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Tutorial on the Differentiation

Asset-backed Trading vs. Proprietary Trading

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Abstract

Let a pump storage plant be shared by various energy suppliers. Acting as partners they have committed themselves to purchasing a pro-rata share of the energy and to pay a pro-rate share of the annual costs. One of these partners – likely the one with the largest share – oversees operating the pump storage plant. The non-operating partners may submit their schedule to the operating partner daily under specified restrictions.

In section A) we demonstrate conceptually, how the added value of flexible power plant capacity can be monetized in the context of asset-backed trading, and how asset-backed trading differs from speculative proprietary trading, especially with a focus on the risk exposure. Section B) sensitizes to the importance of transparency and efficiency in energy trading within the Swiss Federal Electricity Supply Act. We put into the focus the principles for the determination of the electricity tariffs based on the legally binding rulings of the Swiss regulator ElCom as well as the information asymmetry between operating partner and non-operating partners and its impact on the added value potential.

This tutorial paper is addressed to persons, who are interested in critically reflecting the transparency and efficiency in trading units.

Abbreviations:

bps	Basis points
DSO	Distribution system operator
EEX	European Energy Exchange for future contracts
EPEX SPOT	European Power Exchange for spot and intraday trading
EUR	Euro
MW / MWh	Megawatt / Megawatt hour
PFC	Price forward curve
OTC	Over the counter
Phelix	Physical electricity index for market area Germany
StromVG	Swiss Federal Electricity Supply Act
StromVV	Swiss Electricity Supply Ordinance
Swissix	Swiss electricity index for market area Switzerland
TSO	Transmission system operator

A) Asset-backed trading .vs. speculative proprietary trading

Trading transactions in energy trading are characterized by the fact that the time of conclusion of a trading transaction (i.e., obligation to deliver electricity or to use a turbine capacity in the future) and the time of delivery of electricity or use of the capacities **are not identical.** The period between these two points in time is called the **trading period** and can span several hours, days, weeks, months or even years.

Asset-backed traders take advantage of the high volatility in *spot* trading by successively selling turbine capacity when prices are rising and buying it back when prices are falling; similarly, pump-storage power is purchased when prices are falling, and this purchase is *settled* or *closed out* when prices are rising. The greater the volatility in spot trading, the greater the price difference and thus the positive trading success. This trading strategy is known as ***replication strategy*** or ***delta hedging*** and credited to Nobel Prize winners Black-Scholes-Merton, who as part of their work in the 70s on option pricing theory recognized that volatility in markets can be monetized [1]

i) Conceptual illustration of the replication strategy.

We will take the following simplified example as a starting point: The asset-backed trader manages a storage power plant with a turbine capacity of 100 MW. According to the current storage level, price and inflow forecasts, the value of available water in the storage was currently determined to be 38 EUR/MWh. This price represents the so-called *trigger price* and thus the threshold at which it is economically justified to operate the turbines and thus produce electricity.

In the following, we will roughly define the structural framework for spot trading, primarily to illustrate the different profit and loss profiles between *asset-backed traders* and *proprietary traders*, including possible cross-subsidization and its impact on the meaningfulness of segment reporting.

If we take the delivery hour 10-11 a.m. on a Tuesday morning as an example, the market clearing price for an electricity delivery of 1 MWh in this hour 10-11 a.m. on Tuesday is determined at 12h00 on Monday in the so-called day-ahead auction. This market clearing price is published on Monday at 12h00 and is therefore known to all market participants. At 15h00 on Monday, intraday trading (ID trading) begins for all hourly and quarter-hourly electricity deliveries day-ahead (i.e., on Tuesday), also for those electricity deliveries on Tuesday 10-11 a.m. Within the framework of this continuous ID trading, this product is tradable until 15 min before the start of delivery, i.e., until 9h45 a.m. on Tuesday.

On Monday, in the day-ahead auction for delivery on Tuesday, let the *asset-backed trader* offer 50% of the available turbine capacity (i.e., 50 MW) at a price of EUR 38, for an electricity delivery on Tuesday 10-11 a.m., another 25% of the turbine capacity (25 MW) at a price of EUR 48, and the final 25% of the turbine capacity for a price of EUR 68. This kind of staggering of flexible turbine capacities characterizes the replication concept.

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[1] see e.g., Hull, J. (2022): *Option, Futures, and Other Derivatives* (11th edition), Chapter 19, Pearson.

Let the day-ahead auction deliver a market clearing price of 40 EUR/MWh for electricity delivery (Tuesday 10-11 a.m.), which exceeds the trigger price of 38 EUR/MWh. Thus, with the publication of the auction result, say, on Monday at 12h00 a.m., the *asset-backed trader* is obliged to deliver electricity in the amount of 50 MWh on Tuesday from 10-11 a.m.

We now presume four possible price developments (Ia, Ib, IIa, IIb) in intraday trading (ID trading) for this electricity delivery on Tuesday, 10-11 a.m. During these discrete price developments, the trader may adapt the decision. For didactic purposes we limit ourselves to two points in time (to Monday 20h00, eight hours after the day-ahead auction, as well as to Tuesday 8h00, i.e., one hour before the start of delivery), at which the trader may adapt the decision.

Price development Ia: ID price: Mon 20h00, at 50 EUR/MWh; Tue 8h00 at 70 EUR/MWh,
Price development Ib: ID price: Mon 20h00, at 50 EUR/MWh; Tue 8h00 at 30 EUR/MWh,
Price development IIa: ID price: Mon 20h00, at 30 EUR/MWh; Tue 8h00 at 50 EUR/MWh,
Price development IIb: ID price: Mon 20h00, at 30 EUR/MWh; Tue 8h00 at 10 EUR/MWh.

