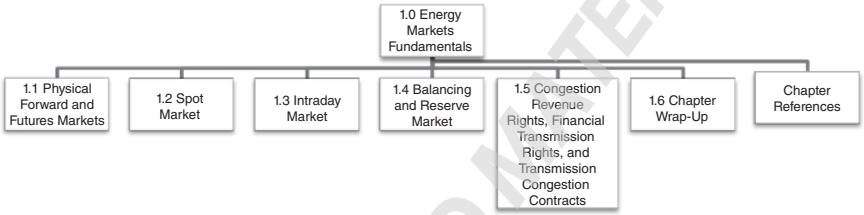
CHAPTER 1

Energy Markets Fundamentals



For sake of clarity, we will focus quite a bit of our attention on electricity markets because the generation and transmission of electricity are two of the primary reasons for the existence of energy markets. In addition, I have spent a part of my professional and academic career studying and working in the electricity markets (Mack 1986, 1999). However, please note that other energy products (oil, gas, etc.) will be discussed as well.

The generation and transmission of electricity are two of the essential reasons for the existence of energy markets.

Power and *energy* are two words often confusingly interchanged. These two key terms are summarized in Figure 1.1 and more rigorously defined as follows:

- *Power* is the metered net electrical transfer rate at any given moment. It is measured in megawatts (MW). A watt is equal to one joule per second. The joule is a derived unit of energy, work, or amount of heat in the International System of Units.

- *Energy* is electricity that flows through a metered point for a given period and is measured in megawatt-hours.
- *Electric power* is the rate at which electric energy is transferred by an electric circuit. The instantaneous electrical power P delivered to a component is given by

$$P(t) = I(t) \cdot V(t)$$

Where $P(t)$ is the instantaneous power (measured in *watts*)

$V(t)$ is the potential difference (or voltage drop) across the component (measured in *volts*)

$I(t)$ is the current (measured in *amperes*)

MWh (megawatt-hour) is a unit of energy

MW (megawatt) is a unit of power

Consumer energy demand, load profiling and forecasting drive power generation and transmission. Specifically, power transmission patterns are determined by location and size of load. In addition, transmission congestion is responsible for significant price volatility in electricity markets and in fact is a primary market driver.

Electricity derivatives may be structured to protect market participants from exposure to price fluctuations, volume risks, high volatility, and so

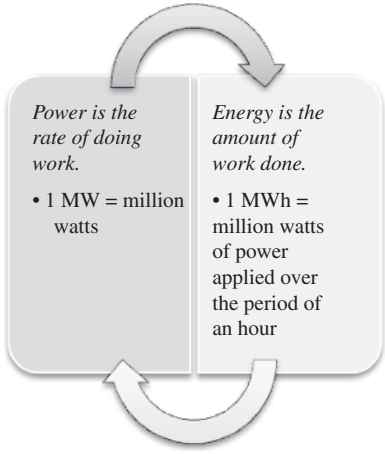


FIGURE 1.1 Power and Energy

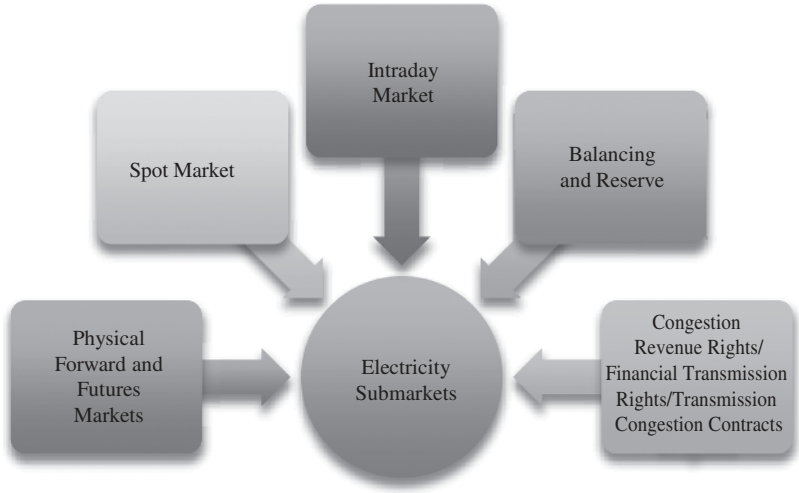


FIGURE 1.2 Electricity Submarkets

forth. Some examples of electricity derivatives are options, price swaps, basis swaps, futures, and forward contracts. We will discuss electricity derivatives and their pricing models in great detail in Chapters 3 and 4.

The electricity markets are segmented into the submarkets highlighted in Figure 1.2 (Burger, Graeber, and Schindlmayr 2007).

