngouana (2015) and Gaspar (2015)). These publications call 'cash' subsidies pre-tax subsidies and the negative externalities created by the extraction and use of energy post-tax subsidies. We don't think this rather strained and stretched redefinition is useful, as it smacks of the use of semantic weapons (and the emotions they evoke) rather than relentless logic and hard facts to promote a cause. The economics profession and the world at large know what negative externalities are and have a standard usage for the word 'subsidy'. The numbers are big enough not to get distracted by semantic warfare.

In 2015, the cost of negative externalities is forecast to be $5.3 trillion

According to recent IMF studies the sum of pre-tax subsidies, fiscal revenues foregone (which is close to a traditional cash subsidy the way taxes and tax expenditures can be viewed as closely related concepts) and the cost of negative externalities for 2015 is estimated to be $5.3 trillion. Pre-tax subsidies and fiscal revenues foregone are 12% of this or $636 billion (Gaspar (2015) and Ebeke and Ngouana (2015)). The rest, the cost of the energy-related negative externalities, is just under $4.7 trillion. If these numbers are anywhere near correct, it is not surprising that there has been a policy response to force the energy producers and/or users to internalize at least part of these costs – a political response that is about to turn a significant amount of fossil fuel reserves into stranded assets.

The headlines about the carbon budget — the cap on future carbon emissions implied by a global commitment to keep the rise in average global temperature over its pre-industrial level to no more than 2 degrees Celsius — refer to a potentially large shift in the figure above, for fossil fuels generally (but most immediately for coal, followed by oil and then by natural gas) out of the URR box into the stranded assets box. Through new taxes, quotas (including tradable permits for extraction or for the right to emit carbon dioxide and other greenhouse gases by burning fossil fuels) and regulations, either extraction costs are raised and/or the prices buyers are willing to pay are reduced to the point that future extraction of previously profitable resources is no longer profitable.

Stranded assets have recently become a subject of interest due to their potential size….

There are three reasons why 'stranded assets' have relatively suddenly become a subject of considerable interest, debate and controversy. The first is that the amounts involved are likely to be big. The numbers that could be involved were large enough for the Governor of the Bank of England, Mark Carney — speaking as the head of the UK's Prudential Regulation Authority (and indeed head of every aspect of financial regulation and supervision except for 'conduct') — to warn investors in the fossil fuel industry about possibly huge losses from climate change action. Tougher rules on climate change could leave between 66% and 80% of the world's proven fossil fuel reserves stranded." [49] That would be a fair amount of asset impairment.

…and have changed the peak oil hypothesis…

The second reason stranded assets are in the news is that only a few years ago, the prevailing concerns about 'peak oil' were concerns about peak oil *supply*. In the 'stock' version this referred to the belief that the total amount of oil that was recoverable, given current technology and reasonably foreseeable future technological developments, at non-prohibitive costs of exploration and extraction had peaked. In the 'flow' version of the peak oil hypothesis, the maximum amount that could be extracted at non-prohibitive costs in a period of, say, a year, was about to peak. Stranded assets change the peak oil hypothesis in two ways. First, it generalizes it from oil to all fossil fuel assets. Second, the hypothesis refers to peak *demand*.

…and demonstrate a clash between environmental concerns and the desire to have cheap and reliable sources of energy

The third reason 'stranded assets' are a hot topic is that it refers to the outcome of the collision of two important human desiderata. It is the clash between environmental concerns, especially the desire to limit global warming, and the desire to have cheap and reliable sources of energy.

The risk of much of the world's fossil fuel reserves becoming stranded assets as a result of a political response to global warming is of course not the only risk associated with climate change. Carney lists physical risks (natural disasters etc.), liability risks and transition risks (the risks associated with a transition to a low-carbon intensity world, which includes the risk of fossil fuel assets becoming stranded).

Note also that global warming is not the only environmental externality created by fossil fuel extraction. Coal mining (especially open pit mining) can destroy areas of outstanding natural beauty. Mine tailings pollute water and the soil, as does the extraction of shale gas and tight oil.