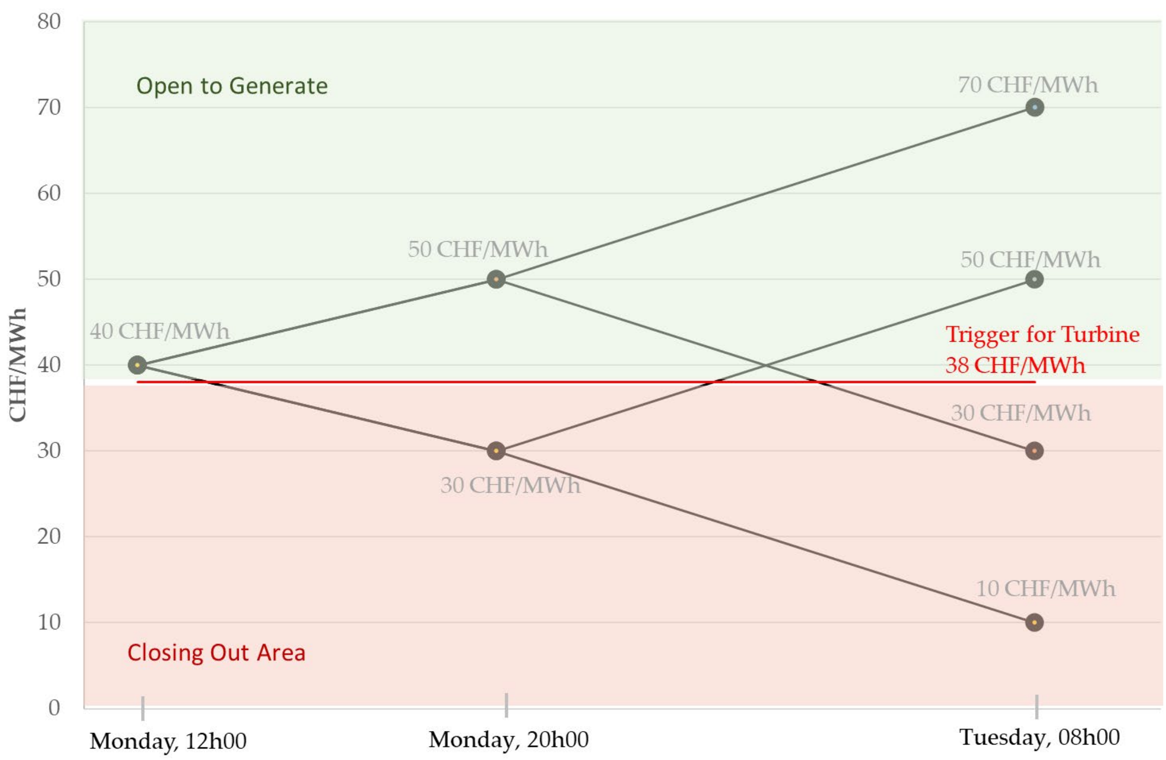

Figure 1: Representation of the four discrete price developments incl. trigger price for turbine at the designated trading points

The above variability for ID prices is typical for spot trading and arises in particular from changing forecasts for the feed-in of New Renewables, triggered by changing weather forecasts (including fog banks). The volatility of ID prices is 150% and corresponds to the value we used in our work[2] to derive the imputed volatility driven earnings of *asset-backed trading* in the spot market.

[2] Frauendorfer K., Gutsche R. (2021): *Empirische Analysen zu Finanzberichten der Alpiq, Axpo und BKW (Geschäftsjahre 2009-2018): Eine Studie für die Stakeholders der Schweizer Stromwirtschaft zur Prüfung*, ior/cf-HSG, Universität St.Gallen S. 47f (Link zur Studie).

The four price developments (see Figure 1) represent a discrete price process and were chosen in such a way that up and down movements occur with equal risk-neutral probabilities (i.e., 50%). This implies that the expected price at the end of each subperiod equals the observed price at the beginning of that subperiod. The risk-neutral probabilities characterize the so-called *martingale measure*. Therefore, the price process fulfills the martingale property, based on which the fair value of the turbine and pump capacity can be determined. Herewith, *martingale pricing* is applied. According to the assumption that we work with risk-neutral probabilities the risk-free interest rate process is set equal to 0 herein for purely didactic purposes, so that the discounting factor process equals 1 over the subperiods.

The *Black Scholes dynamics* characterize an arbitrage-free and complete market. Martingale pricing is also applicable to arbitrage-free markets which are incomplete. Further, preferring an empirical measure over the risk-neutral measure requires to derive the associated stochastic discount factor process, which transforms an empirical measure again into a martingale[3]. This is why *martingale pricing* may be seen as remarkable generalization of the Black Scholes Model.

ii) Risk exposure of an asset-backed trader in the power spot market

An *asset-backed trader* has the **right (but no obligation)** to *reverse* or *settle* or *close out* the trading transaction in the event of a more favorable price development on the trading platforms by means of a so-called offsetting transaction. In this case of *a close-out* of the trading transaction, no physical delivery or use of the capacities takes place. The positive price difference results in a positive trading profit. The *asset-backed trader* is therefore not exposed to the risk of having *to close* their trading business in the event of poorer price developments. The available capacities (i.e., *assets*) enable the *asset-backed trader* to meet the contractual obligations at the time of delivery or deployment in all cases.

Under **price development Ia**, the *asset-backed trader* will sell another 25 MW of turbine capacity on Monday 20h00 and on Tuesday 8h00 likewise another 25 MW (i.e., 25% of turbine capacity each). The *asset-backed trader* thus commits to delivering 100 MWh of electricity on Tuesday, 10-11 a.m.

The earnings achieved in the day-ahead auction and ID trading under price development Ia are: EUR 50*40 + 25*50 + 25*70 = EUR 5'000.

The comparison between the value of the physical delivery at the market clearing price of the day-ahead auction in the amount of 100 * 40 EUR = EUR 4'000 and the resulting added value of the *asset-backed trading* in spot trading in the amount of EUR 1'000 or 25% of the market value of the physical delivery becomes important.

Under **price development Ib**, on Monday 20h00 the *asset-backed trader* will sell another 25 MW of turbine capacity at the ID price 50 EUR/MWh; however, on Tuesday at 8h00, he will close out (i.e., buy back) the already sold 75 MW of turbine capacity because the ID price has dropped to 30 EUR/MWh – below the trigger price of 38 EUR/MWh. It is therefore more economically efficient to keep the water in reservoir. Hence, there is no turbine operation and thus no physical delivery.

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[3] see e.g., Björk, T. (2020): *Arbitrage Theory in Continuous Time*, Part III, 4th edition, Oxford University Press.

The earnings achieved in the day-ahead auction and in ID trading under price development Ib are: EUR 50*40 + 25*50 – 75*30 = EUR 1’000. Thus, asset-backed trading in the spot market generates earnings without physical delivery.

Under **price development IIa**, on Monday 20h00 the *asset-backed trader* will close out (i.e., buy back) the 50 MW sold in the day-ahead auction, as the price has dropped to 30 EUR/MWh below the trigger price of 38 EUR/MWh; it is economically more efficient to keep the water in the reservoir at this point. The *asset-backed trader* is not obliged to deliver electricity at that moment.

On Tuesday 8h00 a.m., however, the *asset-backed trader* will sell the entire turbine capacity 100 MW, as the price has risen to 50 EUR/MWh, thus above the trigger price of 38 EUR/MWh. The turbine is operated, generating 100 MWh which is delivered on Tuesday 10-11 a.m.

The earnings achieved in the day-ahead auction and in ID trading under price development IIa are: EUR 50*40 - 50*30 + 100*50 = EUR 5'500. A physical delivery with a market value of EUR 4'000 based on the market clearing price of the day-ahead auction takes place. The resulting added value of *asset-backed trading* in spot trading is EUR 1’500 or 37.5% of the market value of physical delivery at the time of the day-ahead auction.

