Deliverable 3.2:

MARKET ARCHITECTURE, CONTRACTS AND REAL-TIME PRICE EXPOSURE OF LARGE INDUSTRIAL CONSUMERS

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This note summarizes the preliminary findings from the analysis of the electricity supply contracts of industrial consumers connected to the transmission grid in Belgium between 2014-24. The data were obtained from CREG under a non-disclosure agreement.

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1. Problem definition

Work package 3.2. examines how the architecture of the electricity market mediates demand response from industrial consumers. Industrial consumption accounts for a large share of total electricity consumption in most advanced economies, and while this consumption is largely baseload, some industrial processes are, in fact, flexible. Batch production can be shifted in time to match the electricity system conditions. Cold storage can rely on thermal inertia to modulate energy use. Some industrial sites with cogeneration can switch to other energy sources when electricity prices are high.

Tapping into this flexibility requires that these industrial consumers be incentivized to adjust their load to market conditions. This is where market architecture matters. Electricity markets in continental Europe operate through a system of Balancing Responsible Parties (BRPs), which aggregate generation assets and loads and are incentivized to maintain the balance between generation and load within their perimeter. BRPs are the only entities authorized to participate in wholesale markets. Most industrial consumers are not BRPs but instead contract with BRPs to purchase electricity. The degree to which they are exposed to market conditions, therefore, depends on these contractual arrangements.

Market conditions for eliciting industrial demand response are much less well understood than demand response by retail consumers. The reason is that contractual terms tend to be consumer-specific and are not public information. There are a few empirical studies that exploit situations where contracts are observed (see e.g. Patrick and Wolak, 2001, Schwarz et al., 2002, Jessoe and Rapson, 2015), but they are now dated. A few studies use interviews to uncover the obstacles to flexibility (e.g. Olsthoorn et al., 2015, Leinauer et al., 2022, Scharnhorst et al, 2024). To our knowledge, our research as part of work package 3.2. is the first to exploit granular contract information and to do so, in a changing context where flexibility is increasingly encouraged.

2. Description of datasets

We have obtained access – through a non-disclosure agreement with the CREG – to all contracts signed between 2014 and 2024 between the three largest BRPs and their industrial consumers (defined as consumers with an offtake above 10 GWh per year) connected to the transmission grid. We manually extracted from the contract PDFs information on the customer (access points, location of consumption site, reference consumption volume, on-site generation unit characteristics) and on the contract terms (pricing, exclusivity clauses, flexibility clauses, etc).

Some contracts do not specify the price but let the customer secure specific prices (hedge) by "clicking" on forward prices offered through the BRP. CREG also gave us access to those clicks, as well as the consumers' hourly net offtake, so that we can reconstruct the exact price that consumers end up paying for their electricity consumption.

The contract dataset contains 413 contracts for a total of 676 contract x year observations. Most contracts last for two years, but some are shorter and others are longer. The average contract duration in our data is 1.78 years. Table 1 reports the number

of distinct consumers (identified by the VAT number), sites and EAN connection points for every year in the sample. On average, we have 61 active contracts per year.[1]

Table 1: Contract sample description

Year	Consumers	Sites	EANs	Active contracts
2014	60	85	155	59
2015	63	88	158	61
2016	57	78	147	56
2017	57	79	145	58
2018	59	83	93	61
2019	56	76	144	56
2020	66	91	160	67
2021	69	95	163	70
2022	65	91	160	64
2023	65	89	158	64
2024	61	85	151	60
All years	90	122	201	413

Figure 1: Data coverage of large industrial consumers connected to the transmission grid

