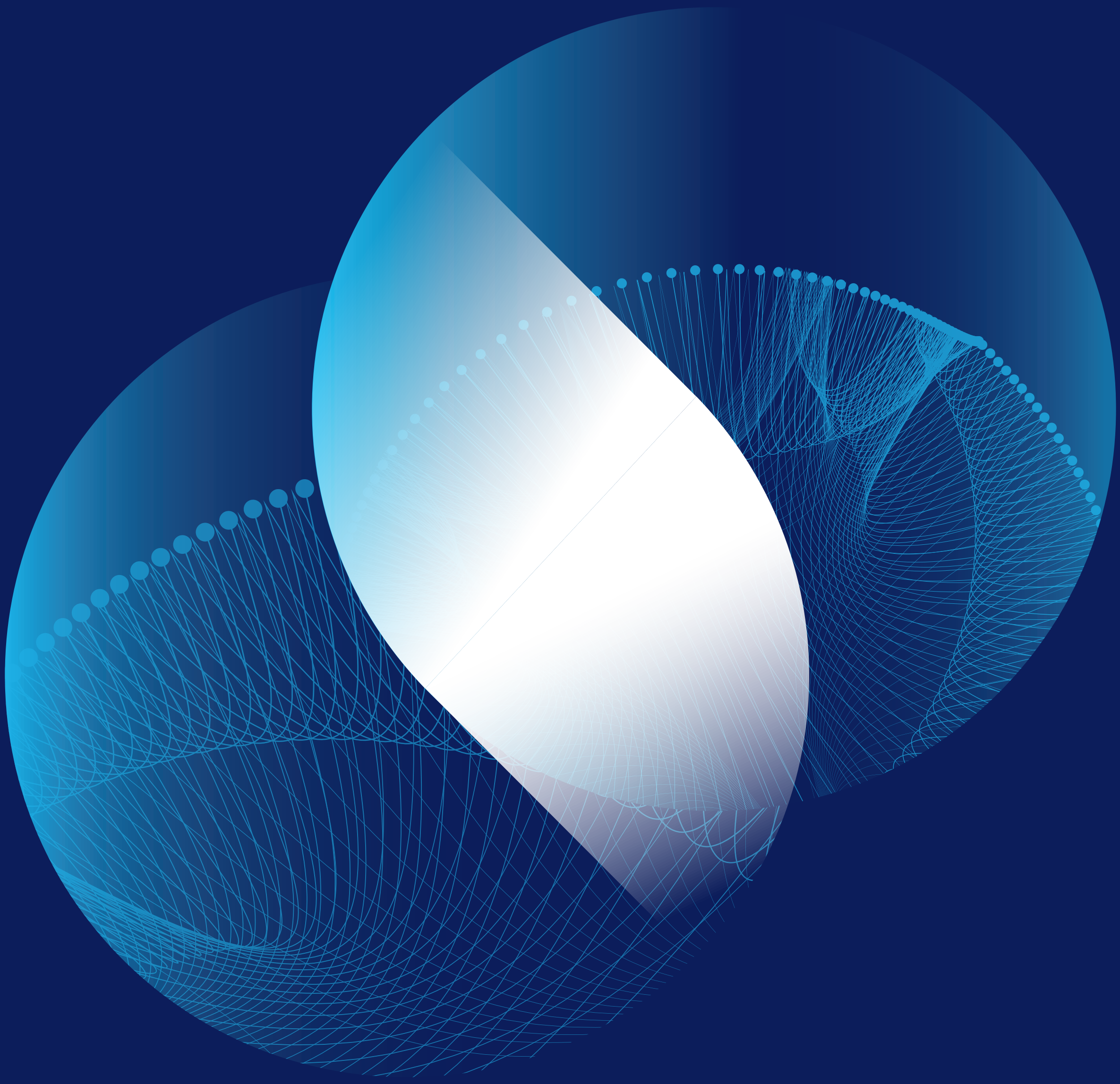
Imperial College Business School | Centre for Climate Finance & Investment

Firm Power Parity:

A Framework for Understanding the Disruptive Threat of Solar + Storage



Summary

Electricity from solar photovoltaics and wind turbines has become cost-competitive with traditional power generation in markets all around the world. Hundreds of billions of dollars in private sector investment are flowing into renewables as a result. There is no doubt that technological innovation is moving the world towards a cleaner energy system.

Yet it remains unclear where, and exactly when, it becomes profitable for consumers to switch away from grid-supplied electricity to clean, on-site power generation. At the heart of this financial consideration is the notion of cost parity. In the case of renewable energy, "grid parity" describes the point of economic indifference between the cost of on-site renewable energy (e.g., rooftop solar) and the cost of conventional supply. At current solar photovoltaic (PV) prices, grid parity (without storage) is now a reality for most residential consumers, regardless of the country in which they live. Given the historically high cost of solar energy, that's an extraordinary achievement.