Under **price development IIb** on Monday 20h00, the *asset-backed trader* will close out (i.e., buy back) the 50 MW sold in the day auction, as the price has dropped to 30 EUR/MWh below the trigger price of 38 EUR/MWh. As the market price remains below the trigger price at 10 EUR/MWh on Tuesday 8h00, there is no turbine operation and therefore no delivery of electricity.

The earnings achieved in the day-ahead auction and in ID trading under price development IIb are: EUR 50*40 - 50*30 = EUR 500. Thus, analogously to price development Ib, *asset-backed trading* in the spot market without physical delivery generates additional earnings. The underlying trading transactions lead to positive cash flows and are therefore settled exclusively in *financial* terms.

iii) Risk exposure of an asset-backed trader in the system services market.

The spot market and the market for system services are in direct competition with each other, as long as they do not get connected. If the transmission system operator (*TSO)* has been committed to the availability of 100 MW of turbine capacity for Tuesday 10-11 a.m. *within a few minutes*, that turbine capacity will not be available to the *asset-backed trader* in spot trading for that delivery period. The *asset-backed trader* will include this lost opportunity in the bid price for the TSO. The value of the physical delivery, the additional earnings from the replication strategy and the probability of the *TSO* calling up the turbine capacity are the key parameters that determine the bid price for the *asset-backed trader in the market* for system services. Depending on the system service, the option premium already includes the value of the physical delivery, even if there is no call on the turbine capacity.

We recognize that the *asset-backed trader* is signing over a type of option right to the *TSO*: The *TSO* receives the right to call on turbine capacity within a few minutes if required. In contrast, the *asset-backed trader* in spot trading applies the **replication strategy**, which allows the monetization of volatility from the classical option theory of finance.

The *asset-backed trader* is not exposed to a financial loss because the option premium is paid even if the *TSO* does not exercise the turbine capacity. Depending on the system service, the value of the physical delivery is either included in the option premium or this value is additionally compensated.

iv) Risk exposure of a proprietary trader

In contrast to the *asset-backed trader*, the *prop trader* (proprietary trader) has the obligation to *close* the entered or opened trade within the trading period, since a *prop trader* has no capacity to meet the contractual obligations in the trade (e.g., to deliver the electricity). In case there is an obligation to *close* out or *settle* a trade, this trade is also referred to as "*open position*". With the obligation to close out, the *prop trader* is exposed to the risk of having to close out the trade under less favorable price developments. The *prop trader* is entitled to hold the open position as long as the assigned loss limit is not exhausted. The *prop trader* is obliged to *close* the open position, at the latest when the assigned loss limit is exhausted.

We use the same market clearing price of the day-ahead auction of 40 EUR/MWh for an electricity delivery on Tuesday 10-11 a.m., as well as those four price developments as we have assumed for the *asset-backed trader*. Since the *prop trader* does not possess turbine capacity, the trades are exclusively conducted on a *financial basis*. The *prop trader* must be able to cover the accumulated loss at any time, which is why the *prop trader* must be allocated a risk capital within which the *prop trader* may execute the trades. That is, at no time may the *prop trader* have a realized or unrealized loss in excess of the assigned risk capital.

Let the *prop trader* be assigned a risk capital of EUR 1'000. Based on chart technical considerations, let the *prop trader* expect falling prices for electricity delivery (Tuesday 10-11 a.m.) in intraday trading, in relation to the day-ahead auction price 40 EUR/MWh. The prop trader therefore opens a short position and sells 100 MW at 40 EUR/MWh on Monday at 12h00 a.m.

Under both **price development Ia** and **price development Ib**, the *prop trader's* risk capital of EUR 1'000 each is used up on Monday at 20h00: The market price has increased to EUR 50, the *prop trader* records an unrealized loss of EUR 100*40 - 100*50 = EUR 1'000, therefore *the prop trader* is obliged to *close out* the open short position in the amount of 100 MW. This is done by purchasing 100 MW at the market price of 50 EUR/MWh. The *prop trader* has used up the risk capital under these two price developments and may not trade again until new risk capital is allocated.

Under the **price development IIa** and **IIb**, the prop trader finds an unrealized profit of EUR 1'000 each on Monday at 20h00. If *the prop trader* decides to realize the profits in the amount of EUR 2*1'000, the losses in the amount of EUR 2*1'000 from price developments Ia or Ib are compensated. If the prop trader decides to leave his short position open and to close out the open short position (sale of 100 MW) on Tuesday at 8h00, the prop trader will experience a loss of EUR 1'000 under price development IIa and a profit of EUR 3'000 under price development IIb. Again, due to the *martingale property* of the discrete price process the losses in the amount of EUR 3*1'000 and the profits in the amount of EUR 3'000 compensate each other.

v) Summary

We note that using the replication approach results in exclusively positive cash flows for the *asset-backed trader* across all four selected price developments. In case of a physical delivery, the *asset-backed trader* will receive the value of the physical delivery (200 MWh) based on the market-clearing price of the day-ahead auction in the amount of EUR 8'000 (= 200 MWh *40 EUR/MWh), as well as an additional EUR 1'000 and EUR 1'500 by means of the replication strategy under price developments Ia and IIa, which corresponds to 25% and 37.5% of the market value of the physical delivery, respectively. The replication strategy generates further earnings of EUR 1'000 and EUR 500 in those two price developments Ib and IIb, respectively, in which no physical delivery takes place.

Over all four price developments, a physical delivery of 200 MWh results. In addition to the market value of the physical delivery of EUR 200*40 = EUR 8'000, a further EUR 4'000 is generated on the basis of the replication strategy in *asset-backed trading*. The resulting added value is 20 EUR/MWh (= EUR 4'000/200 MWh) and thus 50% of the day-ahead market price.

Assuming equal probability of the four price scenarios we get an expected physical delivery in the amount of 50 MWh with a market value of EUR 2'000, an expected further EUR 1'000 is generated based on the replication strategy in asset-backed trading. The resulting expected added value is 20 EUR/MWh (= EUR 1'000/50 MWh) and thus in expectation 50% of the day-ahead market price. This added value depends directly on the volatility: the greater/smaller the volatility, the greater/smaller the added value in *asset-backed trading.*

A *prop trader* faces a loss of EUR 1'000 under each of the three price developments Ia, Ib and IIa and a profit of EUR 3'000 under price development IIb. In total, across all price developments, the balance is zero. This is not a coincidence, but a consequence of the assumed arbitrage-free market with the underlying martingale property of the selected price process. The greater the volatility of the market price, the faster the loss limit of the *prop trader* is reached, whereupon the trader - if no new risk capital is spoken - must refrain from further trading activities.

Above, we have disregarded transaction costs. Thus, we may conclude that under the assumption of arbitrage-free markets, the *prop trader* has no sustainable profit potential, but rather incurs trading losses when transaction costs are included.

B) Importance of transparency and efficiency in trading

The Swiss Federal Electricity Commission (ElCom) is responsible for monitoring competition on the Swiss electricity market and securing compliance with the Swiss Federal Electricity Supply Act (Strom VG) [4].

