Institution: University of Sussex		
Unit of Assessment: 17 – Business and Management Studies		
Title of case study: Innovative price modelling to mitigate the financial risks of energy companies and investors in adapting to new, renewable energy systems		
Period when the underpinning research was undertaken: 2013 – present		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Michael Coulon	**Role(s) (e.g. job title):** Senior Lecturer in Finance	**Period(s) employed by submitting HEI:** 2013 – 2021
Period when the claimed impact occurred: Aug 2013 – present		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Dr Coulon's research has for many years been at the forefront of innovative model development for the changing behaviour of modern energy markets and systems, particularly in light of traditional models failing to adapt to new regimes, structures and renewable sources. Coulon has worked with one of Europe's largest energy companies and with three American firms to apply his models to their businesses. Coulon's insights have enabled these companies to better understand and mitigate financial risk, make business decisions, value complex products or investments, and hedge changing risks. Ultimately, this allows them to maintain profits and avoid unforeseen losses while adapting to the energy landscape of the future.

2. Underpinning research

Energy firms are currently managing a major transition to new, renewable energy sources and structures. During this time of rapid change, classical econometric models often fail. Instead, the sector needs flexible modelling frameworks that can be tailored to particular markets and applications. To meet these challenges, Coulon has developed practical and easily implementable structural models for energy markets, particularly electricity and natural gas, but also environmental markets for carbon emissions or green certificates. These models accurately and efficiently simulate outcomes over long-term horizons and provide the basis for decision-making strategies for broad portfolios of assets.

Coulon's unique hybrid approach to modelling provides a major advantage over classical approaches. Pure econometric statistical price models that look only at price, without considering supply and demand drivers, miss the complexity of the market. At the other extreme are complex optimization models, which consider supply and demand details such as individual generator constraints. The hybrid structural models developed by Coulon [**R1**] retain the advantages of simpler structural models while providing a greater level of detail, capturing regional fuel mixes, demand patterns and price variations in order to better manage and hedge against geographical distributions in supply and demand. **R2** describes some new material on tractable structural models that allow for explicit derivative pricing formulas – a key advantage in practice.

Both **R1** and **R2** focused on the US energy markets. Coulon has also adapted his structural power price models to the European market, where there are more challenges such as the large influx of intermittent renewables and related environmental targets. These challenges demand flexible new models and lend themselves more to structural models than econometric ones, since price histories are short and unreliable amid dramatically changing market conditions. The work in **R3** enhanced Coulon's earlier modelling techniques and adapted them to several important obstacles in the German market, including the rapidly-growing solar and wind power production that characterises the ongoing energy transition. **R4** explains Coulon's mathematical

modelling of tradeable certificate prices for green power – an important new product that had been entirely unexplored by other quantitative researchers.

Coulon's ongoing research aims to extend natural gas and power price models to newer and more complex challenges facing European power markets during a time of cross-border integration, technological change, and major supply-side shifts due to renewables. Rigorously quantifying and managing these new interdependencies is critical to the business models of many energy firms.

3. References to the research

R1 Moazeni, S., **Coulon, M**., Arciniegas Rueda, I., Song, B. and Powell, W. B. (2016) A non-parametric structural hybrid modelling approach for electricity prices. *Quantitative Finance*, 16(2). pp. 213-230. http://dx.doi.org/10.1080/14697688.2015.1114363

R2 Carmona, R. and **Coulon, M**. (2014) 'A survey of commodity markets and structural models for electricity prices', in Benth, F., Kholodnyi, V. and Laurence, P. (eds.) *Quantitative energy finance: modelling, pricing, and hedging in energy and commodity markets*. New York: Springer-Verlag, pp. 41-83. https://doi.org/10.1007/978-1-4614-7248-3_2

R3 Coulon, M., Jacobsson, C. and Ströjby, J. (2014) 'Hourly resolution forward curves for power: statistical modelling meets market fundamentals', in Prokopczuk, M. (ed.) *Energy pricing models: recent advances, methods and tools.* Palgrave Macmillan. ISBN 9781137377340 https://sro.sussex.ac.uk/id/eprint/51608/ Available on request.

R4 Coulon, M., Khazaei, J. and Powell, W. (2015) SMART-SREC: a stochastic model of the New Jersey solar renewable energy certificate market. *Journal of Environmental Economics and Management*, 73. pp. 13-31. http://dx.doi.org/10.1016/j.jeem.2015.05.004

4. Details of the impact

Through proactive engagement and collaboration with the energy industry in both the US and Europe, as described below, Dr Coulon's research has contributed significantly to the model development process in several energy companies. His research has enhanced firms' trading, valuation and risk management capabilities (for example, enabling better hedging against price volatility or more accurate pricing of new contracts or investments in physical assets) and reduced their exposure to loss of profits. In the process, his work has contributed to a greater understanding of market risk and price behaviour.

4.1 Applying structural models at a leading European energy company

As a result of his specialist research, Coulon was approached to collaborate with Alpiq, a leading Swiss energy company which operates in 31 European countries. The company produces power as well as selling it in the European markets. In 2019, Alpiq owned CHF7.4bn (£6.08 billion) of assets and supplied customers in Europe with 40 TWh of energy [**S1**].