[49] Mark Carney (2015), "Breaking the tragedy of the horizon - climate change and financial stability" - speech given at Lloyd's of London, 29 September, http://www.bankofengland.co.uk/publications/Documents/speeches/2015/speech844.pdf

What Drives the Likelihood, Magnitude and Timing of Fossil Fuel Reserves Becoming Stranded Assets?

The decision leading an asset to be stranded will depend on the cost of such action and the perceived costs of inaction

A lot of attention is being paid on the political and regulatory decisions that could potentially strand a significant share of the currently recognized natural resource (coal, oil and gas) assets. However, the actual decisions that would lead these assets to be stranded will depend on the costs of such action and the perceived costs of inaction.

The Scientific and Political Case for Human-made Climate Change and Its Consequences

Political leaders are noting that the scientific case that there are some human-made contributions to the rise in global temperatures is nearly equivocal

As Governor Carney noted in his recent speech, the scientific case that there are some human-made contributions to the increase in global temperatures is by now nearly equivocal.[50] The scientific case for human-made climate change essentially rests on four factors: (1) we have recently observed extreme events that are without precedent over perhaps millennia; (2) many of these events can be related to a warmer atmosphere; (3) the increase in global warming since the mid-20th century is highly likely to have been caused by anthropogenic greenhouse gas emissions and other anthropogenic drivers; and (4) the increase in the greenhouse gas emissions and other anthropogenic drivers is a direct consequence of human activity.

Politicians are making serious efforts to get global agreements limit greenhouse gas emissions

As for the politics, we have been surprised over the past 5 years or so by the degree to which the educated public – and especially the business community in the US and Europe – has accepted (1) that global warming is happening; (2) that there is a significant man-made contribution to the rising concentration of greenhouse gases; and (3) that policy measures (carbon emissions or carbon content taxes; tradable greenhouse gas emission quotas/permits etc.) will have to be taken to prevent a planet-wide disaster from occurring during our children's lifetime. Politicians from Obama to Xi are making serious efforts to get global agreements limiting greenhouse gas emissions. Except in Tea Party Land, this is now part of the 'acquis intellectuel'.

China joining the camp that wants to limit CO_2 emissions is an important development

That China now has joined the camp that wants to limit CO_2 emissions – especially those generated by burning coal – is a very important development. It is largely born out of local/national environmental concerns and is therefore not subject to the free rider problem. Much of urban China has become an environmental disaster area, with coal-fired power plants making a significant contribution to the health-impairing and expected life-span reducing air pollution that plagues cities from Beijing to Chongqing. Reducing the emission of these pollutants is now a policy priority in China – and that is only because of the local effects of mainly particulate pollution rather than the global effect of greenhouse gas emissions. The impetus for tackling environmental issues (even though not necessarily climate change) has risen dramatically on politicians' agenda.

[50] See IPCC - Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014)

Why 2°C?

Limiting global temperature to just a rise of 2°C from the pre-industrial average is suggested would avoid some of the worst implications of human-made climate change

The 2 degrees Celsius limit on the increase in average global temperature from pre-industrial average levels originated in an academic paper by William Nordhaus in 1977 and was formally recognized in the Cancun Agreement in 2010. The hypothesis is that, should the increase in global temperatures be limited to 2 degrees Celsius, then some of the worst implications of human-made climate change could be avoided. However, there is no exact science behind the 2°C cut-off. Geology on a global scale is not an experimental science — we only have history for empirical support. The degree to which we face non-linearity in the damage done by higher temperatures at the 2 degrees benchmark is highly uncertain, which would — other things equal — suggest to us that we should expect some slippage relative to this goal. But in our view the 2 degree Celsius goal is best understood as a useful focal point for communication and for negotiations – and in a public debate that is likely to be very fraught and in negotiations between more than a hundred countries, such focal points can be both important and powerful.

The Carbon Budget

No change in the trend trajectory for emissions would bring us to exhaust the carbon budge in less than twenty years

The IPCC suggests that to have an even greater than 50% chance of limiting temperature increases to 2°C, global cumulative CO_2 emissions would need to be limited to approximately 3,010GT, which is the so-called ‘carbon budget.’ Recent estimates suggest that emissions to date have accounted for around 60% or more of this budget, with a roughly 500 GT increase in the last ten years alone. This implies that the ‘no change in trend’ trajectory for emissions would bring us to exhaust the carbon budget in less than twenty years. Of course, the mapping from carbon emissions to the exact effect on the global temperature is also subject to significant estimation uncertainty, but if there is a risk of a serious non-linearity at temperature increases of more than 2 degrees Celsius, the precautionary principle would suggest error on the size of lowering the size of the carbon budget.