Fixed end users in the Swiss *Grundversorgung* (i.e. the Swiss definition of basic supply within StromVG), have to pay regulated electricity tariffs, which have to be determined on the basis of generation costs of the power plants as well as on costs of long- and short-term contracts of the DSO. The Swiss Electricity Supply Ordinance (StromVV) requires that the generation costs applicable for the determination of eletricity tariffs have to be based on an *efficient* production and contracts of the distribution system operator. The legally binding criteria under which electricity production is judged to be efficient, have developed over time through the outcome of appealings filed against ElCom rulings in the Swiss Federal Administrative Court, in the Swiss Federal Supreme Court, respectively[5]. The generation costs of the own production of a DSO have to cover all power plants with location in Switzerland or electricity delivery into market area Switzerland for complying with StromVV[6],[7]. Focusing on a subportfolio of expensive power plants would not comply with StromVV.

Further, also the price of pumped energy requires special attention as these costs take a part in the long- and short term contracts of the DSO. In order to comply with Strom VV, the electricity tariffs have to be based on observed prices in active markets, like the day-ahead market for the market area Switzerland. In particular, according to rulings of ElCom any model based input and therefore any model driven price forward curve (PFC) is not accepted for getting part of the electricity tariffs. The reason for rejecting the application of price forward curves in the rulings of ElCom is due to the fact, that price forward curves are also based on estimations and assumptions made by the management, which finally put the quantification of pumping costs at model risk. As immediate consequence the cost efficiency in the production might be lost. This argumentation has been protected by the Swiss Federal Supreme Court[8]. We recognize in the ruling of ElCom, that the wording "efficient production" for complying with StromVV focuses on "cost efficiency" of the own production and contracts of the DSO.The earnings generated through own production are not part of the generation costs.

In the past 10 years various DOSs filed appeals against ElCom rulings in the Swiss Federal Administration Court, in the Swiss Federal Supreme Court, respectively. We shortly reflect the outcome of those appeals, that relate to the methodology applied by ElCom[9] of how to determine regulated electricity tariffs in compliance with Strom VG. Therein the Swiss Federal Administrative Court[10] considers that a) it remains to be verified whether the shortages

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[4] ElCom (2010): Report on the Activities of ElCom 2009.

[5] Frauendorfer K., (2021): *Teilliberalisierung Marktgebiet Schweiz – gefangen in der Unvollständigkeit*, in: Geiser Thomas/Hilb Martin/Pärli Kurt/Stengel Manuel/Wittmer Andreas (Hrsg.): Ein Kunstflug durch das Recht und die Governance – Festschrift zum 65. Geburtstag von Roland Müller, Zürich/St. Gallen 2021, S. 199 – 216.(Link).

[6] Bundesverwaltungsgericht: Urteil A-1344/2015 (28. Juni 2018)

[7] Bundesgericht: Urteil 2C_739/2018 (8. Oktober 2018)

[8] Bundesgericht: Urteil 2C_297/2019 (28. Mai 2020)

[9] ElCom: Verfügung 211-00033 (20. August 2020)

[10] Bundesverwaltungsgericht: Urteil A-1107/2013, 9.2, (3. Juni 2015)

claimed by the distribution network operators actually exist and whether the conclusion of the corresponding short-term supply contracts was indeed necessary, b) ElCom is to review whether the company's own production facilities are actually used at times when electricity procurement on the market is relatively expensive, or whether electricity is purchased at favourable prices, and c) the distribution system operators know down to the hour how much they produce and who buys how much energy.

The Swiss Federal Supreme Court[11] also considers ElCom to be under an obligation to critically examine the prices charged for purchased energy if there are indications that these are being used at an abusively high level.

In our view, the considerations of the Federal Administrative Court and the Federal Supreme Court imply that speculative proprietary trading transactions in particular are not permitted for setting energy tariffs for the basic supply. The management of short- and long-term contracts generally comprises trading transactions, which could also include proprietary trading. If no strict separation is required between asset-backed trading and proprietary trading, hidden incentives are created to finance losses from proprietary trading via energy tariffs in the basic supply. As a direct consequence, there would be impermissible cross-subsidization, since the end user would finance losses from proprietary trading. As we understand it, ElCom is thus responsible for checking whether losses in proprietary trading are included in the regulated electricity tariffs for the basic supply and are therefore co-financed by the fixed end users.

In its report on market surveillance ElCom points to the legal situation already in May 2019, under which ElCom only receives data that Swiss market participants report to foreign authorities, and trade in electricity that takes place exclusively within Switzerland remains closed to ElCom. ["As a result, ElCom is unable to fully monitor the Swiss wholesale market. There are also no possible sanctions in the event of market abuse or insider trading."] [12] ElCom concludes: ["Market manipulation and insider trading in electricity wholesale are not prohibited in Switzerland today and therefore cannot be sanctioned. This stands in contrast to traditional exchange trading in Switzerland and energy trading in the EU. The necessary legal foundations must be created in order to close this loophole"] [13].

Due to the distortions on the energy markets in the second half of 2021 as well as in 2022 and the resulting threat of liquidity constraints, the Federal Council sent a federal law (GATE) on supervision and transparency in the wholesale energy markets for review in December 2022. The new law serves to close the loophole mentioned by ElCom, so that ElCom is able to also carry out those checks which are listed in the rulings of the Swiss Federal Supreme Court.

i) Efficient management of pump storage plants

Aiming for efficient management, the turbine and pump operations must be matched to each other in the most effective manner regarding costs and earnings. It is undisputed that the capacities of pump storage power plants have high flexibility and that the value of this

[11] Bundesgericht: Urteil 2C_681/2015, 2C_682/2015, 5.2.8, (20. Juli 2016)

[12] ElCom (2019): Report on Market Surveillance 2018 (p. 4).

[13] ElCom (2019): Report on Market Surveillance 2018 (p. 30).

flexibility strongly depends on the meterological framework conditions. We therefore consider it imperative that in particular the short-term weather forecasts are taken into account in the efficient coordination between turbine and pumping operations in order to keep the costs for pumping energy sufficiently low. For achieving this, the asset backed trader has to rely on price forward curves (PFC) in hourly or quarter-hourly granulation.

From the perspective of financial mathematics, storage and pump storage power plants represent a complex portfolio of options that not only carry exercise rights, but also obligations[14]. To determine the optimal use of pumps and turbines resulting from inherent option rights and obligations, electricity traders look to near-term price and inflow forecasts. As a direct consequence, volatility in the spot market is not primarily to be classified as a risk for pumped-storage power plants, but as an opportunity to increase the efficiency in the net gains.

It is important to operate the pumps in the most cost-effective hours. We will illustrate below how the flexibility value of a pumping capacity can be monetized using the same simplified price dynamics, as we have used for illustrating the flexibility value of turbines. Likewise, we will talk about the asymmetry between the operating partner and the non-operating partners.