1. Physical forward and futures markets
2. Spot market
3. Intra-Day market
4. Balancing and reserve
5. Congestion revenue rights (CRRs), financial transmission rights (FTRs), and transmission congestion contracts (TCCs)

We will now take a closer look at these segments of the electricity markets.

1.1 PHYSICAL FORWARD AND FUTURES MARKETS

A *forward contract* is a nonstandardized contract between two parties to buy or to sell an asset at a specified future time at a price agreed upon today. An *electricity forward contract* can be either a financial contract or a physical contract (Figure 1.3).

- If a forward contract is settled before its maturity date, it is a *financial forward contract* since no electric power is physically delivered.
- A forward contract is a *physical contract* if the electric power is delivered physically.

The seller of a physical forward contract is obligated to physically deliver power to a location specified in the power contract (the hub). The forward contract does not specify the location at which the power is generated or consumed. However, the power contract states that the seller is responsible for delivering the power from the generator location to the hub, and the buyer is responsible for delivering the power from the hub to the load location. For both counterparties, this may involve purchasing additional transmission contracts, or purchasing/selling power through the spot market (Skantze and Ilic 2000).

A *futures contract* is a standardized contract between two parties to buy or sell a specified asset of standardized quantity and quality for a price agreed upon today with delivery and payment occurring at a specified future date. The contracts are negotiated at a futures exchange, which acts as an intermediary between the two parties.

A futures contract trader has two options, either to close the contract on or before the maturity date or roll over the contract. This roll over of contracts is referred to as a *swap* (Figure 1.4). With swaps, a trader would simultaneously execute two contracts, close the initial contract and open another longer term maturity date contract. Rolling over of contracts has some cost associated with it.

Electricity futures contracts are exchange-traded legally binding and negotiable contracts that call for the future delivery of electricity products.

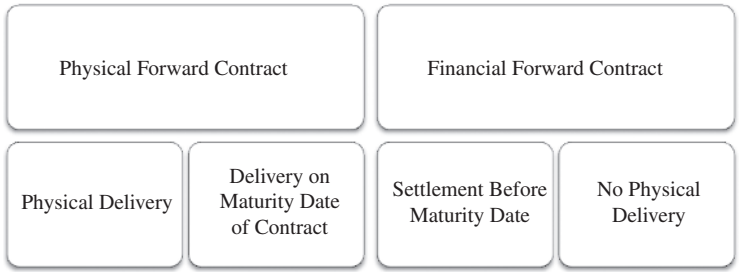


FIGURE 1.3 Forward Contract

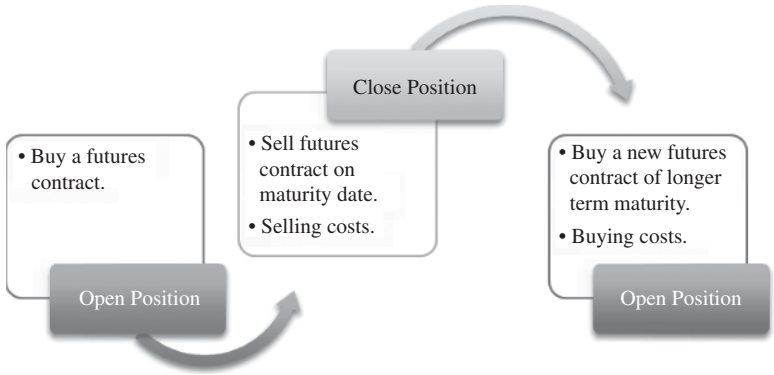


FIGURE 1.4 Swaps

Often times, physical delivery does not take place, and the futures contract is closed by buying or selling a futures contract on or near the delivery date (Stoft et al. 1998).

Forwards, futures, and swaps will be more rigorously defined and modelled in Chapter 3. However, for now the takeaway for the reader is the following:

- Forward contracts are bilateral agreements between a buyer and a seller. They are not exchange-traded.
- Futures contracts are standardized agreements. They are traded on an exchange.
- The forward and futures markets are key markets for trading, speculation, and risk management, allowing market participants opportunities to manage (hedge) price risks.
- The contract delivery dates or acceptance period of forward and futures markets includes dates occurring after the next trading day.

1.2 SPOT MARKET

The *spot market* is a commodities or securities market in which goods are sold for cash and delivered immediately. Contracts bought and sold on these markets are immediately effective.