The Cost of Action

The political and regulatory decisions that end up stranding assets that were previously of material value do not take place in a technological and market vacuum. Clearly, the conclusions about the risk of a significant share of fossil fuel reserves ending up as stranded assets as a result of the political response to climate change depends on a host of assumptions about future political and technological developments that we can hardly be confident about.

These include assumptions about:

- **Future developments in carbon capture and storage technologies** that may make it commercially viable to extract a larger share of the proven reserves of coal, oil and gas resources than would otherwise be compatible with the carbon budget constraint

- **Developments in the technical efficiency and cost of alternative**, and especially renewable sources of energy

- **Development in the technology to store power and to deal with interruptions in power production**, which have been a major obstacle to the wider adoption of wind, wave, tidal (and sometimes even solar) energy. Until recently, there appears to have been little progress in battery technology since the late nineteenth century, but innovations like MIT’s ‘yolk and shell’ batteries (with a titanium dioxide shell and an aluminum yolk) may imply larger storage capacities, a much extended life and faster charging

Conversely, should these technological developments turn out to disappoint – and the resulting costs of restricting carbon emissions correspondingly increase – the likelihood rises that politicians and regulators will shy away from taking drastic measures to limit carbon emissions.

The Free-Rider Problem

The enforcement of the carbon budget constraint is still at risk of falling victim to the free rider problem

Even if technological developments work towards reducing the cost of a fossil fuel-free diet, the enforcement of the carbon budget constraint will still be at risk of falling victim to the free rider problem. Global warming's negative externalities are global. The benefits from burning fossil fuel are local. Every nation would prefer all other nations each to cut back CO_2 emissions a bit more to allow it to emit a lot more. The "free rider/after you" problem is serious and it has clearly been important in preventing earlier agreements to limit carbon emissions.

But it is probably not unsurmountable. For all practical purposes, it will be sufficient to have the US, China and the EU on board. Most other countries are likely to follow. And as noted above, the impetus to take action is currently often local (as in China) which increases the likelihood of action.

References

Caspar, Vitor (2015), "How Large Are Global Energy Subsidies", Presentation at The Brookings Institution, 18 May.
http://www.imf.org/external/np/fad/subsidies/pdf/presentation.pdf

Coady, David, Ian Parry, Louis Sears and Baoping Shang (2015) "How Large Are Global Energy Subsidies?" International Monetary Fund IMF Working Paper, WP/15/105, Fiscal Affairs Department 1 May 2015

Energy 2030: Commodities Analysis

Stranded Assets in Practice

Conventional Wisdom May Be Wrong: Critical Role of Policies and Unintended Consequences

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Two examples highlight the nuances of the "stranded asset" concept, as well as the critical role of policies and their unintended consequences in determining what could be stranded: (1) oil sands producers' surprising apparent embrace of the recent proposal by the Alberta government to impose an emission cap on Alberta oil sands production which indicates carbon intensive industries may be more resilient to regulation than previously anticipated; and (2) the continued reliance on coal, despite the supposed arrival of the Golden Age of Natural Gas.

Canadian Oil Sands

Emission reductions program will leave little room for growth in the oil sands industry in the coming years

The just announced move by the Canadian province of Alberta to adopt a strict emission reduction program provides an illustrative example of the nuances of the stranded asset issue and its interplay with public policy. The province of Alberta, where ~70% of Canada's crude production is sourced and home to the carbon-intensive oil sands industry, recently unveiled an aggressive climate change and emission mitigation project, imposing a suite of strict regulations on carbon emissions, including a per unit emissions tax, an explicit cap of 100 megatonnes of greenhouse gas emissions per year on the oil sands industry and a plan to phase out all coal-fired generation by 2030, to be replaced with renewables and natural gas. The 100 megatonne cap gives the oil sands industry — already producing ~70 megatonnes annually — little room to grow in coming years absent technological innovations to reduce the carbon intensity of bitumen extraction or the adoption of expensive carbon capture technologies. At the same time, the higher tax on carbon will raise breakeven prices for oil sands producers, which are already near the top of the global cost curve.