Spot prices in the day-ahead and intraday markets are subject to high volatility. In addition to the price level, the seasonality of spot prices is of great relevance. Seasonality is modeled on the basis of the historical market clearing prices of the day-ahead auctions (*Phelix* for market area Germany, *Swissix* for market area Switzerland) via the hourly and quarter-hourly PFC. These show the daily, weekly, and annual seasonality over the current year up to and including the fifth subsequent year[15]. The price level of an arbitrage-free PFC is determined by the observable prices of the underlying futures tradable on energy exchanges (e.g., the EEX). Since seasonality is derived from time series or fundamental models that incorporate individual assumptions about demand and supply developments in the underlying market area, there are ambiguities in the generation of hourly forward prices and quarter-hourly forward prices, respectively. These ambiguities manifest themselves at the short end of the PFC in the various shapes, which are subject to a large dependence on short-term weather forecasts.

According to our discussions[16] the ambiguities in the fair value of a schedule that cannot be replicated using futures increase with the forecast horizon: on the one hand, there are no reliable weather forecasts, and on the other hand, the granularity of the standardized delivery periods anchored in the futures decreases sharply in the longer term. It is the incompleteness of OTC markets which cause those ambiguities in the fair value. We recall, that an arbitrage-free market completeness implies the existence of a unique martingale measure, and *vice versa*. However, if an arbitrage-free market is incomplete, one is faced with nonunique martingale measures[17]. This applied to incomplete energy markets immediately implies nonunique fair values of those schedules for pumps or turbines, that cannot be replicated with futures.

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14 Haarbrücker G., Kuhn D. (2009): "*Valuation of Electricity Swing Options by Multistage Stochastic Programming*", Automatica 45, 889-899. (Link)

15 https://www.iorcf.eu: Hourly Price Forward Curves for market areas Germany/Austria (since 2008), Switzerland (since), Austria (since 2017), Germany (since 2017).

16 Frauendorfer K., Gutsche R., Haarbrücker G., Liebenberger C., Schürle M. (2020): *Spannungsfeld: Stromversorgung vs. Stromhandel: Herausforderungen für das Management*, White Paper, ior/cf-HSG, Universität St.Gallen, S.25ff (Link).

17 see e.g., Björk, T. (2020): *Arbitrage Theory in Continuous Time*, Chapter 3 & 9, 4th edition, Oxford University Press.

The ambiguities are much more pronounced for the market area Switzerland than for the market area Germany, as long as futures for the market area Switzerland only cover base deliveries and no peak deliveries. In addition, it should be mentioned that in exchange trading, the liquidity of base futures for market area Switzerland is only a fraction of the liquidity of base futures for market area Germany.

Comparing liquidity within futures trading between the annual base delivery for market area Germany and the annual base delivery for market area Switzerland, we find the following as of trading day September 28, 2020: In the period from January 1, 2020, to September 28, 2020, the trading volume in annual base futures (market area Switzerland) totaled 131 GWh and that in annual base futures (market area Germany) totaled 658'140 GWh. Thus, the trading volume for annual futures of market area Germany is roughly 5'000 times larger than that for annual futures of market area Switzerland. Considering that market area Germany consumes about 10-times more electricity, the ratio is 1:500. We interpret this to reflect the fact that electricity trading for market area Switzerland takes place almost exclusively via OTC trading. In order to quantify the trading costs for OTC transactions, knowledge of the spreads (i.e., difference between buy and sell prices), as well as the imbalance (i.e., the difference between the volumes on the buy and sell side) is important. Based on relevant discussions with electricity traders, we have observed transaction costs between 100-500 bps in the OTC platforms depending on the maturity. It is reasonable to assume that the costs in OTC trading are substantially caused by the ambiguities in the determination of the PFC. Therefore, we also do not consider it reasonable, even price distorting, to adjust the PFC to the prices of OTC trades. In any case, on the part of electricity trading, the ambiguities and high costs in OTC transactions must be considered.

We understand Strom VV with its requirement for efficient production, to mean that account must be taken of ambiguities in the determination of hourly forward prices as well as trading costs. Pump schedules cannot be modeled using a portfolio of futures. Further, we consider it necessary for the short-term weather forecasts to be incorporated into the modeling of hourly forward prices, of quarter-hourly forward prices, respectively. The short-term marketing of the pump storage power plant is therefore based on the short end of the PFC. In the medium-term management, trading decisions are to be implemented accordingly as soon as the reduction in volume and price risks significantly exceed the estimated trading costs and simultaneously dominate the underlying ambiguities.

We have quantified the impact of short-term weather forecasts on price levels[18] and shape in the day-ahead auction (Swissix)[19]. In what way the price level and shape of the *Swissix* contribute to an efficient application planning of turbines and pumps is briefly shown below.

Trigger prices for turbines and pumps are relevant for the marketing of electricity production in spot trading. As an example, consider a weekly storage facility for which, based on current storage levels and projected inflows, optimal use of the turbines is for 32 hours and that of the pumps is for 40 hours. The 168 hourly forward prices of the first week are determined in terms of levels and shape by the weather forecasts. By approximation, the 32 most expensive hours of the total 168 hours in a week will be allocated to the turbine and the cheapest 40 hours to

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[18] Frauendorfer, K., Gutsche R. (2023): *Bilanztransparenz und Effizienz im Energiehandel*, Seminarunterlagen, Durchführung am 21. April 2023, ior/cf-HSG, Universität St.Gallen, S. 130ff (Link).

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the pump. This defines the trigger price for the turbine as the smallest among the 32 most expensive forward prices, and the trigger price for the pump as the largest among the 40 cheapest hours of the hourly PFC. The trigger prices correspond to the strike prices of the underlying call and put options over the 168 hours of a week. Generally, under equal inflow forecasts, the trigger price for turbines falls or rises as the water level rises or falls. Similarly, the trigger price for pumps falls or rises as the level of the upper reservoir rises or falls.

If the trigger prices are calculated on a rolling basis every day as part of weekly planning, incorporating new weather forecasts, this results in new trigger prices every day, which are used as the basis for marketing on the spot market. With the help of *ex-ante* calculated price processes (with price level and shape stochastically depending on storage level and weather forecasts), these trigger prices form the basis for bidding in the day-ahead market and for trading in subsequent intraday trading.

For weekly and annual storage, we can assume that the trigger prices for the following day's 24 hourly electricity deliveries are constant and are determined daily. If, in real time, there is greater precipitation than the model is based on, the trigger prices for turbines and pumps are reduced. There is more water in the reservoir, which increases the need to call the turbine more often and the pump less often. The same applies *vice versa* if, in real time, there is significantly less precipitation than the model is based on. It is these short-term developments in the weather, as well as forecasts about them, that lead to efficient schedules for pumps and turbines. The interaction of the schedules of turbines and pumps defines the efficiency for the net gains of the pumped-storage power plant. The observed market value of the realized pumping schedule represents the cost component as part of the full generation costs that we believe should be passed on to the fixed end users under StromVV.