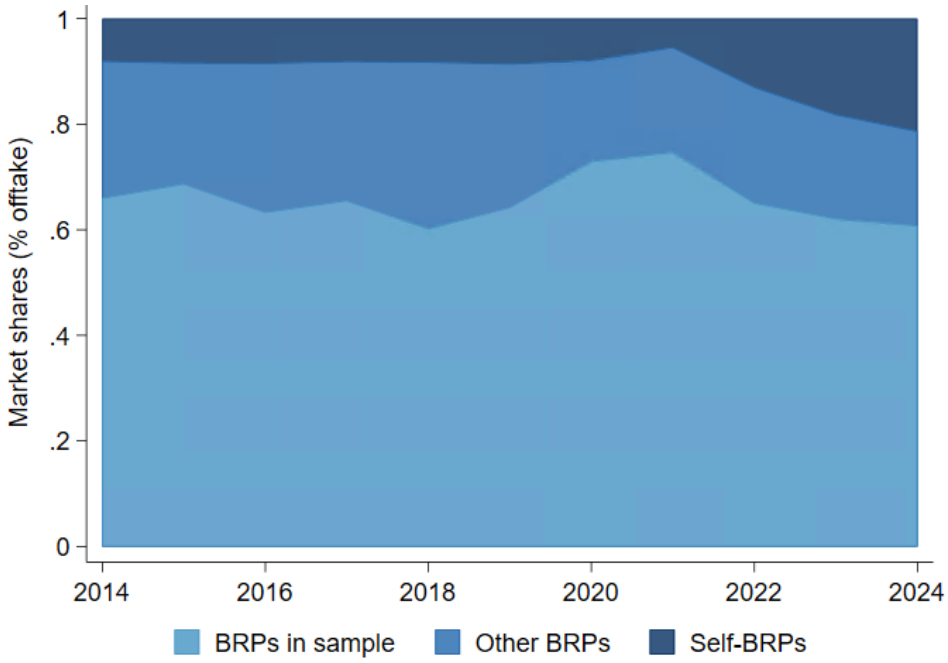


Figure 1 provides a perspective of our dataset. The figure represents the share of total net offtake on the transmission grid of the industrial consumers in our data, i.e. with a contract with one of the three largest BRPs, alongside the offtake share of the industrial consumers served by other BRPs and the offtake share of the industrial consumers acting

[1] A consumer can have different contracts for her different sites, resulting in more contracts than consumers.

as their own BRP. The figure shows that our sample covers approximately 65% of the net offtake of industrial consumers connected to the transmission grid.

3. Contract types and incentives for flexibility

Industrial electricity contracts differ starkly from the simple "pay-as-consumed" contracts of residential consumers. No two contracts are similar. A wide range of clauses exist. For the purpose of looking at the incentives for flexibility that they generate, we categorized them into four groups:

1. **Fixed-price contracts.** The commodity price is known at the time of contract signature and fixed during the length of the contract. The fixed-price category includes both flat-price contracts, where the electricity price does not depend on the time of day, and time-of-use contracts.
2. **Indexed contracts.** The commodity price is not known at the time of contract signature. The commodity price follows either a pre-defined indexation formula or the consumer's clicked forward prices, with the remaining consumption volume charged at the average forward price or spot price for a given month
3. **Share-based hedges.** The commodity price is not known at the time of contract signature. The consumer can decide what share of her actual offtake to secure at a price (through clicks on a reference index, such as base load products published by ICE). This share is constant within a day but can vary monthly, quarterly or yearly. If the consumer has set a share below 100%, her exposed share of offtake is charged at the hourly spot price.
4. **Volume-based hedges.** The commodity price is not known at the time of contract signature. The consumer can secure prices for blocks of baseload volume by clicking on forward prices offered through their BRPs. Some contracts also allow the consumer to submit an offer on the day-ahead market. We put these contracts into the volume-based hedges.

The important difference between these contract categories is whether the consumer is exposed to hourly real-time prices and to what degree. Under fixed-price and indexed contracts, the consumer is not exposed to changes in hourly real-time prices. The only difference between the two contracts is that the price is set before the start of the contract in the first case, whereas the industrial consumer is exposed to monthly price variation in the second. Neither contract exposes the consumer to intraday variations in the real-time price.

