BEUC

Research on consumer risks and benefits of dynamic electricity price contracts

A risk or an opportunity to save?

cambridge econometrics
clarity from complexity

Final Report

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Executive Summary

This study was requested by the BEUC (The European Consumer Organisation) and carried out by Cambridge Econometrics. The **objectives** of the study are:

- To estimate the monthly, quarterly, and annual electricity costs for an archetype household in Austria and France, under varying conditions and use cases:
  - Assuming the archetype household had a fixed price contract in 2020 and 2021
  - Assuming the archetype household had a dynamic price contract in 2020 and 2021
- To explore the differential impact of optimisation with a dynamic price contract, assuming that electric vehicle (EV) charging, washing, dishwashing and tumble drying is carried out when the electricity price is lowest in the day.
- To assess the risks and benefits associated with dynamic pricing contracts, and formulate policy implications for price regulation, on the one hand, and for electricity cost simulations for households, on the other hand.

The analysis is carried out using **publicly available data** regarding electricity prices and consumption:

- For electricity consumption by use category (space heating, water heating, EV charging, dishwashing, tumble drying, washing and other electric household appliances), secondary data and assumptions are processed to construct credible time series reflecting daily and monthly electricity consumption for an archetype household. This gives an accurate enough approximation of electricity consumption across categories, yet the time series are constructed using assumptions.
- The hourly (and daily) electricity price time series are observed at the level of day-ahead wholesale prices. Based on information about average network, distribution and other charges for Austria and France, household electricity prices are then calculated with as many data points as the hourly day-ahead wholesale prices.

The **electricity cost calculations** are performed by matching and multiplying the daily electricity consumption time series with the daily electricity price time series in various combinations to calculate electricity costs for the archetype household considered. The levels of household electricity consumption by category are fixed across simulations, meaning that differences in monthly, quarterly and annual electricity are either because of the pricing or use optimisation. All calculations are performed using statistical software Stata and Microsoft Power Bi, and an online interactive dashboard with the results can be accessed through the linked in the footnote below[1].

The **results** illustrate the following key findings regarding household electricity consumption and costs:

- The main benefit from dynamic pricing occurs when variable prices are on average lower than the fixed price throughout the year, or otherwise put, when the fixed price is higher than the average variable price. The estimates for 2021 illustrate that when variable

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1 https://app.powerbi.com/view?r=eyJrIjoiODdiOWRiZjQtZjkwNy00MTJjLThkNjctZjQ3MTM3MTUwMTdkIiwidCI6IjE1YWQxMGU2LWJlNWYtNDY3ZS05MDZjLWQ4MmRlMzQ1ZDM3ZiIsImMiOjh9

prices are unexpectedly higher than fixed prices for a sustained amount of time, this can lead to considerably higher electricity costs for households.

- Benefits from managing electricity consumption of flexible activities are relatively minor, mainly due to the small share of electricity consumption from flexible activities to the total bill – less than 30% of total electricity consumption by the archetype household.
- EV charging represents the highest cost within the flexible electricity consuming households' activities, suggesting that dynamic pricing is most relevant to those households owning an EV and smart EV charging could lead to savings for those households.
- Among all electricity consuming household activities, space heating represents the highest cost. This is followed by the use of other appliances, electric vehicle charging and water heating.

Several **high-level policy implications** are inferred from the analysis. Publicly available data regarding variable prices paid by households and electricity consumption by type of household and consumption category is sparse or non-existent. More efforts to collect and publish such data would facilitate policymaking and improve consumer protection.

Households should be well-informed about the seasonal and intra-day variations in dynamic prices, as well as their past consumption levels and electricity prices with as much granularity as possible, and how this would have compared with a fixed price contract. They should also be given sufficient information and tools that allow them to assess the extent to which they are able to use appliances flexibly.

The price increases in 2021 illustrate that the main risk of dynamic or variable pricing lies with long-term volatility and sustained prices increases in electricity prices on the market. Placing ceilings and/or other restrictions to sustained price increases over time would mitigate the risk for households while the main objective of demand-side management within a day can still be met.

1 Methodology

The following subsections explain in more detail for which type of household the simulations were made, the data and assumptions used for each household electricity consumption category and the time series used to calculate the electricity costs on a daily, monthly, quarterly and annual basis.

1.1 Archetype household

The archetype household is a four-member household, living in a 100m2 house with a D graded EPC for space heating.

- Owns one recent first-hand electric vehicle with average daily mileage of 29.7 for Austria and 45.2 for France that is fully charged at home, when the electricity price is lowest.
- Uses an electric heat pump for space heating. The EPC score for the house is D, however, thus it is assumed that this scoring is based on primary energy use of a gas boiler and the equivalent electricity demand for heating with a heat pump is derived.
- Owns an electric washing machine, dishwasher and tumble dryer. EPC information is used to derive the assumptions for the analysis.
- Uses other electric appliances for activities such as cooking, freezing, office-work, entertainment, light, air and charging. The annual electricity consumption for these appliances, excluding the categories referred in the bullet points above, is obtained from real word data available for France and Austria.

The data and assumptions described below are collected with the objective to proxy the electricity consumption behaviour of this archetype household as closely as possible with publicly available information.

1.2 Data inputs and assumptions

1.2.1 Electricity prices

Two types of electricity prices are used, based on common household contracts with energy providers: dynamic and fixed electricity price. For both dynamic and fixed electricity prices, the analysis uses information relating to the retail and the wholesale (hourly day-ahead) price of electricity.

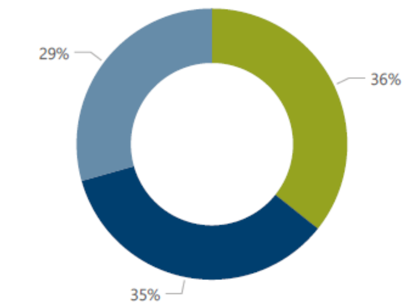
Fixed electricity prices for Austria are based on the reported fixed electricity prices at the website of the Austrian electricity and gas market regulator[2], E-Control. For the French regulated market price, the analysis uses the information reported through Selectra, an electricity and gas price comparison website.[3] For Austria, the fixed electricity price is reported for 2020, in semestrial frequency. For France, the fixed electricity price – *tarif bleu* – was reported for both 2020 and 2021, but without semestrial breakdown.

The fixed retail electricity price that is used in the analysis as the representative price faced by households may differ substantially between regions, providers and household categories.

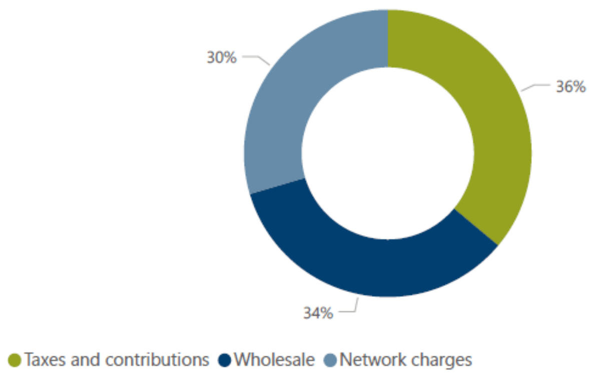
[2] See. E-Control - Unsere Energie gehört der Zukunft - www.e-control.at

[3] See. https://www.kelwatt.fr/

Fixed retail electricity price components - First semester



Fixed retail electricity price components - Second semester



Austria

Fixed Retail Price for 2020 in EUR per kWh

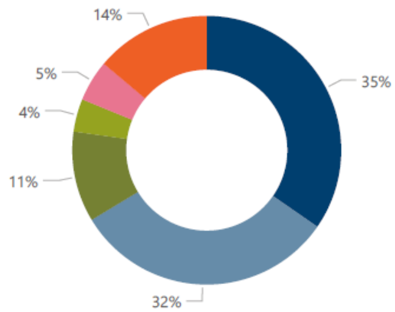
0.205

First semester

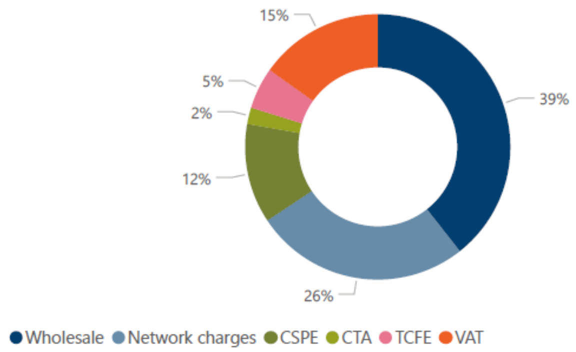
0.211

Second semester

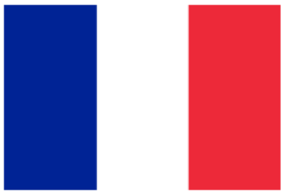
Fixed retail electricity price components: 2020



