2. Energy economy in enterprises

Energy demand is increasing all around the world, and so is the price. The development of electricity prices in the German industry (figure 2.1) shows a clear increasing trend.

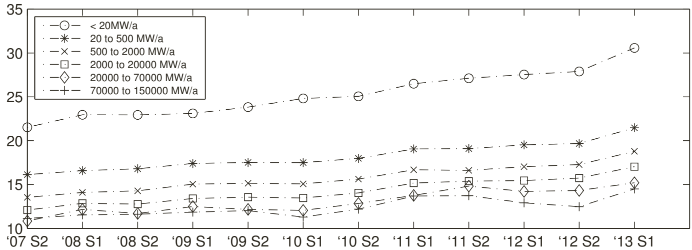

Figure 2.1.: Development of the electricity price for industry enterprises in Germany. Including all taxes, in cent/kWh. (Source: Eurostat (2013))

The reason for this lies in the scarcity of resources and the rising prices for conventional energy sources. Furthermore the political factor plays an important role: the taxes and contributions are raised regularly. For example, the EEG levy increased from 2 cent per kWh in 2010 to almost 5.3 cent per kWh in 2013. Next year it will be raised again, to 6.24 cent. Taxes and contributions establish the fixed part of the electricity price, except for some exemption clauses like discounts on the net usage costs for companies with a high number of operating hours.

While the proportion of energy costs on the total costs of enterprises keeps increasing, energy management becomes more and more important. The past years revealed a raising awareness of the opportunities which are offered through proper dealing with the subject energy.

For enterprises, there are different types of electricity procurement which mainly differ in the degree of risk and the attainable price. We introduce these types in the next section.

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2.1. Electricity procurement

Long before the markets were deregulated, retail contracts, more precisely full service contracts, were the only way for end customers to procure electricity. The actual pricing for retail contracts happens in the wholesale market, that is between producers and merchants. We intuitively expect lower prices in the wholesale market than in the retail market and we are right, apart from a few exceptions. The reason is that merchants always have the possibility to resell the purchased energy at the wholesale market if the retail prices are too low. As a consequence, wholesale and retail prices are directly connected.

In a deregulated market, the variable part of the electricity price, that is excluding all taxes and contributions, is indeed manageable. There are different factors which influence the price more or less. The four most important factors are displayed in figure 2.2.

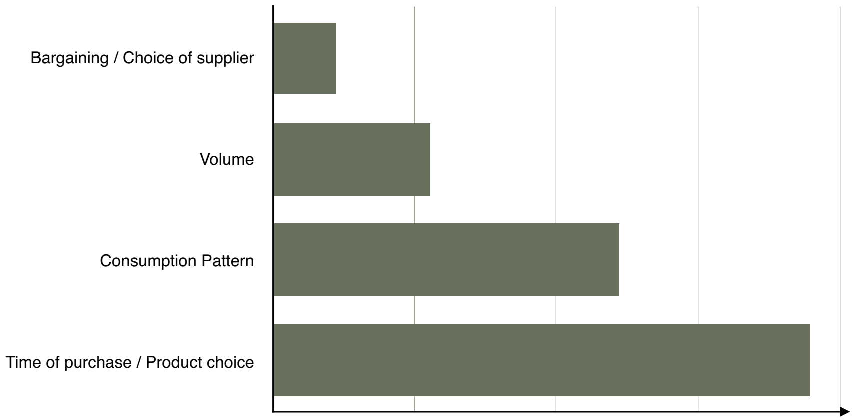

Figure 2.2.: Price influencing factors.

Given the dominating role of purchasing time and product choice on the price, it seems that the conventional contracts are not in conformity with the market anymore. Therefore the customer should intervene in the pricing routine between merchants and producers and no longer accept the retail prices as given. In the past years we can see an increasing willingness on the customer side to question retail prices and contemplate about alternative procurement methods. If and only if this trend holds, customers can prospectively establish a negotiable demand side again.

Retail products

Since there are many possible ways of electricity procurement, we want to analyze the most common retail products below. We refer to a market as retail market, if electricity is sold to an end customer and the sold volume depends on the consumption of the respective customer.

- **Common full service contracts**

  Full service contracts were the first-ever electricity retail products to hit the market. The customer purchases all of his power consumption from one provider at a given price. With this type of contract, the provider carries all the risk for the customer. Following this, the risk premium is the highest premium under all retail products. In other words, the customer sort of "buys" price security from the provider.