Both the share- and volume-based hedged contracts expose the consumer to changes in hourly real-time prices, but they do so differently. With share-based hedges, the consumer is hedged for a portion of its hourly consumption. Suppose that fraction is 60%. This means that any increase in its consumption is only exposed to the real-time price for 40% of that increase. We refer to this as its marginal exposure. With volume-based hedges, the consumer is exposed to 100% of real-time price variations for the hourly consumption volume above or below its hedges.

Figure 2 and **Error! Reference source not found.** illustrate the difference. In Figure 2, the consumer has hedged – through its contract – 80% of its consumption. The figure

represents its consumption through time (a day, a week). The shaded area represents the consumer's consumption volume exposed to the real-time price.

In Figure 3**Error! Reference source not found.**, the consumer is under a volume-based hedging contract and has hedged a baseload volume *h*. Any consumption volume that differs from this is fully billed at the real-time price. This is represented by the shaded area in the figure.

Figure 2: Hedging with a share-based contract

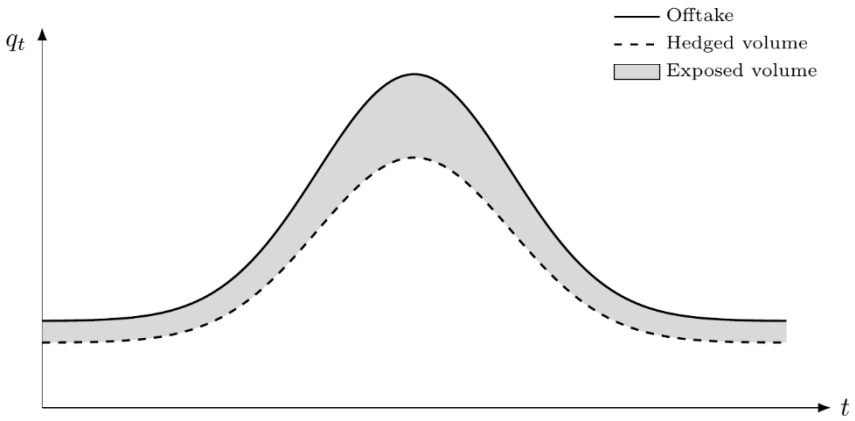
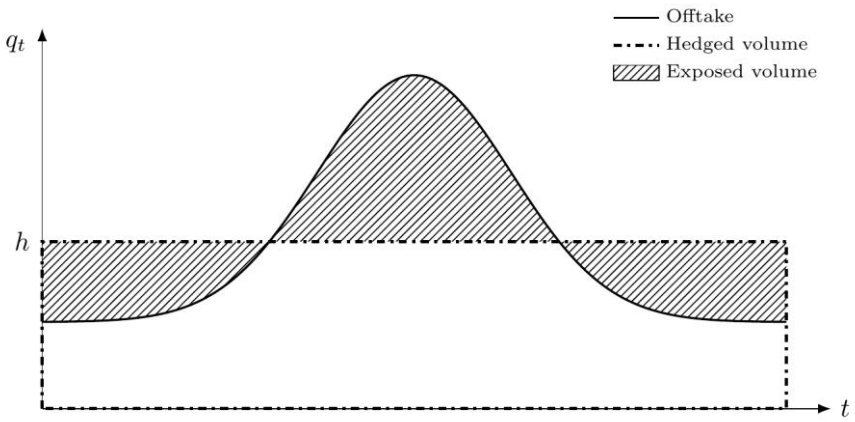


Figure 3: Hedging with a volume-based contract



4. Evolution of contracting practices over time

This section documents how contracting practices have changed over time.