For the sake of completeness, we note that in the case of daily storage, trigger prices are to be recalculated hourly. Therefore, trigger prices for hourly electricity deliveries will vary over the 24 hours of the following day. For daily storage, therefore, short-term management is even more relevant with the lens of StromVV.

ii) Exercising flexibility efficiently

Due to the valuable flexibility to use turbines and pumps of pump storage power plants on an hourly basis, these power plants are suitable for the use of system services. From financial mathematics, system services can be modeled as written options from the electricity trader's point of view, which give the transmission system operator the right to exercise the flexible power capacity at any time within the agreed contract period. Since the contracted flexible turbine and pump capacities cannot be used for spot trading simultaneously, the value of the written option - i.e., the fair value of this exercise right - is determined by the opportunity costs. This fair value should form the basis for the offer to the transmission system operator. The transmission system operator is only granted the exercise right to access turbine and pump capacities during the contract period.

It is up to the operating partner to choose which power plants comply with a call from the TSO in the most efficient way. The operator's electricity trader will choose the power plant of that storage lake with the lowest trigger price for the turbine when turbine power is required. Similarly, when a pumping capacity is required, the power plant of the reservoir with the highest trigger price for the pump will be chosen.

Reservoir levels change at short notice and are subject to regional fluctuations due to regional differences in precipitation and inflows. As a result, trigger prices also fluctuate, which means that the additional value creation potential of the storage lakes varies in the short term. Based on these relationships, the power plants that are suitable for system services are combined in a pooled system.

With the very short-term demand, there is additional value-creation potential for the operating partner. Both temporally and contractually, to our knowledge, the other partners have no influence on the choice of which power plant *de facto* supplies the system service.

iii) *Asymmetric information in asset-backed trading*

We will show by way of example how, within spot trading, the consumption of electricity and the provision of pumping capacity are valued separately from each other, and what effects different trading periods - due to different maturities, defined through so called gate closures - entail for operating partner and non-operating partners. We understand the hourly auction-based market clearing price of the hourly schedule for pumping capacity reported to the operating partner to be the relevant price for pump energy in the replication concept. This price is determined independently of the contractual structures between the operating partner and the other (i.e., non-operating) partners.

We understand the difference between trading result from asset-backed trading in spot trading and the hourly auction-based market price of the schedule for pumping capacity reported to the operating partner as trading savings generated by holding pumping capacity in reserve. These trading savings can also be interpreted as time value for flexibility of the implied option portfolio, which is why we refer to it as the flexibility premium for pumps.

We recognize that on the part of the operating partner there is not only a consolidation of the schedules of the other partners, but also an overriding of their schedules. This override results from the additional earnings potential associated with price developments between the different gate closures. This override makes economic sense and increases economic efficiency. In our view, corresponding incentives should therefore not be prevented.

For the present question, trading transactions for electricity via the spot market are relevant, which means that the trading period extends over several hours. We distinguish two maturities defined through two gate closures: gate closure I is the point in time when the non-operating partners report the scheduling of their proportional pumping capacities as a schedule to the operating partner. gate closure II is that later point in time when the operating partner reports the final schedule for the pumping capacities to the TSO. Especially in the first years of partial liberalization within Switzerland, the number of timetables that non-operating partners were allowed to hand over to the operating partner was very limited per trading day. In those years, as a direct consequence, there was a remarkable asymmetry - between operating partner and the other partners - in the degrees of freedom to manage their own shares of storage energy.

To apply the replication strategy to flexible pump capacity, we use the same discrete price dynamic of above (Figure 2): Let the *asset-backed trader* manage a pump capacity of 100 MW. According to the current storage level, the hourly forward price and inflow forecasts, let the value of the available water in the reservoir be assessed at 42 EUR/MWh. This price represents the *trigger price,* thus the price threshold up to which it is economically justified to use the pumps, and thus purchase electricity from the market to pump the water into the upper reservoirs.

On Monday, in the day-ahead auction, let the *asset-backed trader* offer 50% of the available pumping capacity (i.e., 50 MW) at a price of 42 EUR for an electricity consumption on Tuesday (9-10), another 25% of the pump capacity (25 MW) at a price of 32 EUR, and the final 25% of the pump capacity for a price of 22 EUR. This type of staggering of flexible pumping capacities again characterizes the initial step of the replication concept.

On Monday 15h00, let intraday trading (ID trading) begin for all hourly and quarter-hourly electricity deliveries of the following day (day-ahead), also for those day-ahead electricity deliveries on Tuesday between 9-10 a.m. (e.g., on EPEX SPOT). Within the framework of continuous ID trading, let the hourly product be tradable on the energy exchange until 15 min before the start of delivery, i.e., until 8h45 a.m. Gate closure II being of relevance for the operating partner thus falls at 8h45 a.m.

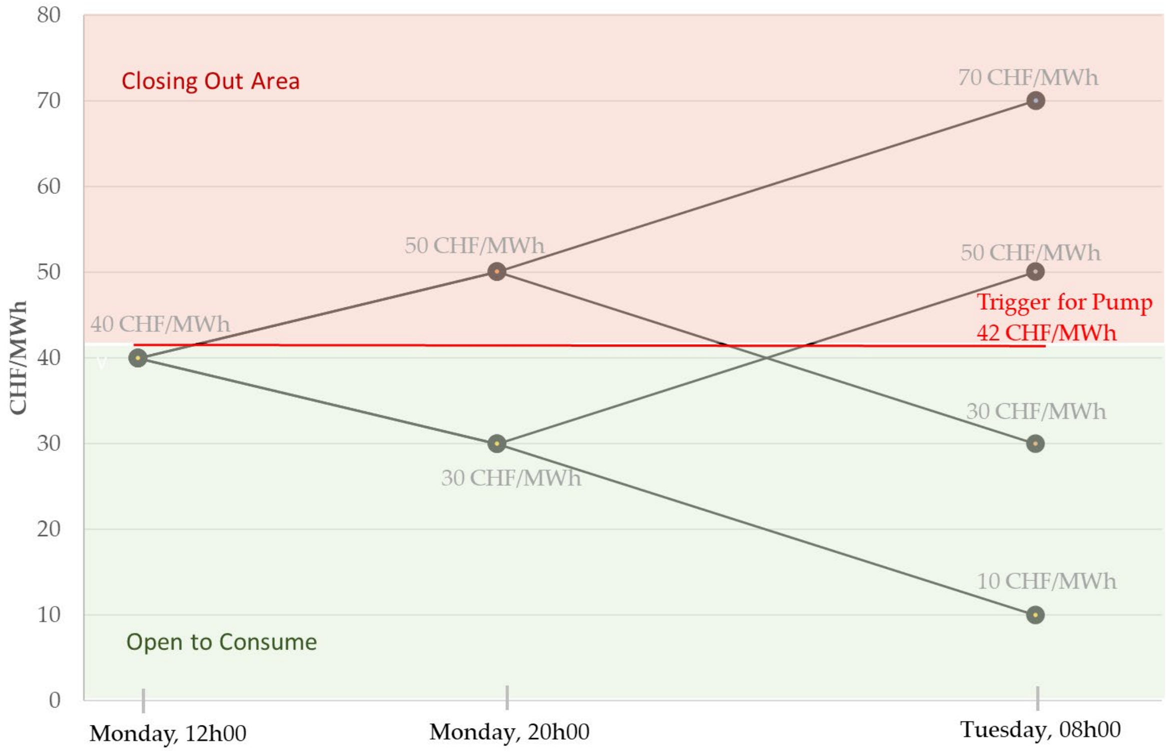

Figure 2: Representation of the four price developments incl. trigger price for pump at the designated trading points