  Normally, the fixed energy price per unit (MWh) P is composed through

  $$P = B + M + R \quad .$$

  In this equation, B denotes the basic price, M denotes the retail margin and R denotes the risk premium. The basic price B for a contract period $[t_0, t_1]$ is the expected price for that particular period. A load forecast $(l(t))_{t=t_0}^{t_1}$ is required in order to calculate B. Then, B is obtained through

  $$B = \frac{\sum_{t=t_0}^{t_1} l(t)F(t)}{\sum_{t=t_0}^{t_1} l(t)} \quad , \tag{2.1}$$

  where $F(t)$ is the forward price for a delivery at time t (valid at the conclusion of the contract).

  Consequently, the provider carries the risk of forecasting errors which can cause higher costs. This risk depends to a large extent on the structure of the customers load profile and is covered by the risk premium R.

- **Indexed contracts**

  Indexed contracts allow customers to fix the wholesale energy price at several times. The advantage of this type of contracts is, that concluding a contract during a period of high wholesale prices does not necessarily result in a high retail price. When the price level decreases after contract inception, proper indexing can lower the resulting retail price.

  Let n be the number of possible fixings and $I(t)$ the indexed value at time t. With B, M and R as provided in the last paragraph and $t_k \in [t_0, t_1]$ being the times of indexing, the indexed price P_I is given by

  $$P_I = (B + M + R) \cdot \frac{\frac{1}{n}\sum_{k=1}^{n} I(t_k)}{I(t_0)} \quad . \tag{2.2}$$

  In other words, if the mean indexed value accounts for 80% of the indexed value at time t_0, the indexed price is $P_I = P \cdot 0.8$.

  But in this consideration one must not forget the contrary scenario. If the wholesale prices increase after closing the contract, the indexed price could possibly be higher than the price P. Summarizing, the customer assumes a part of the market price risk from the provider.

- **Structured procurement**

  Structured procurement is the acquisition of standardized wholesale products at different times with simultaneous covering of the residual demand at the spot market. In this case, the provider acts more like a broker than a supplier. The customer assumes all the risk from the provider and has to bear all the costs. He is responsible for proper load forecasting as he pays for the balancing power, needed to fix the forecast error, as well. As the imbalance costs can sum up to a quite large part of the total costs, the load forecast should be as exact as possible, which brings us back to the subject of this thesis.

  The resulting price P_{SP} of structured procurement can be written as

  $$P_{SP} = F + S + I + M \quad , \tag{2.3}$$

  where F denotes the future market costs, S denotes the spot market costs, I denotes the imbalance costs and M is the margin for the broker.

The risk premium is omitted because the customer carries all of the risk himself.

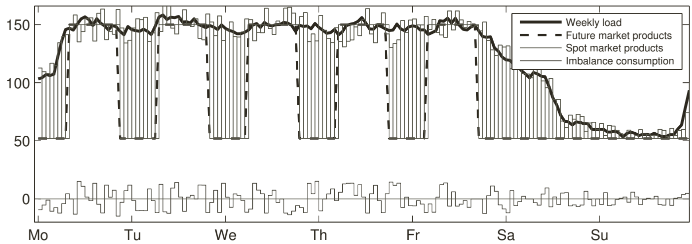

Figure 2.3.: Possible scenario for structured procurement.

Figure 2.3 shows a possible scenario of electricity procurement using future and spot market products. The thick black line displays one week of an example load profile, the dashed line is a combination of baseload and peakload future products. The thin black line shows the spot market purchases which were adapted to the specific load forecast for this week. The remaining line represents the imbalance between forecast and real load. This imbalance energy has to be bought or sold at the balancing market for which the prices are determined by the responsible transmission system operator.

We will consecutively list the advantages of structured procurement over conventional contracts:

- No restrictions in consumption volume.
- Reduction of market risk through diversification of products and scattering of buying times.
- Reduction of the risk premium.
- Saving potential through redistribution of load, peakshaving and others.
- Possible involvement of generation (e.g. solar panels).
- Transparency of costs.

- **Portfolio management**

  Portfolio management is an expansion of structured procurement in a sense that not only standardized wholesale products but all financial or physical products are traded. Additionally, customers with portfolio management might generate electricity on their own and use it for peakshaving or sell it back to the market. Possibly the customers don't even use a broker as intermediary (margin M is omitted) but purchase products directly at the wholesale market. Since these products presume minimum order volumes, this is only viable for energy intensive enterprises.

Altogether we notice that there are lots of different procurement methods while each of which has unique advantages and disadvantages. As already stated, they essentially differ in risk and attainable price, which can be seen in figure 2.4.