Contractual practices are shifting toward contracts that expose consumers to real-time prices. Table 2 describes the share of each contract category by year of signature.[2] We see a slow but consistent transition from indexed contracts towards volume-based contracts between 2014 and 2024. Fixed-price and share-based contracts remain limited in our sample. Fixed-price contracts have all but virtually disappeared. Share-based

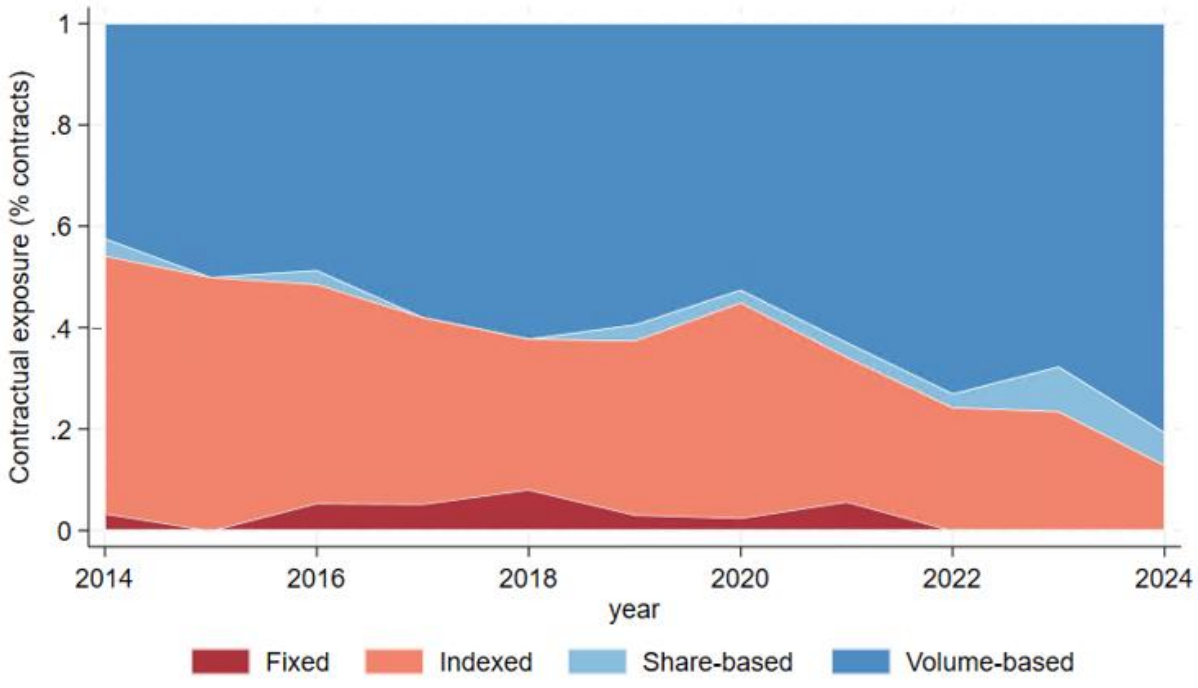
[2] A contract that is extended beyond its initial duration is encoded as a separate contract.

contracts appear to increase slightly toward the end of the sample. Figure 4 shows the same information graphically.

Table 2: Share of contract type of new contracts (by year of signature)

Year	1 and less	>1 and equal or less than 2	3+	Average	New contracts
2014	0.29	0.63	0.08	1.98	59
2015	0.50	0.47	0.03	1.51	34
2016	0.43	0.46	0.11	1.76	37
2017	0.50	0.39	0.11	1.58	38
2018	0.46	0.41	0.14	1.68	37
2019	0.31	0.50	0.19	1.88	32
2020	0.38	0.40	0.22	1.90	40
2021	0.49	0.40	0.11	1.72	35
2022	0.30	0.59	0.11	1.84	37
2023	0.33	0.42	0.24	1.91	33
2024	0.26	0.61	0.13	1.87	31
Total	0.39	0.48	0.13	1.78	38

Figure 4: Evolution of contract types, by year of signature



The observed change in contractual practices is not accompanied by any structural change in contract duration. We looked at contract duration. Though indexed contracts are on average longer (1.9 years) and fixed-price contracts are on average shorter (1.6 years), the difference in contract duration is not significant. The modal contract duration

in the data is two years, across contract categories. Contract duration varies over time but shows no clear structural change.