Surprisingly, major oil sands producers and the industry have embraced the stringent environmental regulations

Conventional wisdom would suggest that these new policies present a serious threat to Canadian oil sands, an industry already challenged by the lower-for-longer oil price environment and takeaway infrastructure hurdles, most recently highlighted by President Obama's rejection of the Keystone XL pipeline proposal. With these new emission targets in place, the Canadian oil sands look like a prime example of assets that could become "stranded" over the coming years. Yet, the reaction from the oil sands industry to the new rules has been surprisingly positive as oil sands producers have apparently embraced the stringent environmental regulations. The plan has been endorsed by the Canadian Association of Petroleum Producers (CAPP) as well as major oil sands producers, including Canadian Natural Resources, Suncor, Cenovus and Shell, indicating that leaders of the industry are optimistic that with the help of technology they can meet the new standards at an acceptable cost.

The reaction could show that producers are determined to keep their supposed "stranded' assets as profitable assets through adaption to new regulations

This unconventional reaction may show that producers are determined to turn supposed "stranded" assets into profitable assets by finding strategies to adapt to new environmental regulations. Over the last year, industries like shale in the US have proven to be surprisingly resilient in the face of collapsing oil prices, experiencing 20-30% cost deflation and rapid efficiency gains. Carbon intensive industries, like the Canadian oil sands, may likewise prove to be more adaptive to increasingly strict environmental regulations than has been previously expected. Technological innovation could help to bring down the cost of reducing carbon emissions for these producers. Experiments are ongoing to see if radio waves, for example, could replace steam, which uses a lot of water and natural gas as a fuel source, to get oil out of oil sands. Certainly, the positive reception of the regulations suggests that producers are relatively optimistic that reasonable margins can be attained.

By embracing the change, producers may change the public's bad perception of oil sands

In fact, for an industry that has become the poster child in recent years for bad practices and environmental and social negligence, the environmental rules may actually turn beneficial for oil sands producers. The industry faces two principal problems: (1) a perception problem from bad publicity and (2) opposition to infrastructure builds – both of which are largely due to environmental issues. But by embracing and adapting to new environmental rules, producers make strides towards solving their perception problem, which may in turn help solve the infrastructure problem as environmental opposition to the industry could ease. For example, if lower emissions standards were met, it could either raise the possibility that the US would allow some future version of the Keystone XL pipeline to go ahead, or make other oil sands-related infrastructure projects more acceptable to the public, governments and other civil society groups. The new rules also reduce uncertainty and the potential for liability with regards to future environmental policy.

It remains to be seen, however, how resilient the Canadian oil sands industry will be in this new regulatory environment. Nevertheless, this case highlights the highly complex and potentially surprising nature of the stranded asset issue. Even in cases where government policy is targeted at specific assets like the oil sands, unexpected results can manifest.

Gas May Not Dethrone King Coal in Many Markets

Policies that aren't targeted enough can also hurt as they don't drive the anticipated result

Less targeted policies can have even greater unanticipated and certainly unintended consequences, as can be seen in the nuances of the battle between coal and gas amidst increasing environmental scrutiny of coal. Conventional wisdom dictates that emission reduction targets should favor natural gas burn over coal burn, yet in many cases emission reduction policies could fail to limit coal-fired generation. Coal-fired generation remains highly competitive on a total cost basis in many parts of the world, and particularly in important growth areas including developing Asia. By the same token, even where the cost of a new gas plant is cheaper than a new coal plant, on an operational cost basis, coal is still the cheapest cost alternative globally ex-US. These dynamics mean that even small adjustments to carbon emission policies can have outsized impacts on the generation mix. Indeed, without targeted policies limiting coal generation, too lenient emission targets could leave coal dominant over gas despite a carbon program.