Due to physical and financial constraints, there are relatively few players in regional electricity spot markets. Hence electricity markets are essentially oligopolies and not *free markets* as in the financial sense. Participants in North American electricity markets trade spot products on a power exchange or through an *independent system operator* (ISO). An ISO is a neutral operator primarily responsible for maintaining reliability of the electric power grid system (Figure 1.5). The ISO performs its function by controlling the dispatch of flexible power plants to ensure that loads match resources available to the system (ISO/RTO Council, 2001).

ISO

An ISO is a neutral operator primarily responsible for maintaining reliability of the electric power grid system. The ISO performs its function by controlling the dispatch of flexible power plants to ensure that loads match resources available to the system.

Please note that we utilize several schematic diagrams in this book to illustrate concepts and processes in the energy industry. We try to be consistent in these diagrams—with regards to symbols and directions of the arrows. However, the directions of the arrows may vary from diagram to diagram—depending on the context.

Key players in the electricity spot markets are listed in Figure 1.6. These market participants submit bids, generally on a *day-ahead* basis. *Day-ahead* products are the most common electricity spot products. A market maker clears the market and announces hourly settlement point prices. Trade on

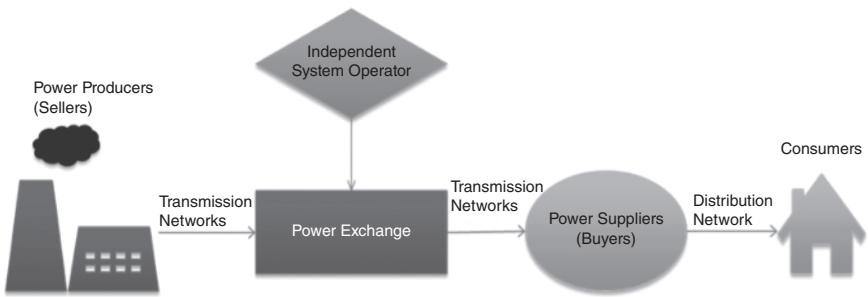


FIGURE 1.5 Role of the Independent System Operator (ISO) in the Electricity Markets

FIGURE 1.6 Spot Market Participants

the spot market is *physical*, meaning that physical delivery is expected. If a market participant defaults on delivery, it is required to pay the price differential between corresponding day-ahead market and real time market settlement point prices.

> *In the* day-ahead *market, electricity products are traded for the delivery on the next operating day.*

In the *day-ahead* market, electricity products are traded and delivered the next day. If the next day is not a trading day, then electricity products can be delivered between the next day and the next trading day. *Day-ahead* products are the underlying assets of futures contracts on a power exchange.

Electric power markets possess some of the characteristics of more matured commodity and financial securities markets. However there are some unique characteristics of the operation of the wholesale electric spot market that have implications for energy trading. Some of these unique characteristics are listed in Table 1.1 (KPMG 2006; Pilipovic 2007; Weron and Misiorek 2005).

TABLE 1.1 Some Unique Characteristics of Electricity Markets

Prices	Quantifiable exogenous variables that may affect electricity prices: ■ *Transmission constraints* ■ *Weather-induced demand spikes* ■ *Generator bidding patterns* ■ *Seasonality of load*
	Psychological and sociological factors may cause an unexpected buyout of certain contracts, leading to price fluctuations.
	Electricity spot prices exhibit strong *mean-reversion*, which is gravitation toward a "normal" equilibrium price level that is usually governed by the cost of production and level of demand. ■ Electric energy is a *secondary energy* source. ■ It's generated from the conversion of other *primary energy products*: oil, natural gas, coal, wind, nuclear, solar, hydro, etc. ■ Hence, the price of electric power is affected by the prices and availability of these primary energy sources.
Production, storage, and transmission	Volume and cost constraints on production, storage, and transmission of electricity. ■ Necessity for regional transmission networks prohibits the creation of a global power market. ■ Since there is *no global electricity market*, electricity products can vary from one regional electricity market to another.
	Electricity cannot be easily stored and must be available on demand. Exceptions are hydroelectricity (hydro-pumped power) and battery farms, which create storable energy.
	Storage constraints produce volatile day-to-day behavior.
	Nonstorability requires continuous balancing of supply and demand.
Volatility	Electricity spot prices can be much more volatile than prices of natural gas and other commodities.
	The high volatility of spot prices is a result of the nonstorability of electricity.

TABLE 1.1 (*continued*)

Market Maturity	Financial and some commodities markets are more mature.
Deregulation	Since the 1970s, some regional electricity markets have undergone significant restructuring, in part, due to market deregulation. Worldwide deregulation of electricity markets led to the restructuring of the generation, transmission, distribution, and pricing of electricity and other energy derivatives.
Seasonality of price process is multi-scale	■ Intraday ■ Weekly ■ Monthly ■ Annual
Non-normality of electricity spot prices (Figure 1.7)	■ *Positive skewness:* Skewness or skew refers to the extent to which a distribution is not symmetrical. ■ *Leptokurtosis:* The condition of a probability density curve to have fatter tails and a higher peak at the mean than the normal distribution.