Fixed retail electricity price components: 2021



France



Fixed Retail Price (Tarif Bleu) in EUR per kWh

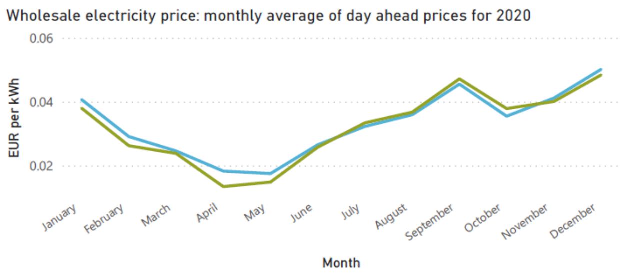
0.1558

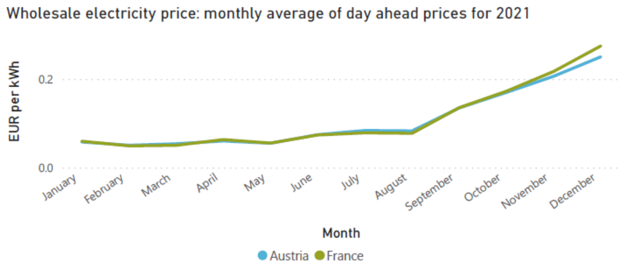
2020

0.1557

2021

Wholesale electricity prices are collected through the European Network of Transmission System Operators for Electricity (ENTSO-E), an association for the cooperation of the European transmission system operators.[4] The ENTSO-E Transparency Platform provides a plethora of information relating to the European electricity system, collected from data providers such as TSOs, power exchanges and other qualified third parties.



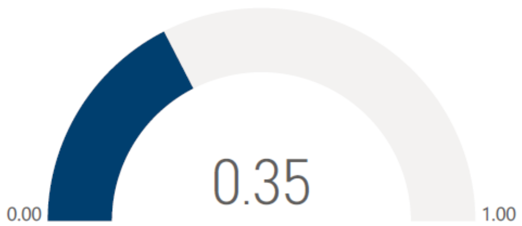


	Austria	France
Wholesale electricity price: 2020 average of day ahead prices	0.033 EUR per kWh	0.032 EUR per kWh
Wholesale electricity price: 2021 average of day ahead prices	0.107 EUR per kWh	0.109 EUR per kWh

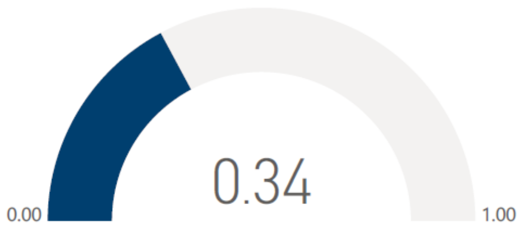
Wholesale dynamic electricity prices for France and Austria are based on the reported Day-ahead Prices (12.1.D) table, expressed in Currency/MWh. For Austria, the analysis uses the BZN|AT bidding zone; for France the BZN|FR is used.

Austria

2020 Share of wholesale energy price in retail price - First semester

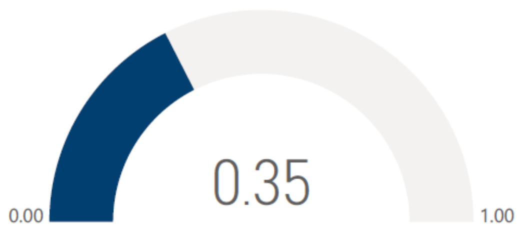


2020 Share of wholesale energy price in retail price - Second semester

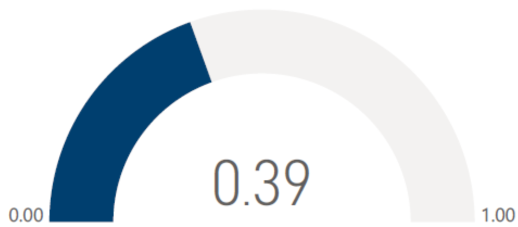


France

2020 Share of wholesale energy price in retail price



2021 Share of wholesale energy price in retail price



[4] See. [ENTSO-E Mission Statement (entsoe.eu)]

Retail dynamic electricity prices for France and Austria are calculated using information on the relationship between the fixed wholesale electricity price and the fixed retail electricity price. For Austria, the retail dynamic price was calculated by applying a fixed share of wholesale in retail price of 0.35 for the first semester of 2020 and 2021, and 0.34 for the second semester of 2020 and 2021. For France, the retail dynamic price was derived by applying a fixed share of 0.35 for 2020 and 0.39 for 2021.[5]

1.2.2 EV charging

For the calculation of the electricity costs associated with the charging of electric vehicles, the analysis is based on the following assumptions.

Assumption	Scope	Unit	Austria	France	Sources
Mileage	Daily	km	29.7	45.2	Statistics Austria, BEUC[6]
Charging at home	Fixed		100%	100%	Assumption
Charging box capacity	Fixed	kW	7	7	Product info
EV battery capacity	Fixed	kWh	60	60	Product info
Usable EV Battery capacity	Fixed	kWh	48	48	Product info
EV efficiency	Fixed	kWh / 100km	14.7	14.7	Product info
Consumption	Daily	kWh	4.4	6.6	Calculation
Consumption	Yearly	kWh	1606.0	2425.5	Calculation
Charging time	Daily	Minutes	37.4	57.0	Calculation
Days to deplete battery	NA	Days	11.0	7.2	Calculation
Time to charge full battery	NA	Minutes	411.4	411.4	Calculation

Assumptions regarding charging box capacity and EV battery capacity reflect current market standards.

1.2.3 Space heating

For the calculation of the electricity costs associated with space heating, the analysis is based on the following assumptions.

Assumption	Scope	Unit	Austria	France	Sources
Primary energy demand (per m2)	Yearly	kWh/m^2	150.0	180.0	OIB
Heating degree days	Daily	HDD	1700	2014.889	Degreedays.net
Efficiency assumption (gas boiler)	Fixed		0.9	0.9	Assumption

[5] The reported shares were verified using online price comparison websites and Eurostat. See: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics; https://prix-elec.com/energie/etranger/autriche ; https://prix-elec.com/tarifs/electricite/decomposition; https://prix-elec.com/energie/etranger/autriche ; https://prix-elec.com/energie/etranger/autriche .

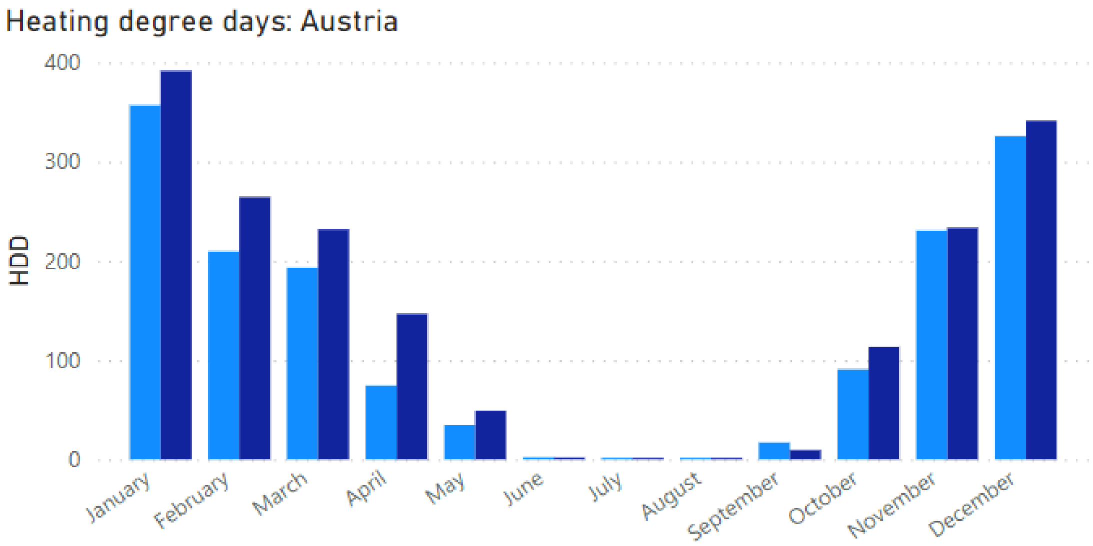
[6] https://www.beuc.eu/publications/beuc-x-2021-040_electric_car_ownership-an_affordable_option_for_all_consumers.pdf