Contracts are becoming increasingly complex as they deal with changes in energy procurement practices and flexibility markets. Table 3 shows how contract clauses have evolved over time. We distinguish between the period 2014 to 2022 and after 2022 because of the Russian invasion of Ukraine in March 2022 that triggered an energy crisis in Europe. We observe three structural changes in contract characteristics. First, consumers are increasingly securing their electricity through on-site generation or off-site power purchase agreements (PPAs), which are accounted for in the contract.[3] Second, consumers are becoming more active players on the wholesale market: more than 50% of contracts signed after 2022 let the consumer purchase electricity from other market players or sell their flexibility. Third, the share of consumers exposed to an imbalance penalty for deviating from their nominated consumption has increased. The penalty is typically set at the spot or imbalance price for every quarter-hour of the day and allows the BRP to shift the quantity risk to the consumer. Some of these clauses go hand-in-hand. BRPs ensure in their contracts that they are not held responsible for imbalances stemming from their consumers selling their excess electricity or flexibility to a third party outside of their balancing perimeter.

Table 3: Evolution of contract clauses (in % of new contracts signed in each period)

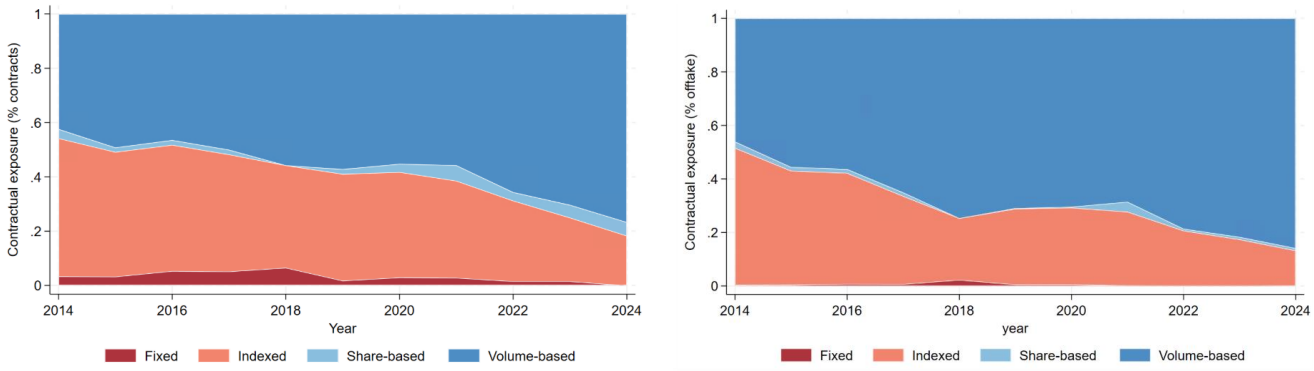
Period	Interruptibility clause	PPA clause	Exclusivity clause	Imbalance penalty	Own generation
2014–2022	0.09	0.01	0.81	0.20	0.20
2023–2024	0.08	0.03	0.48	0.25	0.28
Total	0.08	0.01	0.76	0.21	0.21

Consumers' exposure to real-time prices also increases in active contracts. Active contracts are the contracts running in a given year, regardless of their signature year. Figure 5 shows the evolution of contract types among active contracts, as a share of active contracts and as a share of offtake. Given their short durations, active contracts evolve closely with new contracts.

Fixed-price and share-based hedging contracts are marginal for the consumer segment in our sample. What is interesting is to compare the evolution of contract shares (left) and contract offtakes (right). Volume-based hedging contracts are more prevalent among larger consumers, which increases their share in the righthand side figure. Fixed-price and share-based hedging contracts are more prevalent among smaller consumers. These contracts – for the segment of industrial consumers connected to the transmission grid and served by one of the three BRPs – are marginal.