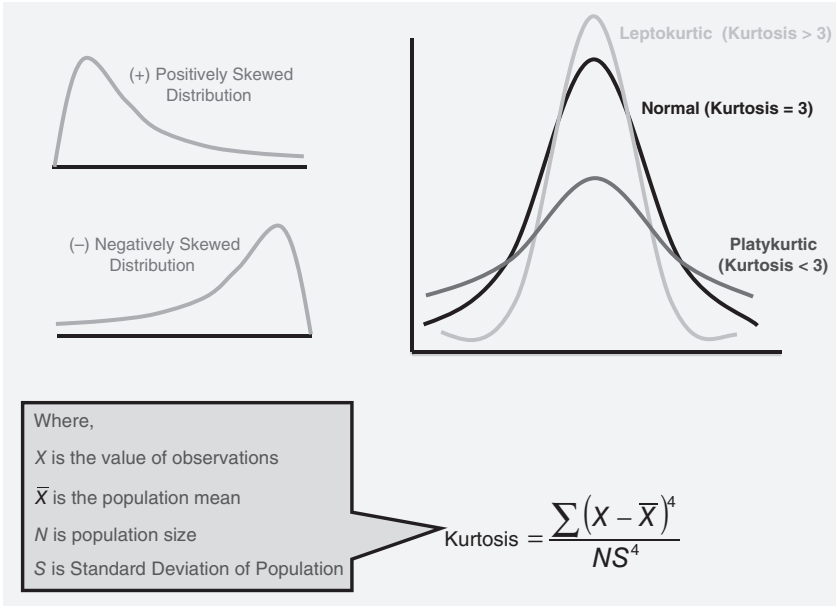


FIGURE 1.7 Nonnormality of Electricity Spot Prices Graphs

1.3 INTRADAY MARKET

The intraday market is for electricity products with a delivery on the same day. This market can be utilized to satisfy short-term needs of electricity or to sell short-term overcapacities. This market is also most commonly referred to as the *real time market*.

Energy market participants can utilize the intraday market as follows:

- To optimize their position to reduce risks associated with unexpected price fluctuations
- As a portfolio management tool

1.4 BALANCING AND RESERVE MARKET

Balancing and reserve markets are influenced by national regulation. In the *reserve market* an ISO is allowed to purchase electricity products to compensate for imbalances between supply and demand in the system. The *balancing market* allows electricity firms and traders to submit offers to sell and bids to buy energy from the system by altering generation or consumption.

*The **balancing market** allows electricity firms and traders to submit offers to sell and bids to buy energy from the system by altering generation or consumption.*

Transmission system operators (TSOs) are entrusted with the task of guaranteeing power system security. They procure balancing services in the balancing or real-time market accordingly (Tractebel Engineering 2009).

Since the deregulation of the electricity markets, TSOs no longer hold power generation resources in direct ownership. To maintain the power system balance, TSOs procure balancing services from:

- *Power generators*—they are the main providers of balancing services.
- *Load*—through contractual switching-off schemes. Due to technical limitations, load plays a limited role in the balancing market.

Various types of balancing services are listed in Table 1.2.

TABLE 1.2 Types of Balancing Services

Primary Frequency Control	A joint action of generating units and loads spread evenly across an interconnected network. Local automatic control that adjusts generation and consumption levels to stabilize a power system frequency following a disturbance. Activated within 30 seconds.
Secondary Frequency Control	Goal is to bring the power system's frequency back to its target value following a disturbance. This control is supplied by the generating units located in the control area where the imbalance originated. Activated within 15 minutes.
Tertiary Frequency Control	Refers to all automatic or manual changes in generation and load levels. Assist secondary control in performing its task. Restore secondary control reserves, or optimally redispatch secondary control power according to economic considerations.

1.5 CONGESTION REVENUE RIGHTS, FINANCIAL TRANSMISSION RIGHTS, AND TRANSMISSION CONGESTION CONTRACTS

The following financial instruments are used by energy market participants to manage variability in congestion costs between one point and another, based on *locational marginal pricing* (LMP).

- Congestion revenue rights (CRR)
- Financial transmission rights (FTR)
- Transmission congestion contracts (TCC)

LOCATIONAL PRICE

Note: A power generator receives the locational price at the point where it injects power into the market. In addition, a load pays the locational price at the point where it withdraws power from the market.