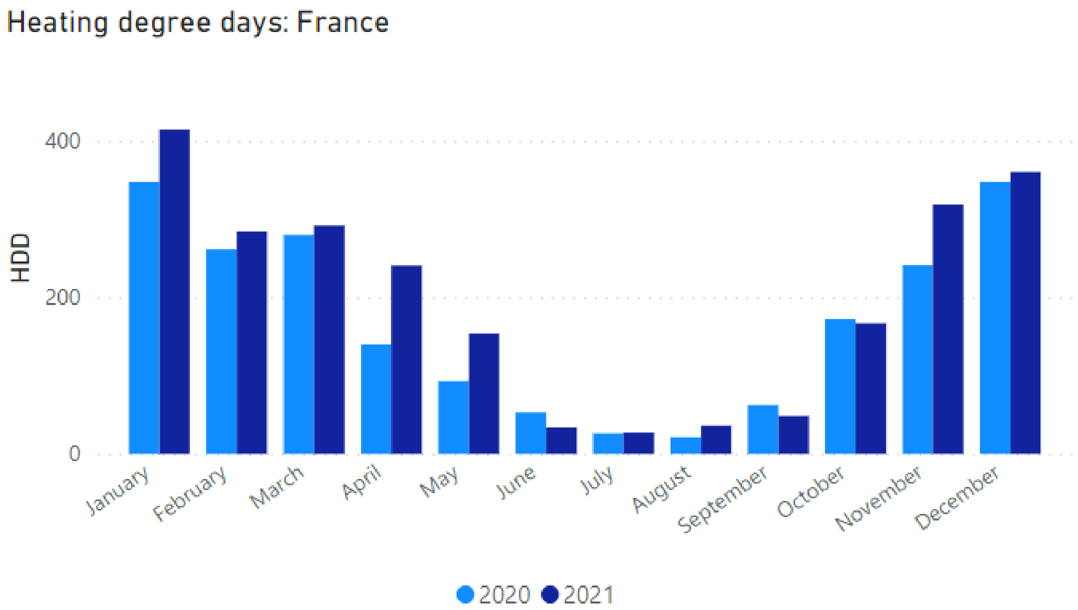
Useful energy demand (per m2)	Yearly	kWh/m^2	135.0	162.0	Calculation
Square meter	Fixed		100	100	Assumption
Useful energy demand	Yearly	kWh	13500.0	16200.0	Calculation
SPF/COP	Fixed		2.8	2.8	Assumption
Consumption (heatpump)	Fixed	kWh	4821.4	5785.7	Calculation
Consumption (per m^2)	Yearly	kWh/m^2	48.2	57.9	Calculation
Consumption per heating degree day	Fixed	kWh/HDD	2.8	2.9	Calculation

Heating degree data for a representative sample of weather stations per country was drawn from degreedays.net. Based on the heating degree day data for the sample of weather stations, a country-wide average heating degree days (HDD) time series was generated. The table below presents the sample of cities for which the weather stations were included for the calculation of the national average daily heating degree days.

Country	City
Austria	Graz, Innsbruck, Klagenfurt, Linz, Salzburg, Vienna
France	Bordeaux, Brest, Clermont-Ferrand, Grenoble, Lille, Lyon, Marseille, Montpellier, Nancy, Nantes, Nice, Paris (greater city), Rennes, Rouen, Saint-Etienne, Strasbourg, Toulouse, Tours

The following figures present the estimated number of heating degree days by country, aggregated to monthly values. Differences between the two countries are due to differences in temperatures and the selected base temperatures. For the calculation of the heating degree days for each country, a base temperature of 12 degrees was used for Austria and 18 degrees for France.





1.2.4 *Water heating*

For the calculation of the electricity costs associated with water heating through the use of an air-to-water heatpump, the analysis is based on available data regarding average annual electricity consumption for water heating.

Assumption	Scope	Unit	Austria	France	Sources
Consumption	Yearly	kWh	1016.1	752.0	Statistics Austria, ADEME
Consumption	Daily	kWh	2.8	2.1	Calculation

For Austria, the data is obtained from Statistics Austria and the estimate is based on the average consumption of a four-member household as reported for the years 2008, 2012 and 2016.

For France, the data is directly obtained from a study carried out by the Agence de la Transition Ecologique (ADEME).[7]

1.2.5 Washing machine

For the calculation of the electricity costs associated with the use of an electric washing machine, the following assumptions were used:

Assumption	Scope	Unit	Austria	France	Sources
Consumption (EPC, 220 cycles)	Yearly	kWh	150.0	150.0	Product info
Wattage	Fixed	kW	0.5	0.5	Product info
Demand per cycle	Fixed	kWh	0.682	0.682	Calculation
Cycle duration	Fixed	min	81.8	81.8	Calculation

These assumptions reflect current market standards for washing machines for household use with 8 to 9 kg capacity.

1.2.6 Dishwasher

For the calculation of the electricity costs associated with the use of an electric dishwasher, the following assumptions were used:

Assumption	Scope	Unit	Austria	France	Sources
Consumption (EPC, 280 cycles)	Yearly	kWh	266.0	266.0	Product info
Wattage	Fixed	kW	1.2	1.2	Product info
Demand per cycle	Fixed	kWh	1.0	1.0	Calculation
Cycle duration	Fixed	min	47.5	47.5	Calculation

These assumptions reflect current market standards for dishwashing machines for household use.

1.2.7 Tumble drying

For the calculation of the electricity costs associated with the use of a tumble dryer, the following assumptions were used:

Assumption	Scope	Unit	Austria	France	Sources
Consumption (EPC, 160 cycles)	Yearly	kWh	200.0	200.0	Product info
Wattage	Fixed	kW	0.8	0.8	Product info
Demand per cycle	Fixed	kWh	1.3	1.3	Calculation
Cycle duration	Fixed	min	93.8	93.8	Calculation

[7] https://librairie.ademe.fr/changement-climatique-et-energie/4473-panel-usages-electrodomestiques.html

These assumptions reflect current market standards for tumble-drying machines for household use.

1.2.8 Other household appliances

For the calculation of the electricity costs associated with the use of common household appliances, such as the ones used in cooking, freezing, kitchen, office, entertainment, light, air, chargers, standby, the following assumptions were used:

Assumption	Scope	Unit	Austria	France	Sources
Consumption	Daily	kWh	7.7	8.0	Calculation
Consumption	Yearly	kWh	2814.0	2918.4	Statistics Austria, ADEME

For Austria, estimates are based on the average consumption of a four-member household as reported for the years 2008, 2012 and 2016.

For France, estimates are derived from a study carried out by the Agence de la Transition Ecologique (ADEME) using household data collected between April 2019 and April 2020.[8]

1.3 Time series

1.3.1 Overview

Based on the data inputs and assumptions listed above, the following time series, with hourly or daily observations for one year, are processed.

Time series	Observations
Wholesale electricity price, fixed	Fixed
Retail electricity price, fixed	Fixed
Wholesale electricity price, dynamic	Hourly
Wholesale electricity price, dynamic (daily average)	Daily
Retail electricity price, dynamic	Hourly
Retail electricity price, dynamic (daily average)	Daily
Retail electricity price, dynamic optimised (daily lowest)	Daily
Space heating electricity consumption	Daily
Water heating electricity consumption	Daily
Washing electricity consumption	Daily
Dishwasher electricity consumption	Daily
Tumble drying electricity consumption	Daily
Other appliances electricity consumption	Daily
EV charging electricity consumption	Daily
Space heating electricity consumption	Daily

[8] https://librairie.ademe.fr/changement-climatique-et-energie/4473-panel-usages-electrodomestiques.html

By multiplying the daily consumption values by the respective daily fixed, dynamic or optimised prices, one can obtain estimates of spending on electricity on each electricity consumption category, a combination of electricity consumption categories or all electricity consumption categories combined.

In this study, optimisation is performed by multiplying the daily dynamic optimised prices (i.e., the lowest hourly observation for each day) those categories for which use can be programmed to occur at specific times (i.e., EV charging, washing, dishwashing and tumble drying).

By multiplying the daily consumption values by the respective daily fixed, dynamic or “optimised” prices, one can obtain estimates of spending on electricity on each electricity consumption category, a combination of electricity consumption categories or all electricity consumption categories combined.