In Europe, this exact story has largely played out already. The power market there sees more robust generation from coal than gas despite the cost of emissions, although gas is supposed to be the cleaner fossil fuel. Emission permit prices have not been high enough to tilt the generation balance from coal to gas as gas prices have remained relatively high in Europe while coal prices have stayed low. Meanwhile, Europe has seen robust support for renewable energy, leading to a surge in wind and solar installation. This additional zero marginal cost production has driven down the price of electricity, only further encouraging the use of coal as the cheapest cost generation fuel.

Coal consumption is still expected to rise in 6 of the 10 largest coal consuming countries or regions because of policy-design or comparative generation economics that may still favor coal. These surprising dynamics of coal versus gas under regulatory constraints on carbon emissions are another illustrative example of the complexity of the stranded asset issue. In practice, a nuanced approach to this issue must be taken to fully assess potential risk and reward going forward.

Appendix A

Pricing Carbon Under Uncertainty: A Practical Approach for Finance

In the face of many uncertainties, the most straightforward way to price the risk in investment decisions will be to assume a carbon price. However, what that price should be at any given moment is anything but straightforward. Other carbon markets offer some signposts, priced anywhere between $0 and $50/ton. In the EU ETS, the world's largest carbon market to date, emissions pricing has ranged between zero and almost €30/ton. California has seen allowances price between $11/ton and $23/ton. Prices in the US Northeast RGGI have been below $5/ton. The US government has calculated its "social cost of carbon" around $40, but depending on assumptions could actually be higher.[51]

For those regions with some form of power markets, the price of CO_2 regionally should be set by the marginal cost of abatement there. The marginal abatement cost curve could make up of both the actual carbon reduction cost and coal-to-gas switching in the power sector, as switching away from coal to gas is also a carbon reduction strategy. There are many moving pieces that affect the marginal cost of abatement, including local politics and macro conditions. (Note, this applies more to power plants that operate in competitive markets or markets with multiple players, rather than one that has an effective monopoly over all aspects of power generation.)

Figure 67. Carbon prices vary widely

Source: Bloomberg, Citi Research

In the US, for example, the theoretical carbon price could be ~$14/ton if coal-to-gas switching is the marginal abatement strategy. Here's how it works: At $35/ton for Illinois Basin coal and $10/ton for transport so that the delivered cost of coal is ~$45/ton, 23.6-MMBtu/ton in head content and 10 MMBtu/MWh in heat rate for operating a generic coal plant, the marginal generation cost could be ~$19/MWh. At

[51] http://www.epa.gov/climatechange/EPAactivities/economics/scc.html

$3.5/MMBtu Henry Hub gas, the marginal generation cost of a combined cycle gas power plant should be around ~$26/MWh, assuming that a gas plant emits ~50% less carbon than a coal plant. The carbon price that makes generation costs of both sources equal would be ~$14/ton (because the generation costs become $33/MWh for both the coal and gas power plants). Note that there are other commodity price dynamics involved, but this could be the first step of a broader analysis. The more predictable and stable the price signal is, the better incentive it will be.

Crucially, in an environment of uncertainty around whether and how carbon might be priced, environmental policy risk shapes market outcomes. Climate[52] policies and potential future policies may create more of a liability for fossil fuel asset than an incentive to build renewable energy assets. Numerous development and financial institutions have already backed away from financing coal for exactly this reason – there are clearly large future liabilities around climate change and climate policy that are extremely hard to price. The World Bank has already cut back its financing of coal projects globally[53], while other financial institutions have also reduced financing of coal development[54]. And if you can't quantify the risk, it's much harder to be comfortable taking it. For this reason, the rise of climate policy creates large liability which will disincentivize investment in the most emissions intensive assets (coal power), even if the liability is hard to quantify.

Although the prospect of pricing in the negative externalities of carbon may have positive incentive for renewable energy investment, markets still cannot yet easily price environmental incentives or lend against them in many cases. A renewable energy developer might have a hard time borrowing against the unknown future value of credits; hence lenders may not allow renewable energy developers to price the benefit of such credits in their return models. That said, a portfolio investor like a utility may seek to increase the share of renewables in its generation mix as a way to avoid total future carbon liabilities on its portfolio. That could create a greater bid from utilities on the margin for renewable assets. In order to create an incentive for renewable energy investment, policy makers would need to create clear, stable incentives such as carbon pricing or consistent tax or incentive policies.