But as the renewables industry evolves, so too must the language about cost-competitiveness. The notion of grid parity misses the big question going forward: Where and when will it be profitable for consumers to outright disconnect from the grid?

Given the conceptual limitations of grid parity, we have developed a new framework. We call it firm power parity. Building on the notion of cost equivalence, firm power parity is the moment in time at which on-site renewables deliver the same service at the same cost as conventional electricity supplies. Firm power is available when the wind doesn't blow, or the sun isn't shining.

This document provides highlights from the academic working paper[1] that develops our framework and forecasts profitable switching in six major cities around the world. Our number-crunching indicates that despite tremendous advances in technology costs, re-creating high-availability, grid-connected power will not be easy. Cheaper solar + storage will disrupt the electricity supply industry, but it is unlikely that residential consumers will be leading agents of these changes.

The Nine Points of Parity Matrix

Volume of Service

Level of service provided	Residential	Industrial	Wholesale
PV	Energy-Res parity	Energy-Ind parity	Energy-Utility parity
+Day Storage	Day-Res parity	Day-Ind parity	Day-Utility parity
Full defecrion	Full-Res parity	Full-Ind parity	Full-Utility parity

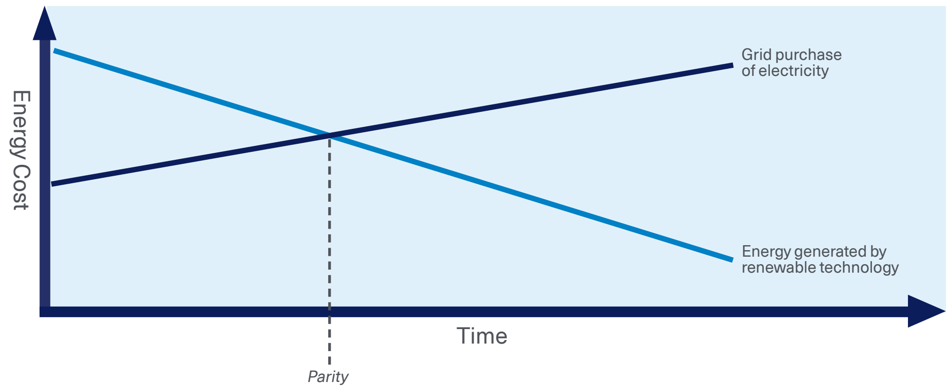
See working paper at: http://ssrn.com/abstract=3031992

Grid Parity

Grid parity has been an intuitive way of understanding the first stage of evolution in more distributed power markets. The simplicity of grid parity has also become its greatest limitation. It does not capture the increasingly complex changes in the relationship between electricity producers and consumers.

When analyzing grid parity, the costs are usually expressed in terms of their levelized cost of energy (LCOE), for example in dollars per MWh ($/MWh). Grid parity had been thought of as a 'tipping-point' at which government support for the clean energy technologies would no longer be required. There are several flaws in such thinking.

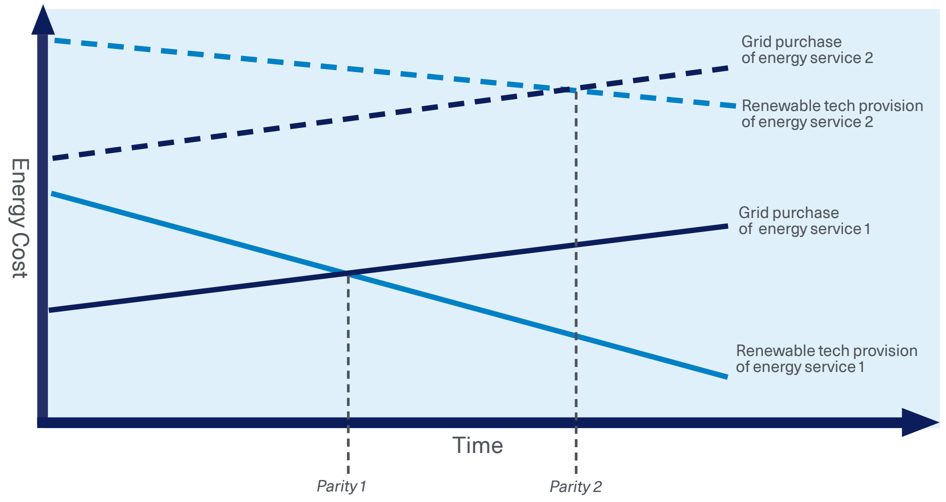
Conventional Grid Parity of Electricity



First, electricity generated from renewable energy is, by its very nature, intermittent. Electricity customers who have already made the switch to on-site generation typically use the distribution network for balancing and storage. Consumers pay for balancing and storage services, to varying degrees, to their utility as part of their monthly bill. Grid parity for residential customers is, in most cases, dependent upon governments ensuring reasonable terms for maintaining grid interconnection.