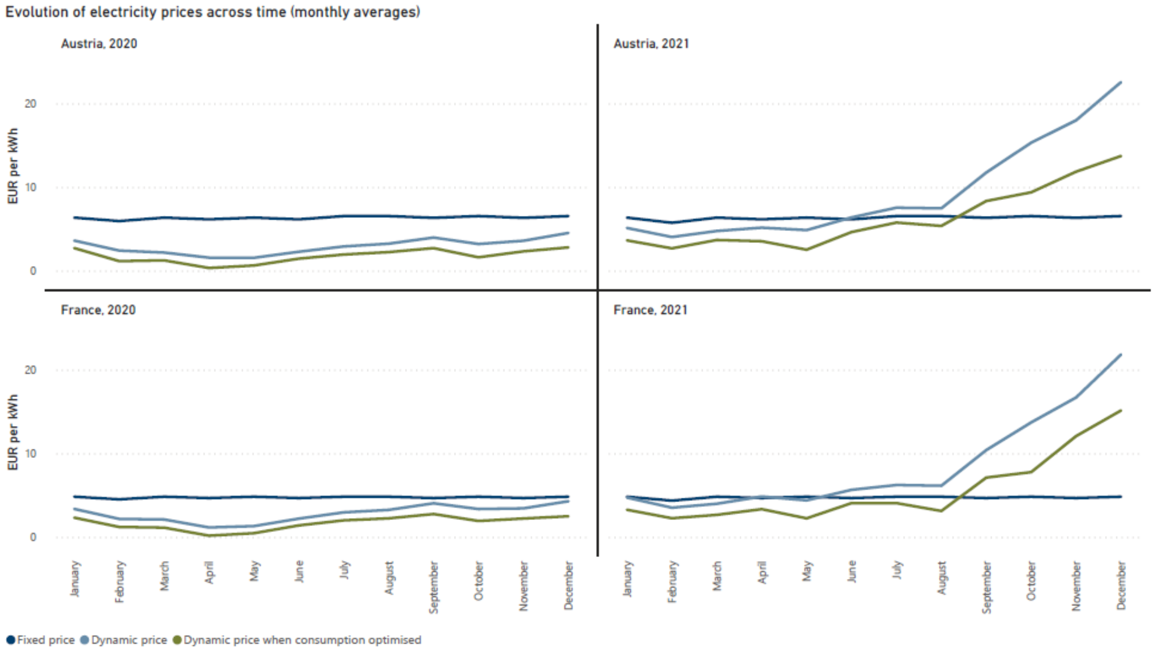
The following subsections provide a snapshot of the estimated electricity price and electricity consumption data used for the analysis.

1.3.2 Household electricity prices

The figure below presents the electricity price data used for Austria and France, for 2020 and 2020.

This clearly shows that household electricity prices have increased over time, in particular in the second half of 2021. While variable prices were lower than fixed prices in 2020 and the first half of 2021, variable/dynamic prices became higher than fixed price from August 2021 and continued to be afterward. This has been the case for both Austria and France.

The price data also suggests that, where households are able to use appliances flexibly and use them at the time in the day when the electricity is lowest, small savings could be obtained.



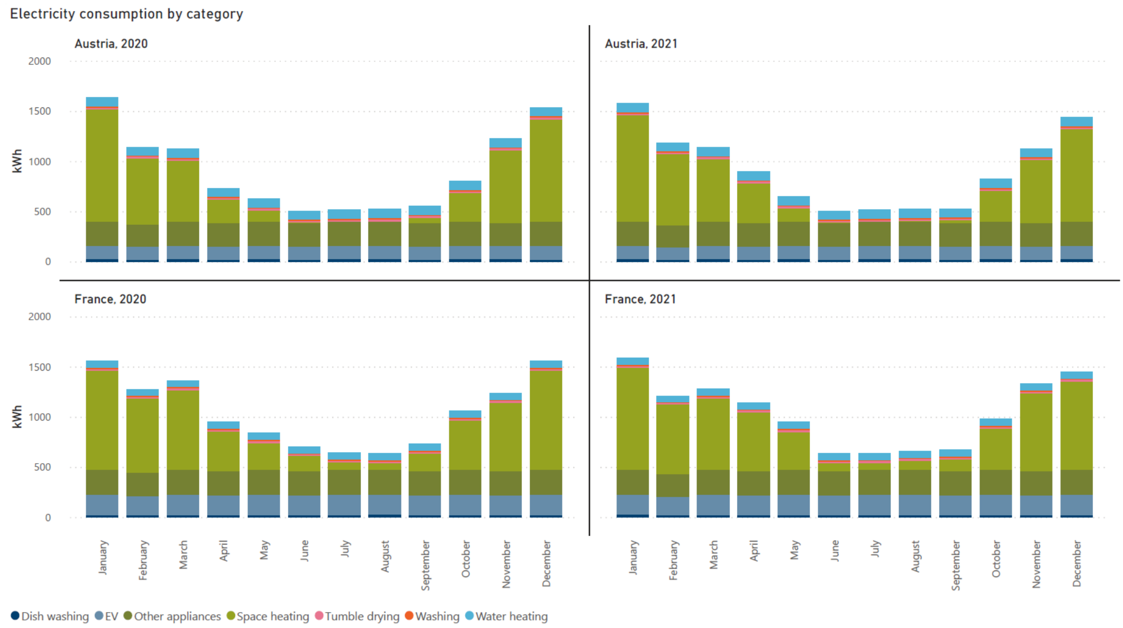
1.3.3 *Household electricity consumption*

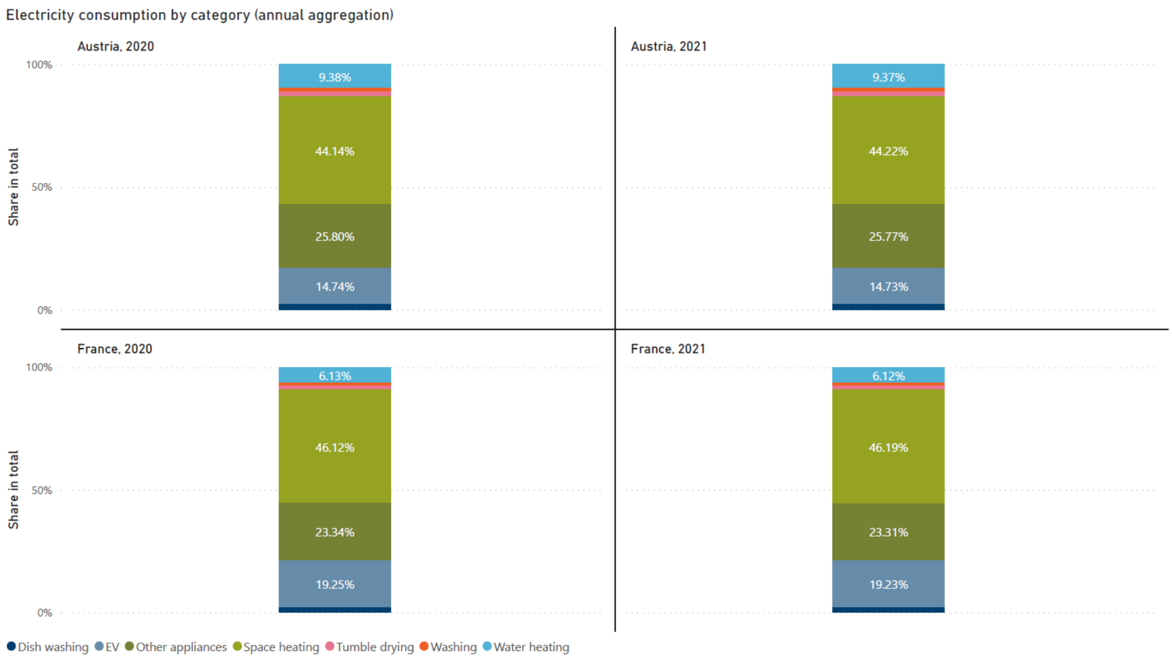
The figures below present the electricity consumption by activity/category and for each month. These are estimated values based on our assumptions, not directly observed.

Space heating represents the highest share of electricity consumption for the archetype household considered for the analysis. Because of the seasonality in space heating (i.e. heating is mostly required during winter months), electricity consumption varies considerably between months.

Electricity consumption for water heating, dishwashing, washing, EV charging, tumble drying and other appliances is fairly consistent across time. Nonetheless, there is in real life likely to be a bit more seasonality in the consumption patterns for some of these categories.

All activities combined, the archetype household is estimated to consume between 10,000 and 12,000 kWh per annum (including EV charging and heatpump use).





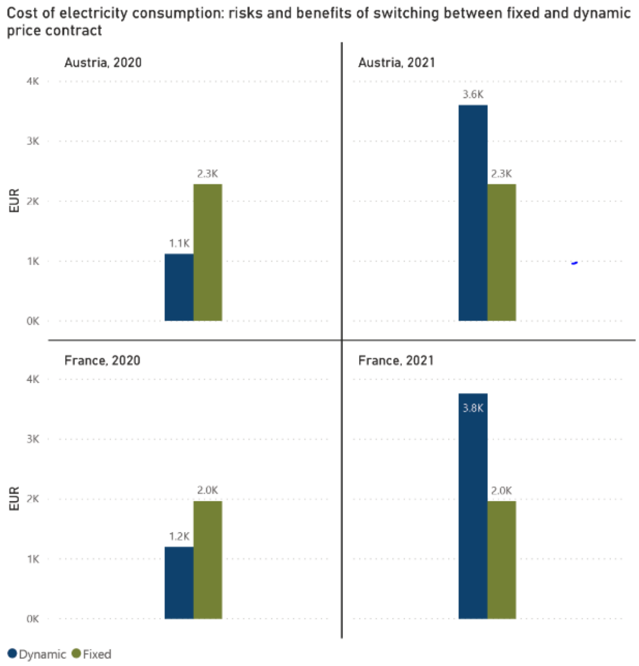
2 Results

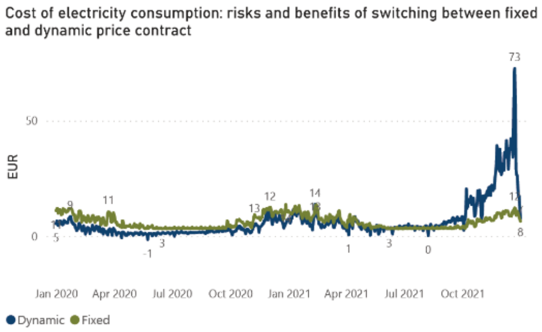
This section presents the results relating to the archetype household shifting from fixed price electricity contract to a dynamic price contract, and the expected benefits of optimising electricity consumption while on dynamic contract pricing. The last part of this section revisits the benefits of optimisation by offering further information relating to the electricity consumption categories considered by this analysis.