Investing in Renewable Energy at the Project Level Is Different in Three Key Ways:

The generation profile of renewable energy (mainly solar, wind, storage etc.) is different from fossil fuel, nuclear or even hydroelectric generation. Investors have to appreciate, to various levels of sophistication depending on how involved they are at the project level, multiple components for renewable energy investment that are different from fossil or nuclear power assets. These components are risk items that need to be incorporated into the return calculation of projects. Hence, different generation profiles of wind and solar, particularly the implied costs of intermittency, compared with the smoother generation profile of fossil fuel, nuclear or even hydro power plants, may require an augmented risk-adjusted return on capital (RAROC) measure.

[52] This refers to instances of potential future CO2 pricing, such as the clean power plant.
[53] Except in "rare circumstances," the World Bank has ceased funding new coal power plants.
[54] Citi announced its intentions to cut back on financing for coal mining projects, citing climate change as the principal motivation. The bank has also noted that its credit exposure to coal has significantly reduced since 2011, and will continue to decline.

Renewable energy projects face additional risks that fossil fuel power plants don't, such as shaping and variable generation risk, the cost of ancillary services, and data integrity.

- Even if there is no intermittency, **shaping risks** relate to the mismatches between electricity demand and generation during the day and seasonally. Often renewable energy generation is strongest overnight for wind and strongest in the middle of the day for solar. But the morning ramp-up in electricity demand after wind has died down but before the sun rises, and, more importantly, the heavy demand during the evening when usually both wind and solar generation is low, present demand gaps that require generation to fill. The strength of wind and solar generation also varies seasonally. Hence, pricing in the non-renewable energy generation or storage needed to fill the demand gaps add to the overall cost.

- **Variable generation risks** relate to the intermittency of renewable energy generation, which require fast-ramp backup generation facilities, storage assets or demand-side management that could ramp up or down when there is a drop or surge in generation. Calculating the probability of these happening, at what magnitude and having backup electricity supply (or demand response) ready are additional risk items that go into the overall risk-adjusted return.

- **Ancillary services** provide the voltage support, balancing and other services that maintain the integrity of the power grid. These have to be priced-in.

- **Data integrity** is another issue for both historical calculations and forecasts. It would be difficult to price in the above risks and costs without an accurate picture of what the generation profile and intermittency look like in the past. Without good data, it would also be difficult to forecast how much generation one should expect from wind and solar assets, even down to the minutes – one might generally schedule too much or at times too little backup if the forecasting of renewable energy generation is not accurate.

The small-scale nature of some green energy projects often preludes larger investors from investing at the project level, unless the projects are pooled together (e.g. many rooftop solar units from multiple homes as one single generation resource). Unlike traditional energy projects that involve large power plants and major capital allocation, the value of small-scale renewable energy or distributed energy resource, despite the growth trajectory expected, is necessarily smaller. Attracting more capital to develop this space requires intermediaries that pool assets together or that distributed generation resources are part of a larger "microgrid" or something to that effect. Even if pooled, some of the contracts signed between solar provider and homeowners, for instance, have terms that make pooling together assets through traditional securitization procedures difficult. Is the solar panel part of the house or not part of the house? What is the default risk? Is it even senior to debt?

Large upfront capital cost, perhaps even around 80% of the total cost, makes financing consideration dominate the overall investment on renewable energy. Financing cost could be nearly 50% of the total project cost in some cases. Therefore, for renewable energy to take off, aside from falling technology and installation cost, it is critical that financing cost has to fall.

Author Biographies

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Renewable Energy Cost Trends and Drivers

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Innovations in Alternative Energy Finance

Marshal Salant is the Global Head of Citi's Alternative Energy Finance (AEF) Group in the Capital Markets Origination Division. AEF focuses on providing full service financing solutions to Citi's Alternative Energy clients for alternative energy projects and pools of projects. Solutions include Construction Financing, Project Debt Financing in the Bank and Bond Markets (144A and 4(2) Private Placements), Tax Equity, Leasing, Project Equity, Warehouse/Accumulation Facilities, ABS Securitizations, and YieldCos, as well as commodities, interest rate, and FX hedging. AEF also provides advisory services, and helps clients access various Loan Guarantee Programs and other forms of government support. AEF is active in Wind, Solar, and Geothermal Power projects, as well as Fuel Cells, Biomass, Synfuels, Waste-to-energy, and other new renewable energy technologies, and Energy Efficiency.