A customer might make his own product choice depending on his special risk preferences, price expectations and, of course, the available load forecasting and risk management techniques. The better these techniques are, the more profitable it will be to turn away from conservative contracts.

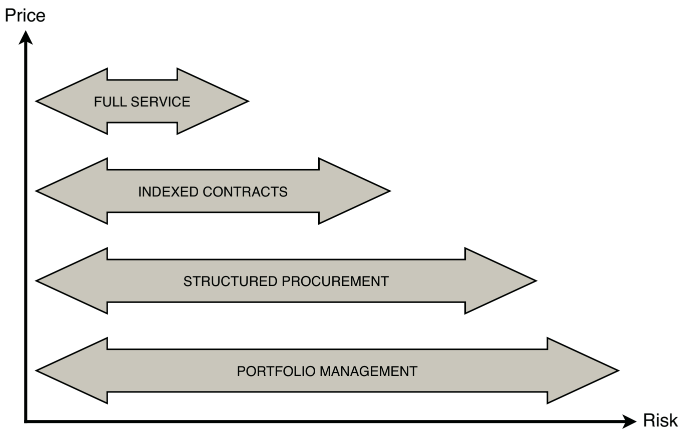

Figure 2.4.: Price-risk relation of various procurement methods.

In the succeeding section we will analyze the role of load forecasting in the energy economy.

2.2. Load forecasting

Already in times of regulated markets, load forecasts have been important for electric utilities and power plants. However, the deregulation of the markets led to the fact that today load forecasting is indispensable for *all* active market players.

There are different types of load forecasting which mainly differ in their respective time horizon, whereas the categorization varies from publication to publication. We characterize these types as follows:

- **Long-term load forecasting (LTLF)**

  LTLF describes the forecasting of periods of time which lie several years (up to decades) in the future. This type of models is especially interesting for electric utilities or transmission system operators which want to plan the extension of capacity or networks.

- **Medium-term load forecasting (MTLF)**

  MTLF characterizes forecasts for the next year or the year thereafter. These models are essential for customers who operate structured procurement or portfolio management. In this thesis, we will primarily concentrate on MTLF.

- **Short-term load forecasting (STLF)**

  STLF handles time horizons of a single day up to a week or two. For instance, short-term forecasting of the grid load is necessary for the scheduling of power plants. Furthermore, it is used by electric utilities to ensure the short-term availability of supply. Due to the time horizon being only a couple of days, many STLF models include weather forecasts as well.

There are various approaches and models for the different types of forecasting, for which we will give a short overview in section 2.4.

Load forecasting has become an integral component of the planning of electric utilities, suppliers, transmission system operators and other market participants. As already stated, in this thesis we will focus on MTLF for end customers. On the one hand, suppliers use these models to price full service contracts. On the other hand they are used by customers who operate structured procurement or portfolio management. Also, precise load forecasts can help customers to perform a transparent price evaluation and hence an assessment of their running contract.

In general, forecasting the load for a single customer is much more difficult than forecasting the grid load. There are several reasons for this: firstly, the history of data for the grid load is considerably longer than it is for a specific customer. Secondly, in case of the grid load (being the cumulative load of all customers), the stochastic effects of individual customers neutralize each other to a certain extent, which is why the grid load is very homogenous. The same diversification argument holds for significant changes in consumption patterns. Another very important difficulty in single customer MTLF is that load profiles of customers in different sectors partly show serious distinctions, as we will show in the next section.

2.3. Industry load profiles

When it comes to comparing different load profiles, one has to divide between factors which are relevant for model identification and those which are not. For instance, the cumulated load or mean load will not affect the model choice at all. The seasonal behavior of a load profile is, however, much more important for model adaption. Load profiles normally show different seasonalities:

- **Yearly seasonality:** In winter months, consumption usually is higher because of heating and lighting. However, in some sectors there is also a higher consumption in summer months because of cooling (e.g. groceries).
- **Weekly seasonality:** The consumption on Tuesdays, Wednesdays and Thursdays is, in general, very similar. Mondays and Fridays can show a special load pattern, for example because of machine starting or shutdown. The load on Saturday totally depends on the sector, while Sundays are usually very similar again.
- **Daily seasonality:** Except for customers producing in three-shift operation, load is obviously higher in daylight hours than it is throughout the nighttime.