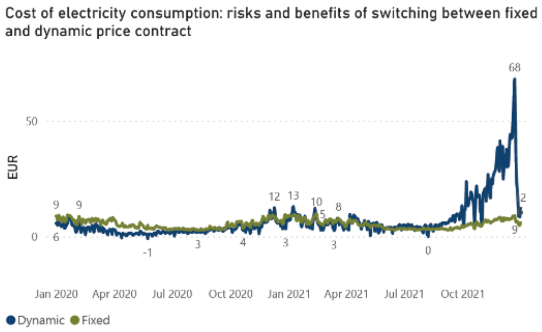
2.1 Fixed versus dynamic contract pricing

In 2020, dynamic electricity prices were on average lower than the fixed electricity prices, leading to considerable savings that can be made by the archetype household holding a dynamic pricing contract versus the same archetype household holding a fixed price contract. Thus, in a context of relative price stability on the market, dynamic pricing can present a benefit.

In 2021, however, electricity prices went up considerably compared to electricity prices in 2020, leading to a considerable increase in the electricity bill for the archetype household. In a context of relative price volatility, the potential savings from holding a dynamic price contract can be undone rapidly when unexpected yet sustained price hikes emerge. This poses a risk for a household with a dynamic pricing contract. For both countries, the 2021 losses of switching from a fixed to a dynamic price electricity contract outweigh the 2020 savings.





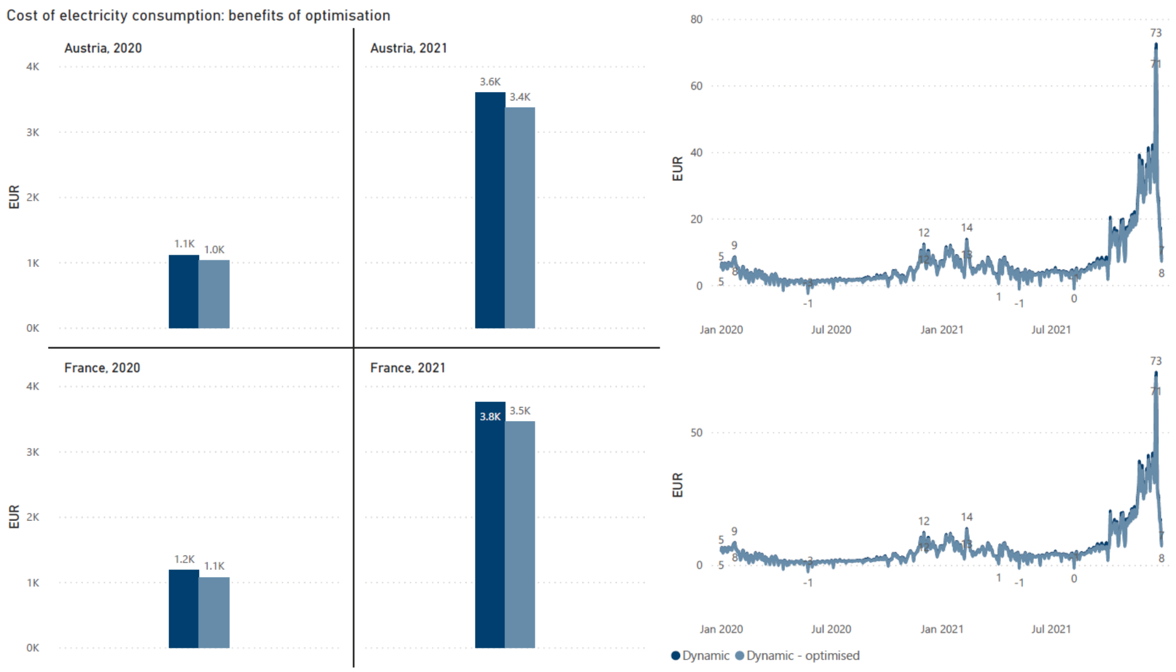


For Austria, the 2021 electricity price increase resulted in the dynamic price surpassing the fixed price from August onwards. If in January 2020 our archetype household would have switched from a fixed to a dynamic price electricity contract, it would have saved around € 1,163. In other terms, it could have spent 50% less. If the same household would have instead performed the switch in 2021, it would need to pay €1,324 extra. This is equivalent to 58% more than it would have had to pay for electricity consumption had it opted for a fixed price contract.

For France, the 2021 electricity price surge resulted in the dynamic price exceeding the fixed price from August onwards. If in January 2020 the representative household would have switched from a fixed to a dynamic price electricity contract, it would have saved around € 769. In other terms, it could have spent 39% less. If the same household would have instead performed the switch in 2021, it would need to pay € 1,800 extra. This is equivalent to 92% more than it would have had to pay for electricity consumption had it opted for a fixed price contract.

2.2 Non-optimised versus optimised use

'Non-optimised' refers to the use of appliances at times in the day when the electricity consumption is most convenient for the household, rather than at the time of the day when the prices is lowest. In the analysis, the average daily price is used to calculate the electricity costs associated with this user behaviour. 'Optimised' refers to EV charging and managed use of a dishwasher, washing machine and tumble-dryer at the time the electricity price is lowest in the day.

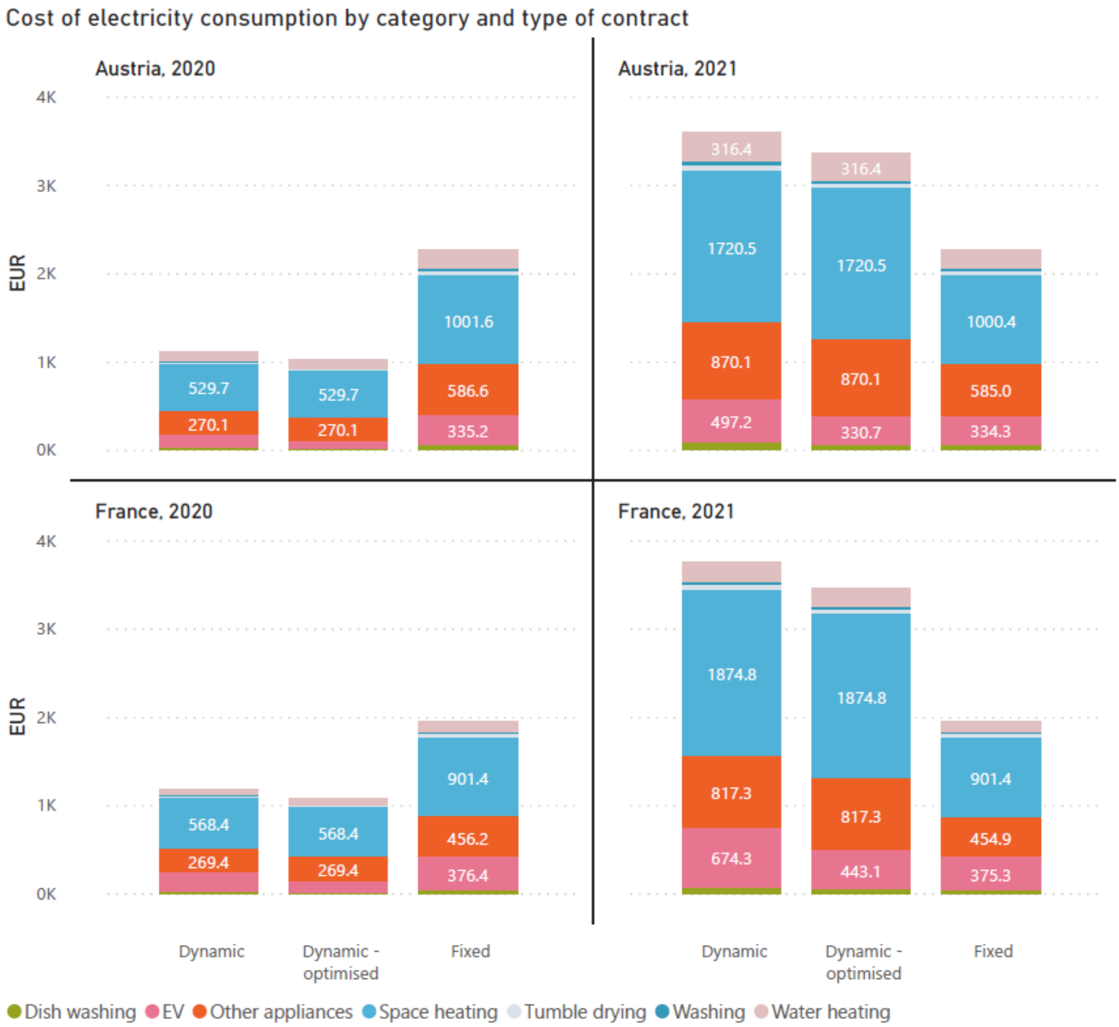


Based on the simulations performed in this study, the benefits from optimising electricity consumption of these appliances for which the use can be programmed to occur at specific times in the day, are relatively minor. A switch from non-optimised consumption pattern to an optimised one is associated with limited savings – less than 10% of the cost of the non-optimised consumption. This is the result of two factors:

- First, only four of the activities provide most potential for a flexible/optimised consumption pattern. These activities (EV charging, washing, dishwashing, tumble-drying) are estimated to represent close to 27% for Austria and 29% for France of total annual electricity consumption.
- Second, there is little hourly variation in the electricity price for the two countries and years studied, thus the savings from using the appliance at the time of the day when the price is lowest are minor. Switching to an optimised pattern of consumption for each one of the flexible activities results to saving approximately 38% of the value otherwise paid under a non-optimisation scenario – approximately between € 100 and € 300.

2.3 Costs by electricity consumption category

This analysis considered seven electricity consumption categories separately: dishwashing, EV charging, other common household appliances, space heating, tumble drying, washing and water heating. Out of these categories, four are identified as having most potential for cost savings through optimising the timing of electricity use: washing, dish washing, tumble drying and EV charging.

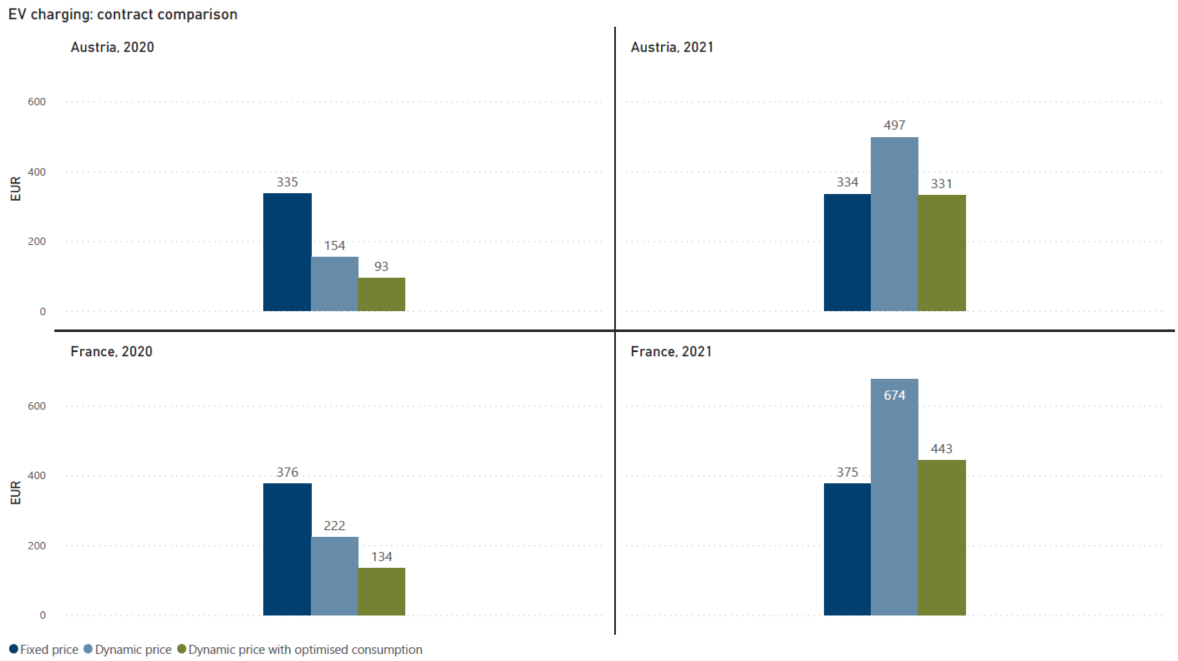


The figure above presents the archteype household's electricity costs broken down by electricity consumption category, under fixed pricing, dynamic pricing and dynamic pricing with optimised use of a washing machine, dishwasher and tumbledryer. The figure clearly shows that space heating is the category that requires the greatest electricity consumption, followed by the electricity consumed for other common household appliances, and therefore also represent the highest share within the total annual electricity bill. Washing, dish washing and tumble drying require the lowest electricity consumption, and therefore also present a relatively low share within the total annual electricity costs. The latter also explains the small differences between the dynamic pricing and dynamic-optimised pricing simulations, as discussed in more detail in section 2.2.

The following subsections discuss each electricity consumption category in more detail.

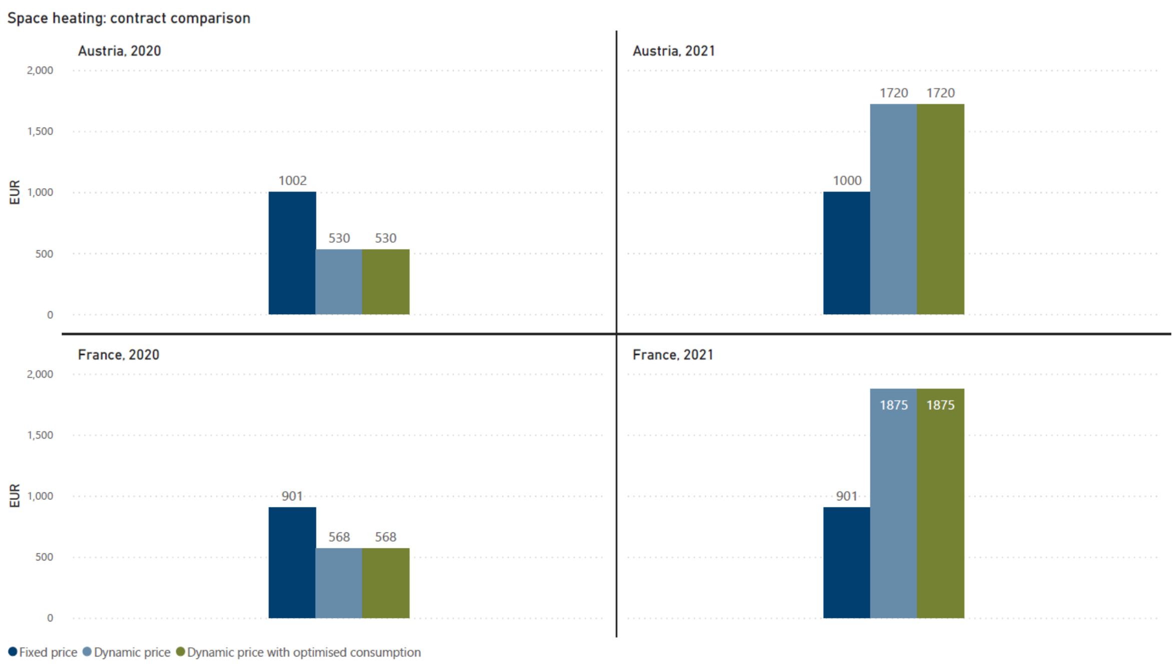
2.3.1 *EV charging*

Electric vehicle charging represents between 14% and 19% of the total electricity costs for the archetype household. Consumption optimisation can generate annual savings for the household of up to 37% of the costs incurred for charging an EV without optimising – between € 61 and € 167. This suggests that for EV charging, it is beneficial to programme EV charging so that charging is carried out when the hourly price is lowest.