Marshal joined Citi from Morgan Stanley, where he was a member of the Capital Markets Management Committee and Head of the Global Structured Products Group. Mr. Salant has broad experience as a financial engineer in Structured Finance and New Product Development of innovative and complex financial instruments. During his years at Morgan Stanley, Mr. Salant led the development of the Structured Notes business, the Collateralized Bond Obligations business, the Structured Credit business, the Structured Tax business, the Structured Insurance Products business and the FIG Client Solutions business. While at Morgan Stanley, Marshal had significant experience in Synfuel and Alternative Energy Tax Equity financings in the Wind, Solar, and Geothermal sectors. Mr. Salant oversaw the investment of more than $2 billion in Tax Equity and developed new financing structures, as agent and as principal, for numerous clients in the Alternative Energy industry.

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Barbara supports various high level leaders in finance, energy policy, and climate change in an advisory role. Over the past several years, she has built and directed the San Giorgio Group, which brings together key financial institutions actively engaged in green, low-emissions finance in collaboration with the World Bank Group, CLP (China Light & Power), and the OECD (Organisation for Economic Co-operation and Development). Buchner regularly speaks at high-profile events as an expert in climate policy and climate finance, and has presented at Climate Week, at the Climate Finance Ministerial, as part of the GCF Private Sector Facility, at COP side-events, and at the BNEF Summit among many others. Barbara was promoted from Director to Senior Director in 2013. Previously she served as a Senior Energy and Environment Analyst at the International Energy Agency (IEA) and as a Senior Researcher at the Fondazione Eni Enrico Mattei (FEEM) where she was involved in a number of activities related to FEEM's Climate Change Policy and Modelling Unit in the field of environmental economics. She holds a PhD in Economics from the University of Graz and was a Visiting Scholar at the Massachusetts Institute of Technology (MIT).

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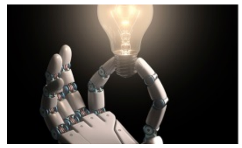

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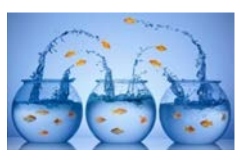

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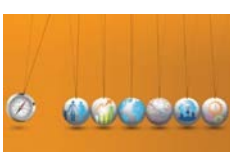

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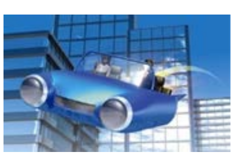

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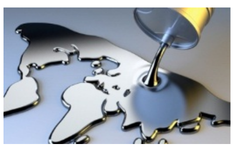

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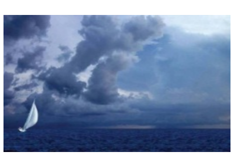

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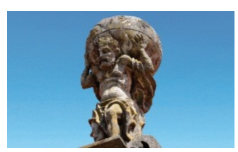

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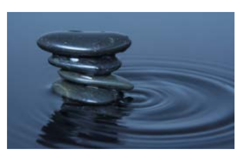

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Key Insights Regarding the Future of Green Energy

INNOVATION

Costs in the power sector can vary significantly across countries. However, one thing that is consistent across regions is that financing costs are significant in the overall spend for renewables projects. / Innovative financing that decreases the cost of financing for renewables is an important driver of relative economics between renewables and fossil fuels going forward.

COMMODITIES

Conventional wisdom believes renewables could be a major winner with gas entering its golden age (perhaps as a bridge fuel to even more renewables) and coal the biggest loser. / Coal could be much more resilient than forecast as prospects for a significant increase in coal pricing that might hinder competitiveness of renewables or gas appear limited and hinge crucially on India and China.

POLICY

New environmental standards globally have increased the cost of fossil fuel extraction while the prices buyers are willing to pay for fossil fuels have reduced to the point that future extraction of previously profitable resources is no longer profitable, making them 'stranded assets'. / Despite policy, the enforcement of carbon budget constraints will still be at risk of falling victim to the free rider problem.