With Figure 2, we recall the same four price developments (Ia, Ib, IIa, IIb) in intraday (ID) trading for electricity consumption on Tuesday, 9-10 a.m., again limiting ourselves to two points in time (to Monday 20h00, eight hours after the day-ahead auction, and to Tuesday 8h00, one hour before the start of delivery) for adapting the trading decision.

Price development Ia: ID price: Mon 20h00, at 50 EUR/MWh; Tue 8h00 at 70 EUR/MWh,
Price development Ib: ID price: Mon 20h00, at 50 EUR/MWh; Tue 8h00 at 30 EUR/MWh,
Price development IIa: ID price: Mon 20h00, at 30 EUR/MWh; Tue 8h00 at 50 EUR/MWh,
Price development IIb: ID price: Mon 20h00, at 30 EUR/MWh; Tue 8h00 at 10 EUR/MWh.

Let the day-ahead auction deliver a market clearing price of 40 EUR/MWh, which is below the trigger price of 42 EUR/MWh for electricity delivery (Tuesday 9-10 a.m.). Herewith, the asset-backed trader is obliged to consume electricity on Tuesday 9-10 a.m. in the amount of 50 MWh.

Below, we work out the added value for the asset-backed trader of both, of the operating partner as well as of the other (i.e., the non-operating) partners of the pump storage power plant. For didactic purposes, gate closure I is set at Monday 20h00 and assigned to the non-operating partners, gate closure II is set at Tuesday 8h00 and assigned to the operating partner.

iv) Added value in asset-backed trading under gate closure II.

The **operating partner** is required to report their pumping capacity deployment schedule to the transmission system operator at gate closure II in accordance with their bilateral contractual relationship.

Under **price development Ia**, on Monday 20h00 the asset-backed trader of the operating partner will close out (i.e., sell) the via day-ahead auction already contracted 50 MW of pumping capacity, because the ID price has risen to EUR 50, and is thus above the trigger price of EUR 42. On Tuesday at 8h00 there is no need for action because the ID price of EUR 70 is above the trigger price of EUR 42. The asset-backed trader of the operating partner does not commit to consume electricity at gate closure I as well as for Tuesday 9-10 a.m. at gate closure II.

The earnings achieved in the day-ahead auction and ID trading under price development Ia are: EUR -50*40 + 50*50 = - 2'000 = EUR +500. This generates earnings through asset-backed trading in the spot market without consuming electricity. It is therefore economically more efficient not to pump water into the upper reservoir.

Under **price development Ib**, on Monday 20h00 the asset-backed trader of the operating partner will close out (i.e., sell) the via day-ahead auction already contracted 50 MW of pumping capacity, because the ID price has risen to EUR 50, and is thus above the trigger price of EUR 42. On Tuesday at 8h00, however, he will purchase power from the market for the available 100 MW of pumping capacity, because the ID price has fallen to 30 EUR/MWh - below the trigger price of 42 EUR/MWh. Thus, it is economically more efficient to pump water into the upper reservoir using the available pumping capacity. The operating manager's asset-backed trader commits to consume 100 MWh at gate closure II.

The financial expenses in the day-ahead auction and ID trading under price development Ib are: EUR - 50*40 + 50*50 - 100*30 = - 2'000 + 2'500 - 3'000 = EUR - 2'500. Important (under price development Ib) is the comparison between the financial expenses to the market value of the consumption in the day-ahead auction. The resulting costs are EUR 1'500 lower due to asset-backed trading, compared to the costs of EUR 4'000 resulting from the day-ahead market. The resulting savings are EUR 1'500 and represent the added value generated due to asset-backed trading in the ID market, which equals 37.5% of the corresponding market value in the day-ahead market.

Under **price development IIa**, on Monday 20h00 the asset-backed trader will buy another 25 MW, as the price is 30 EUR/MWh, further below the trigger price of 42 EUR/MWh. At this point in time, it is economically more efficient to pump water into the upper reservoir at a pumping rate of 75 MW. At that point, the asset-backed trader of the operating partner is obliged to consume electricity.

However, on Tuesday 8h00 the asset-backed trader of the operating partner will sell and therefore close out the contracted pumping capacity of 75 MW, as the price has risen to 50 EUR/MWh, above the trigger price of 42 EUR/MWh. The pump is not used, and no electricity is consumed on Tuesday 9-10 a.m.

The financial earnings in the day-ahead auction and ID trading under price development IIa are: EUR - 50*40 - 25*30 + 75*50 = - 2'000 - 750 + 3'750 = EUR 1'000. Thus, analogously to price development Ia, additional earnings are generated by asset-backed trading in the spot market without consumption. The underlying trading transactions lead to positive cash flows and are therefore settled exclusively in financial terms.

Under **price development IIb**, on Monday 20h00 the asset-backed trader of the operating partner will buy additional 25 MW for pump deployment, as the ID price 30 EUR/MWh remains below the trigger price of 42 EUR. As the market price remains below the trigger price at 10 EUR/MWh on Tuesday 8h00, the remaining available 25 MW will be purchased for pumping the water.

The financial expenses in the day-ahead auction and ID trading under price development IIb are: EUR - 50*40 - 25*30 - 25*10 = - 2'000 - 750 - 250 = EUR - 3'000. Important (under price development IIb) is again the comparison between the financial expenses to the market value of the consumption in the day-ahead auction. The resulting costs are EUR 1'000 lower due to asset-backed trading, compared to the costs of EUR 4'000 resulting from the day-ahead market. This results in an added value from asset-backed trading in spot trading in the amount of EUR 1'000 or 25% of the market value in the day-ahead market.

v) Added value in asset-backed trading under gate-closure I

The non-operating p**artner** is required to report the pumping capacity deployment schedule to the operating partner a few hours prior to gate closure II in accordance with the bilateral contractual relationship with the operating partner. We will assume below, purely for didactic purposes, that gate closure I is Monday at 20h00. This is the latest time point for the asset-backed trader of the non-operating partner to adapt the trading decision.