Coulon's work with Alpiq began in 2012 and led to a formal collaboration between the University of Sussex and Alpiq in 2018 [**S2**]**.** The collaboration initially focused on price dynamics and hourly forward curve construction of the German power market (EPEX), as summarized in **R3**. Christian Jacobsson, former Head of Energy Artificial Intelligence at Alpiq, states:

> "Michael's innovative research on structural models for power prices allowed us to derive new insights into the dynamics of the German day-ahead power market… A key advantage of the approach was the construction of forward price curves and distributions which correctly overlay detailed demand patterns, weather models, and fuel price changes in a tractable stochastic framework. This is critical for the firm when accurately pricing complex assets or contracts, thus increasing profitability while also minimizing risk across our portfolio. Such models have been applied to the entire asset portfolio, power and gas, and especially for the pricing and operative management of the non-standard contract portfolio whose success can to a great extent be stated to rely on Michael's contributions over many years." [**S3**]

In early 2018, Coulon's work with Alpiq shifted towards new modelling challenges specific to the growth of renewables, and especially to wind park management. Coulon jointly developed new

modelling techniques with Alpiq, which have "had an important impact on the firm's approach to the new challenges linked to growing renewable generation" [**S3**].

Jacobsson describes the benefits of Coulon's work for both Alpiq and society as a whole:

> "The work has improved our ability to manage wind and solar parks offering their power while facing uncertain wind forecasts and highly volatile prices. This is a key component of Alpiq's push to become a market leader in advanced optimization, trading and risk management solutions for the new energy markets. In addition to benefiting the firm directly, such solutions are critical to society in a world where electricity will be supplied by many distributed intermittent sources like wind and solar, hard to predict and uncontrollable." [**S3**]

4.2 Advising and influencing decisions in US energy firms

Coulon worked with US energy company **Public Service Enterprise Group (PSEG)** between 2013 and 2017. Building on the ideas in **R1**, he developed solutions tailored to the firm's specific needs for managing power price risk across a complex grid of generating units and customer demand.

Ismael Arciniegas Rueda (Head of Structuring and Quantitative Analytics at PSEG from 2010 to 2017) states that Coulon's research "helped us to greatly expand our understanding of the markets, their price dynamics, and how to build rigorous mathematical models for predicting future changes" [**S4**]. Insights from Coulon's work influenced the firm to source the required percentage of renewables each year in a more cost-efficient manner and "the implementation of models built on Michael's research had a significant positive impact on the firm's business decisions and profitability" [**S4**].

Rueda describes the nature and the significance of Coulon's work, which provided the company with unique insights:

> "Our initial project with Michael extended his earlier work on structural electricity price models to build in demand patterns and congestion effects at zonal or regional levels. The approach retained the attractive features of his previous analysis, such as quantifying the dependency on fuel forward prices, while facilitating the inclusion of new location-specific constraints of the PJM market. The collaboration… was also valuable to PSEG's trading activities. The model was used to inform the valuation and risk management of assets dependent on locational power prices which required forecasting for many years, a challenge which other models in the literature were not equipped to handle." [**S4**]

This initial collaboration led to a new structural price modelling project based on replicating and extending Coulon's "ground-breaking research" [**S4**] on solar renewable energy certificate (SREC) markets [**R4**]. Rueda explains the value of this modelling for PSEG:

> "His was the first formal framework developed for predicting the behavior of these certificate prices, and linking them to their key fundamental drivers. As these were very illiquid and volatile markets prone to large price swings, this model was especially critical in providing a benchmark for our traders to better understand and forecast prices in challenging new markets." [**S4**]

Coulon has also collaborated with two other US companies, both of which have implemented power price models for clients based on his research. Scott Shander, Director of Analytics at **Commodity Risk Solution (CRS),** a US consultancy firm that provides solutions for renewable energy deals to corporate clients, describes his firm's collaboration with Coulon:

> "In 2017, we contacted Michael Coulon to build on his extensive research on structural models for electricity markets, in order to develop a new approach for a large client deal. Our collaboration with Michael over about six months focused on applying his modeling techniques to the Russian power market via a simulation study which facilitated a successful completion of the transaction. Through the use of Michael's deep knowledge

and research in the US markets, he helped CRS conduct a similar structural study of the electricity stack in Russia to aid in econometric fundamental analysis." [**S5**]

Shander explains how Coulon's insights benefited CRS and its clients:

> "This analysis proved critical for a buyside client negotiating a long-term renewable energy transaction (of total value over $60 million) as it not only provided a thorough market risk assessment, it aided in deal structuring to meet the client's objectives. Although at first glance quite complicated and technical academic papers, Michael's research on electricity markets provides valuable insights and practical modelling tools that can make a clear difference in real world applications." [**S5**]

Between August 2013 and May 2015, Coulon collaborated with **Scoville Risk Partners**, which provides advice and analytics for the energy sector. During this time, he enhanced the company's understanding of volatility and its links with other energy prices, as [text removed for publication] explains:

> "The thoughts and insights embedded in Michael's research (not to mention the numerous discussions that we have had) have influenced how we have approached these problems… His work on structural models of spot prices in commodities has directly impacted how we think about (and model) energy price series, in particular the nonlinear interaction of the prices of 'fungible' energy sources and what is generally referred to as the 'spiky' nature of such price series." [**S6**]

5. Sources to corroborate the impact

S1 Alpiq Annual Report 2019

S2 Collaboration Agreement between Coulon and Alpiq, 2018

S3 Statement from Christian Jacobsson, Head of Energy Artificial Intelligence, Alpiq

S4 Statement from Ismael Arciniegas Rueda, Head of Structuring and Quantitative Analytics, PSEG

S5 Statement from Scott Shander, Director of Analytics, Commodity Risk Solution

S6 Statement from [text removed for publication], Scoville Risk Partners