Congestion revenue rights (CRR) are defined as financial instruments, made available through the CRR allocation, CRR auction, and Secondary Registration System, that enable CRR holders to manage variability in congestion costs based on the LMP. CRRs are acquired primarily, although not solely, for the purpose of offsetting integrated forward market congestion costs that occur in the day-ahead market (CAISO 2013).

Financial transmission rights (FTRs) are defined as financial instruments entitling an energy market participant to a stream of revenues (or charges) based on the hourly congestion price differences across a transmission path in the day-ahead market. FTRs allow energy market participants to hedge against their congestion costs by acquiring FTRs that are consistent with their energy deliveries (Kristiansen 2004; PJM 2013).

Transmission congestion contracts (TCCs) enable energy market participants to hedge transmission price fluctuations. A TCC holder has the right to collect or the obligation to pay congestion rents in the day-ahead market for energy associated with transmission between specified points of injection and withdrawal (NYISO 2013).

The financial contracts—CRRs, FTRs, and TCCs—are summarized in this section for the sake of completeness in describing the power submarkets. However, they will not be discussed any further in this book.

1.6 CHAPTER WRAP-UP

This chapter gives the reader an overview of how the electricity markets are segmented into the following submarkets.

1. Physical forward and futures markets
2. Spot market
3. Intraday market
4. Balancing and reserve
5. Congestion revenue rights (CRRs), financial transmission rights (FTRs), and transmission congestion contracts (TCCs)

The first two submarkets, involving physical forwards, futures, and the spot markets, lay the foundation for the subsequent chapters. These concepts will be defined more rigorously from a quantitative modeling perspective. In addition, I will provide a variety of examples and case studies to illustrate how these energy submarkets work.

REFERENCES

Burger, M., B. Graeber, and G. Schindlmayr. 2007. *Managing Energy Risk*. Chichester, England: Wiley Finance.

California ISO (CAISO). 2013. "Congestion Revenue Rights." www.caiso.com/market/Pages/ProductsServices/CongestionRevenueRights/Default.aspx.

ISO/RTO Council. 2001. www.isorto.org.

KPMG Energy Reform Implementation Group. 2006. "Review of Energy Related Financial Markets: Electricity Trading." www.ret.gov.au/energy/Documents/erig/Financial_markets_review_KPMG20070413120316.pdf.

Kristiansen, Tarjei. 2004. "Markets for Financial Transmission Rights." *Energy Studies Review* 13(1). http://digitalcommons.mcmaster.ca/cgi/viewcontent.cgi?article=1250&context=esr.

Mack, Iris. 1986. "Block Implicit One-Step Methods for Solving Smooth and Discontinuous Systems of Differential/Algebraic Equations: Applications to Transient Stability of Electrical Power Systems." PhD diss., Harvard University Press.

———. 1999. "Day-Ahead Lunch-Time Electricity Demand Forecasting: Applications to Electricity and Weather Derivatives." Master's thesis, London Business School.

New York ISO (NYISO). 2013. "Transmission Congestion Contracts." www.nyiso.com/public/markets_operations/market_data/tcc/index.jsp.

Pilipovic, Dragana. 2007. *Energy Risk: Valuing and Managing Energy Derivatives,* 2nd ed. New York: McGraw-Hill.

PJM. 2013. "Financial Transmission Rights." PJM Markets and Operation. www.pjm.com/markets-and-operations/ftr.aspx.

Skantze, Petter, and Marija Ilic. 2000. "The Joint Dynamics of Electricity Spot and Forward Markets: Implications of Formulating Dynamic Hedging Strategies." Energy Laboratory Report No. MIT-EL 00-005. http://web.mit.edu/energylab/www/pubs/el00-005.pdf.

Stoft, S., T. Belden, C. Goldman, and S. Pickle. 1998. "Primer on Electricity Futures and Other Derivatives." Environmental Energy Technologies Division: Ernest Orlando Lawrence Berkeley National Laboratory, LBNL-41098, UC-1321. http://eetd.lbl.gov/ea/emp/reports/41098.pdf.

Tractebel Engineering. 2009. "Study on Interaction and Dependencies of Balancing Markets, Intraday Trade and Automatically Activated Reserves, Final Report." Katholieke Universiteit Leuven, TREN/C2/84/2007. http://ec.europa.eu/energy/gas_electricity/studies/doc/electricity/2009_balancing_markets.pdf.

Weron, R., and A. Misiorek. 2005. "Forecasting Spot Electricity Prices with Time Series Models." International Conference of The European Electricity Markets EEM-05, www.mendeley.com/research/forecasting-spot-electricity-prices-time-series-models.