When analyzing load profiles from different sectors one can observe significant differences in seasonal patterns. The most obvious differences are to be found in the weekly structure. Figure 2.5 shows the weekly consumption of customers in different sectors. In each plot, every grey line is one week of the year (52 in total) and the black line is the mean over all weeks.

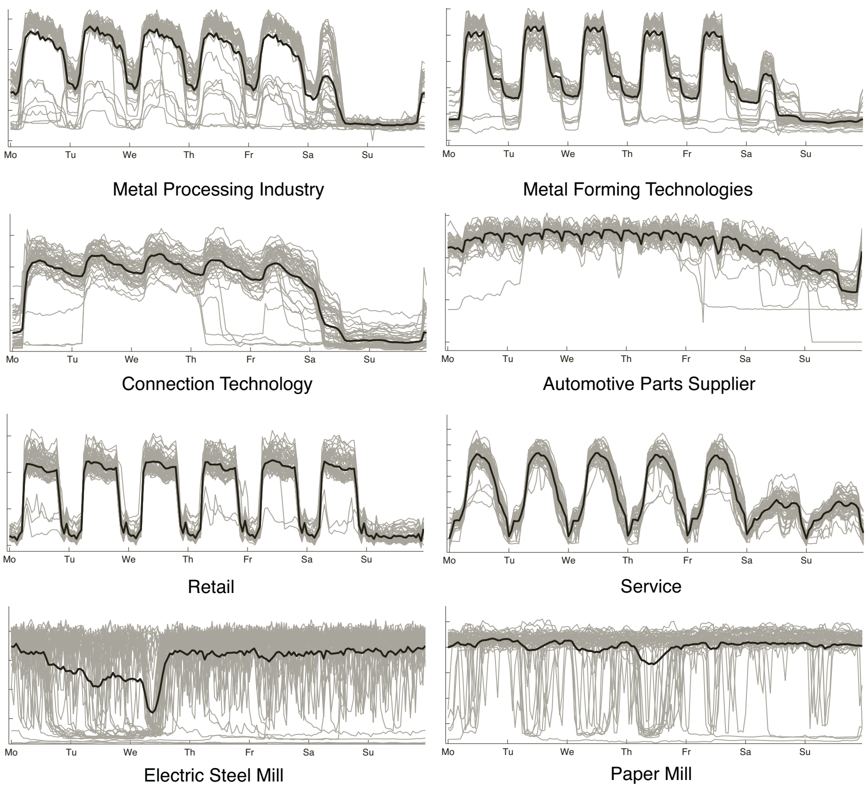

Figure 2.5.: Various industry load profiles. (Source: *statmath GmbH*)

There are a lot of things to remark when looking at these profiles. The two profiles in the top row, for example, are typical industry customers operating in two shifts. The load decreases in the evening to a certain level and goes up again in the morning hours. There were some saturdays with high and some with low load. Also, in a few weeks or for a couple of days, the load decreased to its minimum level (which is usually greater than zero due to exterior lighting or the like). A possible reason are machine outages or public holidays, for example. The visible load peaks usually indicate machine starting.

The profiles in the second row show industry customers with a three-shift system. The customer with the right profile is even working throughout saturdays. Additionally, we can clearly see the recurrent daily patterns during weekdays. The profile on the right side seems to be predestined for a purchase of high volume future products.

Row number three reveals two profiles which, at the first sight, show quite chaotic behavior. Indeed they are typical profiles for their respective industry. Remarkable is that deviations from the "normal level" (the expected load) are very asymmetric. There are a lot of inverse peaks which most likely are caused by short time machine shutdowns. The profile of the electric steel mill shows an odd pattern on wednesdays (already starting on tuesdays) which is, with closer examination, easy to describe: the electric blast furnace of the steel mill has to be cleaned once a week. In order to do that, it has to be turned off and cooled down. Since the blast furnace causes a high proportion of the total consumption, we observe the decrease of load in the middle of the week.

The last row of figure 2.5 contains load profiles of customers from the retail and service sector. The majority of profiles from these sectors is very homogenous and thus, compared to others, easy to predict. The weekdays (including saturday for the retail profile) show almost exactly the same pattern. The profile on the right is a cumulated consumption of a service provider and a restaurant, which explains the load on saturday and sunday.

The variety of different load patterns makes it hard to find a comprehensive forecasting model. In fact, finding a suitable method for a particular customer requires testing of various models on real data. One could also consider hybrid solutions since there could be different models for a given load profile, each of which having its own advantages. Though we will concentrate on one particular method in this thesis, we will give a short overview on forecasting models in the following section.

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