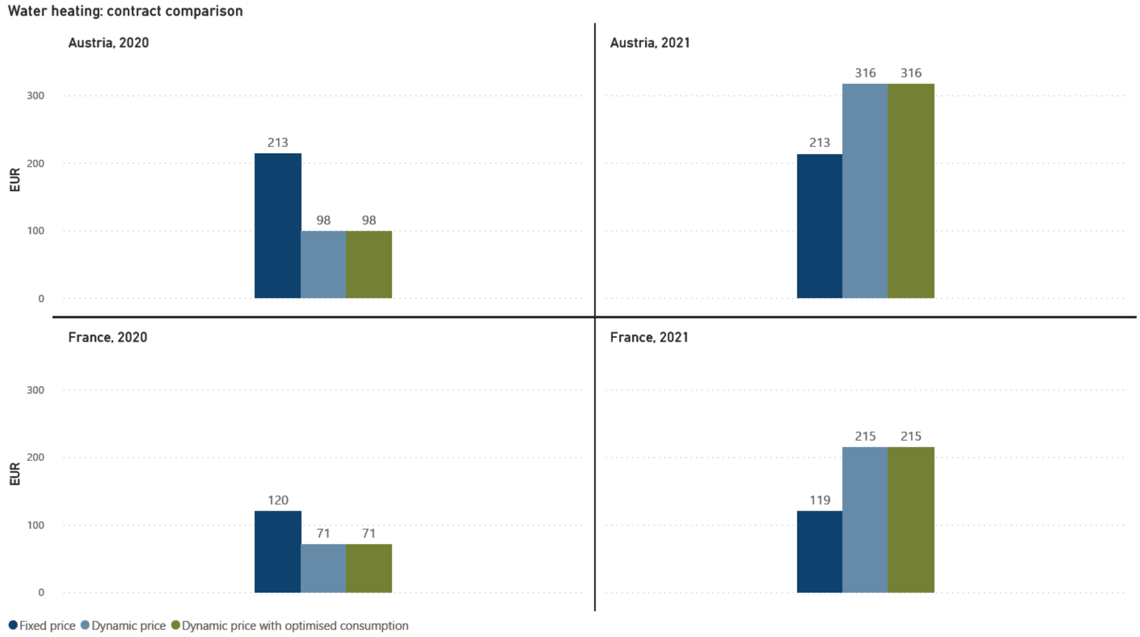
2.3.2 *Space heating*

Space heating represents between 44% and 48% of total electricity costs for the archetype household. Space heating is not commonly optimised, yet new heating technologies and improved energy efficiency of buildings hold the potential for more managed used of space heating. Space heating consumption displays high seasonality for both Austria and France.



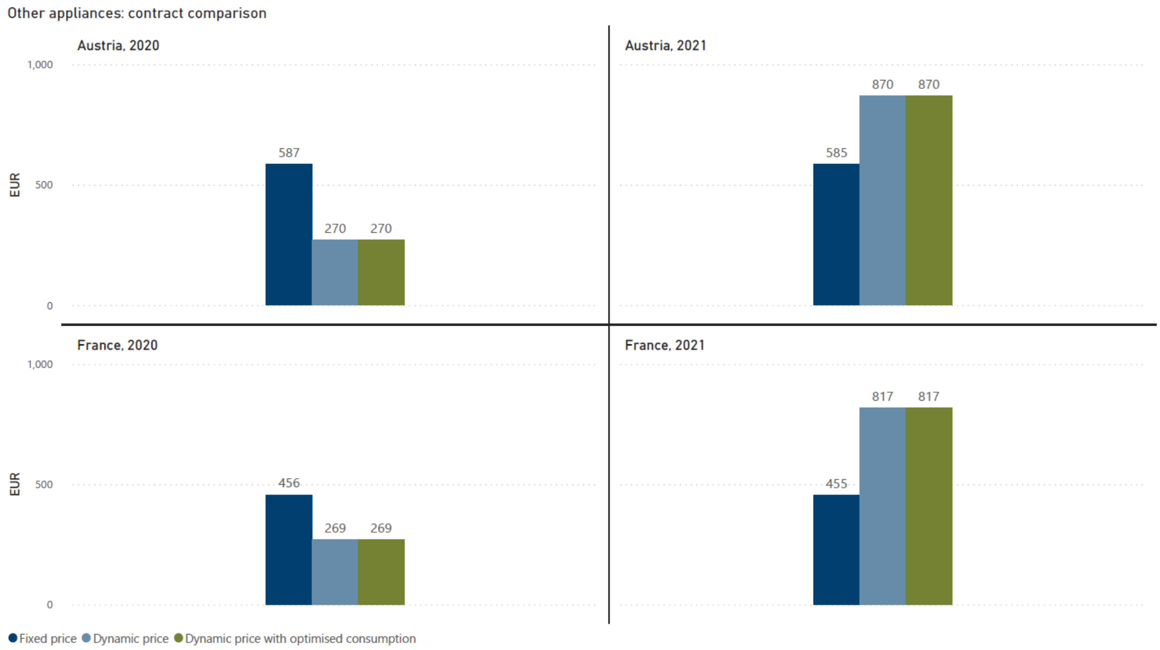
2.3.3 Water heating

Water heating represents between 6% and 9% of total electricity costs for the archetype household. Water heating is not commonly optimised (i.e., used when most needed).



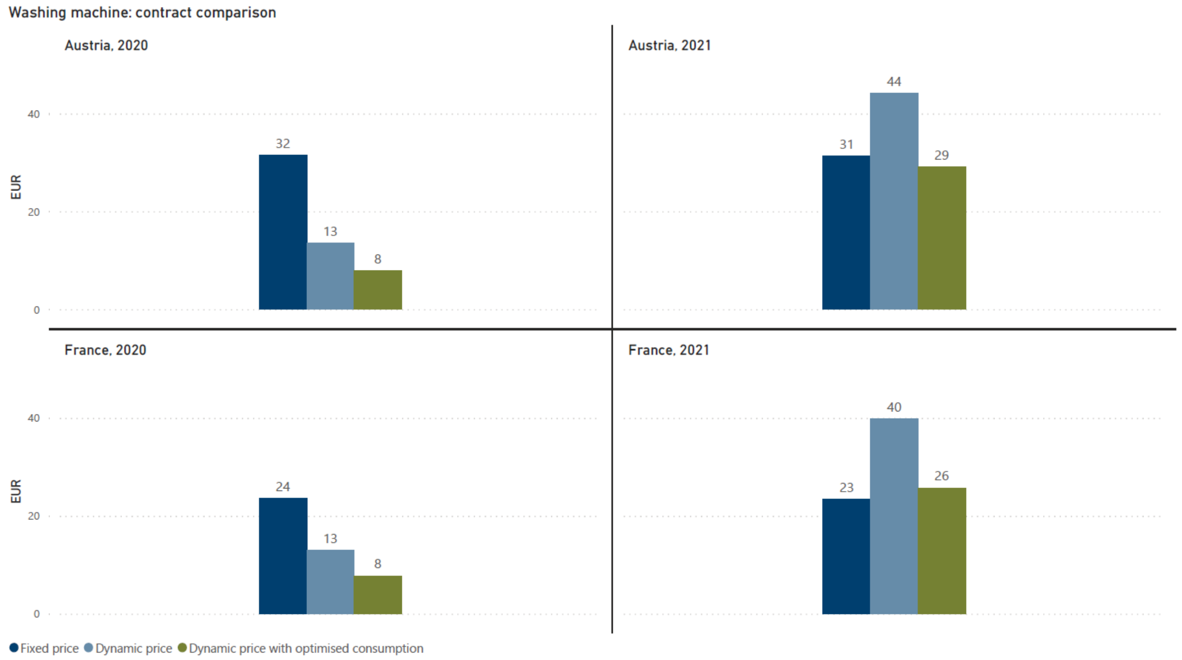
2.3.4 Other household appliances

The electricity consumed by common household appliances represents between 22% and 25% of total electricity costs for the archetype household. The use of household appliances is not commonly optimised (i.e., used when most needed)