[3] These alternative sources of electricity change the load profile of the consumer.

Figure 5: Evolution of contract types, among active contracts (by share of contracts and by share of offtake)



5. Evolution of exposure

Section 4 showed that contracting practices have evolved over time toward contracts that expose consumers to real-time prices. How much they do so depends on the extent to which consumers make use of the possibility, within those contracts, to hedge some of their volumes. A consumer with a share-based hedging contract can decide to hedge up to 100% of their volume, effectively insulating themselves from real-time prices.

We distinguish between two measures of exposure: marginal and average exposure. Marginal exposure is the intensity of the hourly spot-price signal the consumer faces. Marginal exposure is equal to zero for fixed-price and indexed contracts. It is equal to 100% for volume-based contracts, and equal to the share, between zero and 100, set by the consumer, through its click decision, for the share-based contracts. Average exposure is defined as the average share of offtake charged at the spot price. It is an *ex-post* measure, once consumption decisions have been taken. It therefore includes any change in the consumer's consumption in reaction to high (or low) prices.

Figure 6: Marginal exposure by contract type (in % offtake)

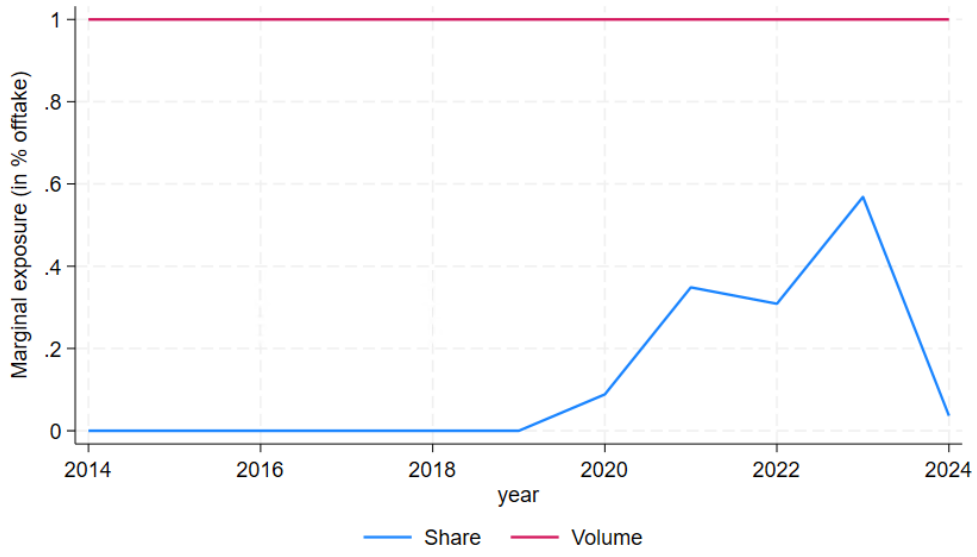
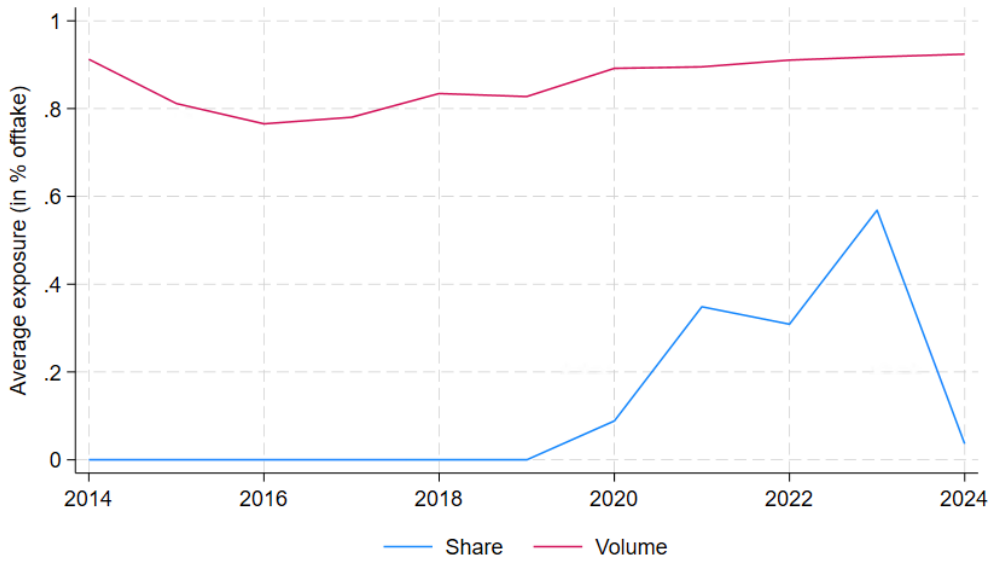