In the present case, the trading time Tuesday 8h00 is irrelevant for the non-operating partner. Thus, we determine costs and earnings of the replication strategy under the same four price developments but for the reduced trading period:

Price development I (i.e., Ia Ib): ID price: Mon 20h00, at 50 EUR/MWh.
Price development II (i.e., IIa, IIb): ID price: Mon 20h00, at 30 EUR/MWh.

Under **price development I**, on Monday at 20h00 the partner's asset-backed trader will close out (i.e., sell) the via day-ahead auction already contracted 50 MW of pumping capacity, as the price is 50 EUR/MWh, exceeding the trigger price of 42 EUR/MWh. Thus, under gate closure I, the partner's asset-backed trader does not commit to the operating partner to consume any electricity on Tuesday 9-10 a.m.

The imputed earnings in the day-ahead auction and ID trading under price development I are: EUR -50*40 + 50*50 = - 2'000 + 2'500 = EUR +500. This generates earnings through asset-backed trading in the spot market without consuming electricity. It is economically more efficient for the partner not to pump water into the upper reservoir at gate closure I.

Under **price development II**, on Monday at 20h00 the partner's asset-backed trader will buy the remaining 50 MW, as the price is 30 EUR/MWh, further below the trigger price of 42 EUR/MWh. At this point, it is economically more efficient for the partner to pump the water into the upper reservoir at a pumping rate of 100 MW. At that time, the partner's asset-backed trader is obliged to the operating manager to consume electricity.

The financial expenses in the day-ahead auction and ID trading under price development II are: EUR - 50*40 - 50*30 = - 2'000 - 1'500 = EUR - 3'500. Important (under price development II) is again the comparison between the financial expenses to the market value of the consumption in the day-ahead auction. The resulting costs are EUR 500 lower due to asset-backed trading, compared to the costs of EUR 4'000 resulting from the day-ahead market. For the partner, this results in savings and therefore generating added value from asset-backed trading in spot trading in the amount of EUR 500 or 12.5% of the market value in the day-ahead market.

vi) Summary

We note that using the replication concept results in positive value added for **the asset-backed trader of the operating partner** across all four selected price developments. If a consumption of electricity occurs, the asset-backed trader of the plant operating partner on the one hand applies the value of the consumption (200 MWh) on the basis of the market-clearing price of the day-ahead auction in the amount of EUR 8'000 (= 200 MWh *40 EUR/MWh), and generates savings of additional EUR 1'500 and EUR 1'000 by means of the replication strategy under price developments Ib and IIb. This corresponds to an added value in the amount of 25% and 37.5% of the market value of the electricity consumption, respectively.

The replication strategy generates an added value of EUR 500 and EUR 1'000 in those two price developments Ia and IIa, respectively, in which no electricity is consumed.

Across all four price developments, this results in an electricity consumption of 200 MWh. In addition to the market value of the electricity consumption EUR 200*40 = EUR 8'000, a further EUR 4'000 is generated on the basis of the replication strategy in asset-backed trading. The resulting added value for the operating partner is 20 EUR/MWh (= EUR 4'000 / 200 MWh) and thus 50% of the day-ahead market price.

Assuming equal probability of the four price scenarios we get an expected consumption in the amount of 50 MWh with an expected market value of EUR 2'000. In expectation, further savings are generated in the amount of EUR 1'000 due to the replication strategy of the operating partner. The resulting expected added value for the operating partner is 20 EUR/MWh (= EUR 1'000/50 MWh) and equals in expectation 50% of the day-ahead market price.

For the **asset-backed trader of the non-operating partner**, we can state that applying the replication concept over the reduced trading period results in a positive added value. This added value of the non-operating partner is lower than that of the operating partner. This is because gate closure I entails a shorter action period compared to gate closure II.

Under price development I and thus also under the two price developments Ia, Ib, there is no consumption. The non-operating partner's asset-backed trader will sell and therefore close out the via day-ahead auction already contracted 50 MW of pumping capacity on Monday at 20h00, as the price is 50 EUR/MWh, exceeding the trigger price of 42 EUR/MWh. The non-operating partner's asset-backed trader generates proceeds of EUR 500 under each of the two price developments Ia, Ib.

Under price development II and thus also under the two price developments IIa, IIb, there is a consumption of electricity. The non-operating partner's asset-backed trader spends a total cost of EUR – 3’500 (= - 50 MWh * 40 EUR/MWh - 50 MWh * 30 EUR/MWh) for consuming electricity (100 MWh each) based on the market-clearing price of the day-ahead auction and the ID price on Monday, 20h00. By means of the replication strategy under price developments IIa and IIb, an added value of EUR 500 each is generated compared to the day-ahead auction, which corresponds to 12.5% of the corresponding market value in the day-ahead market.

The replication strategy generates an added value for the non-operating partner of EUR 500 each under the four price developments Ia, Ib, IIa and IIb.

Overall, an electricity consumption in the amount of 200 MWh results over the reduced trading period under the four price developments. In addition to the day-ahead market value of the electricity consumption in the amount of EUR 200*40 = EUR 8'000, a further EUR 2'000 (EUR 500 each under the four price developments Ia, Ib, IIa and IIb) is generated in the non-operating partner's asset-backed trading based on the replication strategy implemented in the reduced trading period (i.e., up to gate closure I). The resulting added value is 10 EUR/MWh (= EUR 2'000/200 MWh) and equals 25% of the day-ahead market value.

Assuming equal probability of the four price scenarios we get an expected consumption in the amount of 50 MWh with an expected market value of EUR 2'000. In expectation, further savings are generated in the amount of EUR 500 due to the replication strategy of the non-operating partner. The resulting expected added value for the non-operating partner is 10 EUR/MWh (= EUR 500/50 MWh) and thus in expectation 25% of the day-ahead market price.

The added value depends directly on the volatility: the greater/smaller the volatility, the greater/smaller the added value in asset-backed trading.

From the above contexts we conclude that on the part of the operating partner not only a consolidation of the non-operating partners' schedules takes place, but also an overriding of the reported schedules can be of added value. This override results from the additional earnings potential associated with the price developments between gate closures I and II. Economically, this override makes sense. The associated added value ought to be compensated in the underlying contracts.

Selected textbooks covering *Derivatives* and *Asset Pricing*

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[5] Frauendorfer K., Gutsche R. (2021): *Empirische Analysen zu Finanzberichten der Alpiq, Axpo und BKW (Geschäftsjahre 2009-2018): Eine Studie für die Stakeholders der Schweizer Stromwirtschaft zur Prüfung,* ior/cf-HSG, Universität St.Gallen (Link zur Studie)

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[7] https://www.iorcf.eu: Hourly Price Forward Curves for market areas Germany/Austria (since 2008), Switzerland (since), Austria (since 2017), Germany (since 2017).