It is also important to recognize that different consumers face different prices for their electricity, with residential consumers typically paying the most. Much of the analysis of grid parity has focused only on homeowners, thereby ignoring cost-competitiveness for commercial and industrial consumers. Furthermore, the price that consumers pay for their electricity is not necessarily static; consumers increasingly face 'Time of Use' (TOU) tariffs in which they pay more for electricity at peak times of demand.

Parity is achieved at different times for different services and consumers



A New Concept

Recognizing the practical difficulties of grid parity, we developed a new concept. Firm power parity is the point in time when renewable energy technologies provide a similar service at a lower cost than grid supplied electricity.

Our framework is constructed using a 3x3 matrix, which allows for differentiation by three distinct consumer types (residential, commercial, and wholesale) and the three levels of energy services (i.e., PV energy-only, PV energy levelized over a day, and PV energy levelized over a year). The framework provides a more comprehensive outlook on market development than grid parity alone and allows for easy comparison between different regional markets.

Differentiating Parity by technology compliment

Rooftop PV	Rooftop PV + Day Storage	Rooftop PV + Annual Storage
Increasing range of services provided		
Energy Cost Avoidance		Full Grid Defection

Differentiating Parity for different volumes of service demanded

Residential Consumers	Commerical/ Industrial Consumers	Wholesale Participants
Increasing volume of service demanded		
High Electricity Cost		Low Electricity Cost

We have initially focused our techno-economic modeling on four points within the firm power parity matrix. As access to finance is a key driver for technology uptake, we developed cost of capital scenarios that reflect a range of potential macroeconomic conditions over the next 20 years.

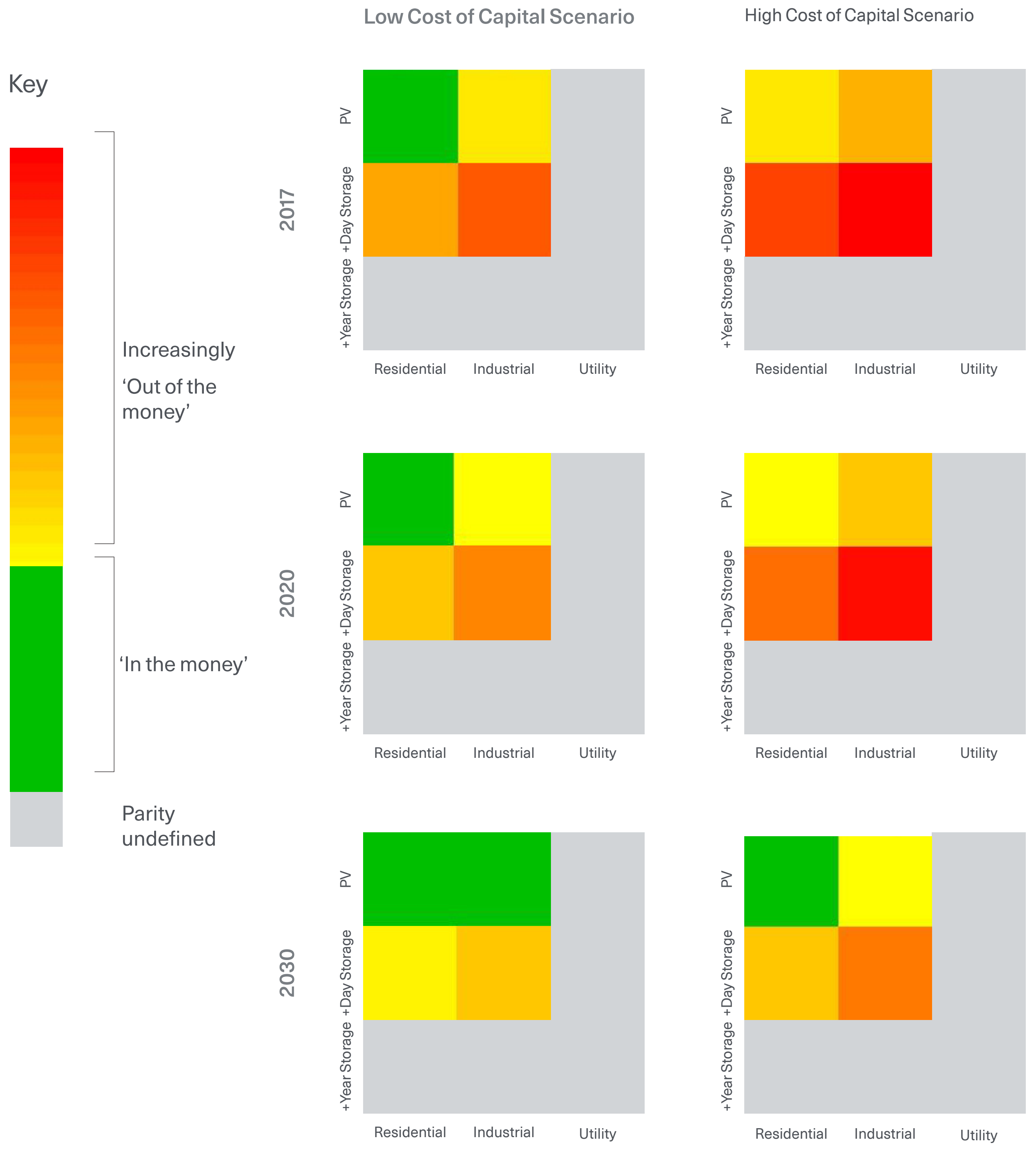
We employed a traffic light system to indicate when parities have been achieved (green), are close to being reached (yellow) and far from being achieved (red). The system provides an easy-to-understand indicator of the profit opportunity for consumers in a given market, at a given time.

