Energy Market Design with Intermittent Energy Sources

Sebastian Schäfers, University of Basel, sebastian.schaefers@unibas.ch
Frank Christian Krysiak, University of Basel, frank.krysiak@unibas.ch
Prudence Dato, University of Basel, prudence.dato@unibas.ch

Overview

Enforced by pressing climate issues and by rising political pressure, renewable energy sources (RES) become an increasingly important aspect of modern energy markets. However, the current electricity market designs especially in Europe do not adequately address the issue of increased intermittency. Newly emerging technologies allow for consumer specific load dropping without compromising the network. Real time pricing, while working well in theory, is unfeasible in different aspects for end consumers. By commoditizing the reliability of supply between consumers and retailers we propose a novel way to link consumption and production risk. We develop a theoretical market model with consumers, retailers and generators. By splitting the consumer demand into tranches and contracting specific levels of reliability, the consumer is able to take on risk according to individual appetite. The retailer solves the constrained profit maximization problem of having the most cost-efficient energy portfolio, taking into account the contracted reliability levels. Additionally, we show how marketing reliability would lead to changes in contract structure between generators and retailer in order to preserve incentive compatibility. We show that by marketing supply security, the overall welfare of the system can be increased.

Methods

We build a theoretical energy market model with with three different involved parties: consumers, retailers, and generators. We consider a block tariff which is in line with the inclining block tariff: (i) a relatively low "lifeline" rate associated to "essential needs," and (ii) a higher rate for extra electricity consumption in excess of those needs. In addition, we make the rate for the extra electricity consumption dependent on the electricity reliability such that a consumer pays higher electricity price for higher reliability.

Consumers buy electricity to gain services from their appliances. We differentiate two types of electricity use. (i) Time-critical use, such as light or communication services, where electricity is required exactly at the time of intended use. (ii) time-uncritical use, such as heat, air conditioning, or food storage (fridge or freezer), where the service requires electricity but not at the exact time where the service is used.

Generators invest either in conventional electricity generation (e.g., gas-turbines) orin different types of renewables. They sell the generated electricity to the retailers.

Retailers sell electricity to consumers and match this demand by buying electricity from generators. In the novel setting that we analyze, retailers will offer contracts to customers that explicitly specify different reliability levels for different types of electricity use. A regulator will force retailers to match these contract by a portfolio of delivery contracts that results in the correct level of reliability. This is different to a traditional market setting, where generators will promise their customers contracts with an implicitly assumed perfect availability of electricity for all purposes and will by this electricity via short-term contracts. In addition to these specifications, retailers interact on an energy spot market. The spot market allowes for realization of further welfare gains, by redistributing overproduction from RES to undersupplied consumers.

Results

We replace the generators' production decisions and the consumer choices in the retailer's problem. We then solve the retailer's problem of finding the optimal energy portfolio. First, we show that the optimal capacities of the conventional and intermittent electricity generation are closer to the optimal capacities under real time pricing than the capacities under full reliability. Reliability pricing is able to create effects that are similar to those of real time pricing. In fact, pricing reliability of supply gives incentive to consumers to adjust their electricity demand depending on their preferred reliability (for instance, to reduce their demand during peak periods). Second, compared to a market where consumers experience full reliability, welfare increases in the system proposed by us. We ensure incentive compatibility for all market participants. We find that the reliability contracted by consumers serves as an inverse price signal, leading retailer to optimize load potential load dropping according to stated consumer preferences. Third, we show that our market design approximates the first-best solution in our model.

Conclusions

The European energy landscape will be subject to major changes, also driven by political forces. The question of is central in order to integrate large shares of renewable energy and efficiecntly allocate intermittencies stemming from this. In our paper we develop an approach that is able to approximate the first-best solution of real-time pricing in terms of allocative efficiency. At the same time it is in many ways easier to implement than real-time pricing on a household level.