Figure 6 shows the evolution of marginal exposure for the share-based and volume-based contracts. Before 2020, the marginal exposure of share-based contracts was equal to zero, i.e., consumers under this type of contract ended up being fully hedged against uncertain spot prices. Exposure has increased steadily from almost 10% in 2020 to 60% in 2023. Exposure fell back to 5% in 2024. A more granular analysis of these data will tell us whether this evolution reflects changes in the pool of customers choosing these contracts or changes in market conditions (e.g. high costs of hedging during the energy crisis).

Figure 7 illustrates the evolution of average exposure between 2014 and 2024 for share-based and volume-based hedging contracts.[4] Average exposure is equal to marginal exposure for share-based contracts. For volume-based contracts, average exposure is relatively high at around 90% throughout the 10 years. Between 2014 and 2020, it decreased but has been increasing slowly and steadily since 2020.

Volume-based contracts structurally increase average exposure. Average exposure is partly the result of consumers' decisions – through their clicks. However, for volume-based contracts, exposure is also inevitable unless the consumer's load profile is completely flat. As soon as a consumer has a load profile that varies within days or weeks (e.g. batch processes, difference between day and night or weekday/weekend consumption, sensitivity to weather conditions), average exposure under volume-based hedging will be positive. This explains why average exposure is higher for volume-based contracts than for share-based contracts.

Figure 7 Average exposure by contract type (in % offtake)



[4] Formally, average exposure is computed as $\delta_{it}^{avg} = |\frac{q_{it} - v_{it}}{q_{it}}|$, where q_{it} is the hourly offtake of consumer *i* in hour *t* and v_{it} is the baseload volume hedged. Average exposure can be larger than one. One caveat is that we do not observe a consumer's volume purchased under a PPA or with another third-party than her own.

6. Next steps

The evidence presented so far shows that contractual arrangements between large industrial consumers and their retailers have undergone a major transformation over the past decade and that, today, those consumers are much more exposed to real-time price signals. This is good news for flexibility.

There are two main next steps.

Understanding contract choice and its determinants over time. First, flexibility is not the only consideration for industrial electricity supply. Industrial consumers need visibility on their energy costs and are averse to price volatility. For consumers with flat load profiles, volume-based hedging contracts can address these concerns while incentivizing demand-side flexibility at the margin. For consumers with irregular load profiles and limited flexibility, they impose higher risks. For those consumers, share-based contracts may be an attractive alternative. On the BRP side, increased on-site and off-site (PPA) generation for industrial consumers, along with the entry of new flexibility services and market participants, means fixed-price or even indexed-price contracts are no longer tenable, as they expose them to greater quantity risk and imbalance prices.

We plan to investigate customer heterogeneity in our data and use the insights generated to inform the development of a theoretical model of contract choice that explains how these choices vary across consumer characteristics and over time.

Incentives for flexibility and actual flexibility. Second, armed with a better understanding of contract choice, we plan to quantify the extent to which the increased financial incentives for providing flexibility are indeed materializing into higher effective demand-side flexibility by industrial consumers.

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