Our modeling on solar PV and lithium-ion battery costs was conducted using data from a global literature review and estimates by researchers at Imperial College London. The analysis employs Monte-Carlo Analysis with a large number of simulations (n=1000) to generate central case projections. Full details of our methodological approach can be found in the academic working paper.

Our analysis does not yet account for the value obtained from a variable or time of use (TOU) tariffs, which would likely act to accelerate the date of firm power parity. Furthermore, it does not incorporate the social costs greenhouse gas emissions from grid-supplied electricity. To keep things simple, we fixed the price of electricity in each market, keeping it constant in 2017 real money terms throughout the forecast period.

Below are visual highlights from one of our six case studies. Despite the relatively small amount of annual sunlight, London is currently at a state of residential energy-only parity for consumers with a low cost of capital. Assuming no changes to real electricity prices and no compensation for services provided to the network, it will take at least another decade for households to install solar PV power generation with day-storage profitably.

Case Study: London over the period 2017-2030



Full results for London, New York, Munich, Bangalore, Johannesburg, and Santiago can be found in the academic working paper.

See working paper at: http://ssrn.com/abstract=3031992

Insights

The advent of cheaper battery storage presents a game-changer for one of the world's largest industries. With storage, consumers can manage a higher proportion of their electricity demand, thereby reducing what they buy from their traditional electricity supplier – or even quit the utility altogether. Mass adoption of a profitable switching opportunity by consumers, and the inevitable response by utilities to raise prices on their remaining customers, has been dubbed "the utility death spiral." So, does the pairing of cheap solar and storage threaten to kill the electric utility business model?

Our results suggest that while it will become increasingly profitable for consumers to generate and store their own electricity, profitably disconnecting from the grid is more than a decade away in most markets. For consumers who already enjoy reliable transmission and distribution infrastructure, the cost of replicating grid reliability (even on a single-day basis) will remain significant.

There are, however, at least a billion people in the world without access to electricity. By some estimates, another billion are served by unreliable networks prone to frequent blackouts. The development of a "mini-grid" business model countries in countries such as India and Kenya demonstrates that the economics of building new private infrastructure in underserved areas are increasingly favorable. The disruptive potential of solar + storage may be most compelling in markets where the utility business model has already failed.

In summary:

We developed a new version of cost parity in electricity markets that is better suited to the competitive landscape of new and conventional energy technologies today.

This concept differentiates the type of parity by the volume of service demanded and the level of service provided.

To road-test the concept, we forecast the timing of four points of parity in six cities over the next 25 years.

Our London case study shows that cost of capital will be an important variable in deciding whether home battery storage is competitive in the future.

Mass adoption of residential battery storage will require access to cheap financing, as already exists for other types of consumer durables.

About the Centre

The Centre for Climate Finance & Investment undertakes cutting-edge research on how capital markets are responding to global climate change. Building on Imperial College London's international reputation for multi-disciplinary analysis, the Centre is helping investors and policymakers overcome the lack of clarity about risk and return in clean energy, low-carbon technologies, and green infrastructure. Our mission is to help shape a global energy transformation through the fusion of business, technology and an entrepreneurial mindset.

Find out more at: imperial.ac.uk/business-school/climate-investing

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