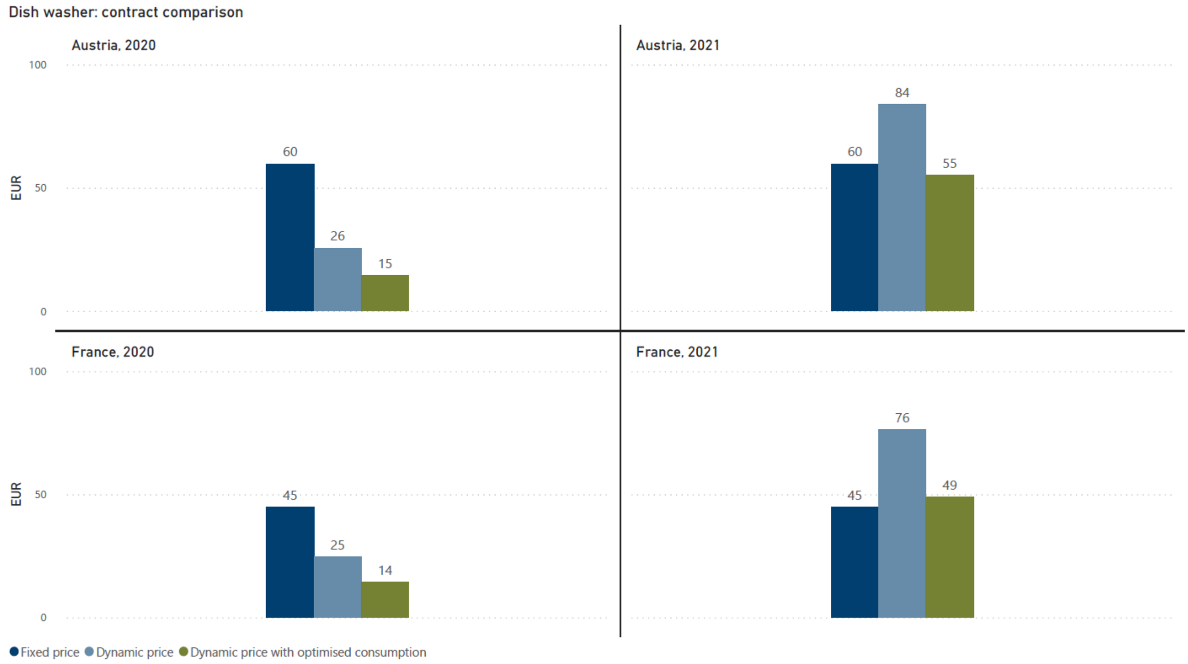
2.3.5 Washing machine

Washing machine use represents around 1% of total electricity costs for the archetype household. Washing machine use can easily be optimised (i.e., used when price is lowest). Annual household savings can reach 40% of the of the costs incurred for washing without optimising – between € 5 and € 15.



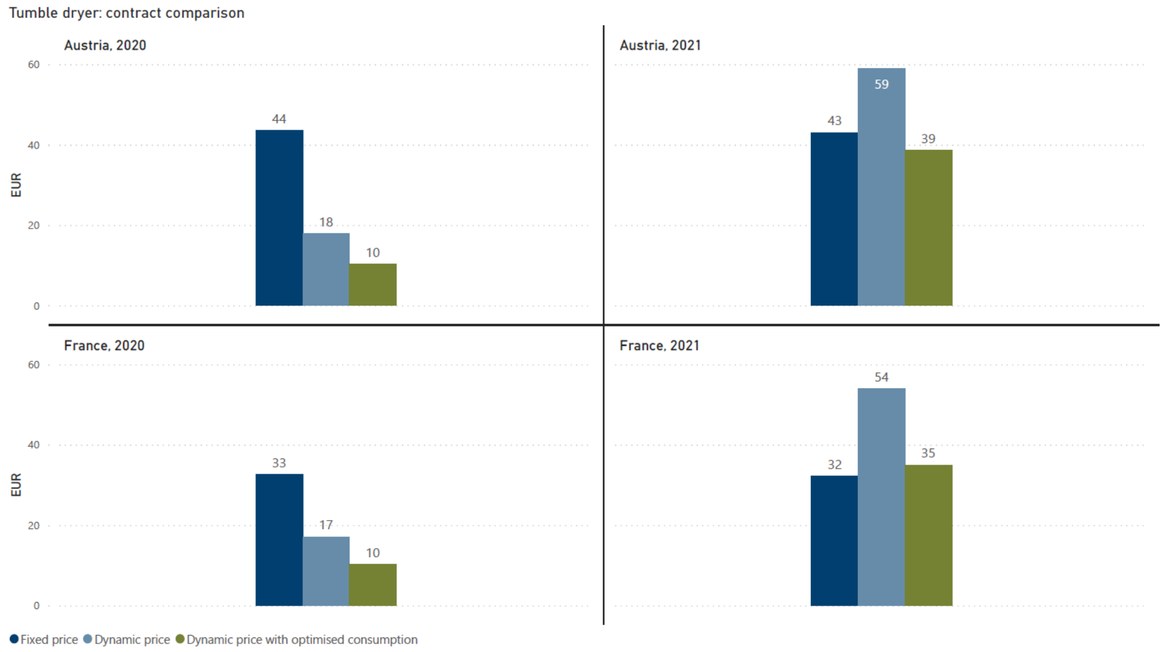
2.3.6 Dishwasher

Dishwasher use represents around 2.5% of total electricity costs for the archetype household. Dishwasher use can easily be optimised (i.e., used when price is lowest). Annual household savings can reach around 38% of the of the costs incurred for washing without optimising – between € 11 and € 28.



2.3.7 *Tumble drying*

Tumble drying represents around 1.5% of total electricity costs for the archetype household. Tumble dryer use can easily be optimised (i.e., used when price is lowest). Annual household savings reach around 39% of the of the costs incurred for washing without optimising – between € 8 and € 20.



3 Policy implications

This section aims to give high-level recommendations with regards to a) how electricity cost comparisons between fixed and dynamic pricing contracts can be calculated without any advanced methods and estimations, and b) broad policy actions for regulators that can be inferred from the results presented in this report, in order to help balance the risks and benefits of dynamic pricing contracts for households.

3.1 Calculating electricity costs for households

Section 1 outlines in detail the methodology this study has followed for the calculation of household energy cost. While this is a data heavy undertaking, it is something that can be replicated by others. The only prerequisite is that the user:

- either is familiar with accessing and processing (publicly) available data
- either is able to access a tool, which contains much of the necessary data and information, and allows the calibration to household idiosyncrasies of any benchmark information used.

The remaining of this section will give a high-level overview of a simple way to compare electricity costs under fixed pricing versus dynamic pricing, with or without managed use of appliances. References are made to section 1 of this report, to avoid repetition.

3.1.1 Steps to calculate energy costs for households

As section 1 discusses, the calculation of energy costs for households is a straight-forward process relying on basic calculations, but contains many steps.

Step 1: electricity price time series

The electricity price charged to households under different energy contracts available for the household is necessary for the evaluation of two key alternative scenarios: fixed price contract and variable/dynamic price contract. This entails obtaining two time series for past prices, the fixed rate (set at a frequency determined by the energy contract) and the variable/dynamic rate (reported on an hourly frequency). Energy prices need to be expressed in local currency per kWh.

If the household electricity price information is not made available by energy providers (publicly or upon request), the user can follow the approach described in section 1 to derive an approximation to the electricity price faced by households based on day-ahead wholesale prices. However, there may be differences between providers in the pricing and – if calculated this way – prices should be seen as estimates.

The <u>output</u> from this step is a time series, for a given year, with hourly observations for the household electricity price.

Step 2: electricity consumption time series

To obtain an accurate representation of the expected magnitude of the electricity costs for a household and the benefits from switching between fixed and dynamic price contracts, the user will need information on the volume of electricity consumed for each activity and the distribution of the activity across the year, month and day (information on the time and frequency of consumption).

Electricity consumption profiles vary between households depending on a multitude of factors. Information such as the size of the household (members and square meters), the energy efficiency rating and the activities for which electricity is used are necessary to approximate the levels and patterns of electricity consumption.

Electricity consumption profiles are also different between different categories of household electricity consumption and – ideally – consumption time series are available broken down for each of these. Commonly, the household electricity consumption categories are the following: space heating (and cooling), water heating, washing (including dishwashing and tumble-drying), EV charging and other household appliances. Further breakdown of the latter is possible.

The output from this step is a time series, with hourly (or daily) observations for the household electricity price by electricity consumption category, for one (non-defined) year.

Step 3: electricity cost time series

To calculate hourly, daily, monthly or annual electricity costs, it is then enough to multiply the respective electricity price time series with the consumption time series (i.e., the hourly price multiplied by the electricity consumed for the same hour, or the daily average price by the electricity consumed that same day). This exercise can be performed at hourly or daily frequencies, subject to data availability, and produces electricity cost time series by consumption category.

To calculate the benefits from full or partial optimisation of electricity consumption for the different categories that allow for flexible electricity consumption, the simplest way to do this is:

- to identify the hours during which the electricity is at the lowest for each day and within the week, e.g., for many countries, the price of electricity is often lower after 09:00 pm and during the weekends.
- then, the user will need to identify the categories for which electricity consumption can be flexible for the household of interest. Often, these include electric vehicle charging; tumble drying; dish washing; washing.

Finally, the user will need to multiply the updated distribution of electricity consumption for the different categories with the appropriate electricity price. This exercise can be performed at hourly or daily frequencies, subject to data availability.

The output from this step are electricity cost time series by consumption category for each price time series, which can be summed up to arrive at the total electricity costs for the household.

3.1.2 A tool to calculate electricity costs

A publicly available tool hosted on an online platform can aid in the calculation of risks and benefits of dynamic electricity pricing by reducing the effort needed for data collection, analysis and communication. The dashboard that this study accompanies presents a reduced form of an electricity cost/benefit calculator with interactive visual elements, and introduction of price and consumption data inputs.[9]

[9] The dashboard can be accessed by following this link: https://app.powerbi.com/view?r=eyJrIjoiODdiOWRiZjQtZjkwNy00MTJjLThkNjctZjQ3MTM3MTUwMTdkIiwidCI6IjE1YWQxMGU2LWJlNWYtNDY3ZS05MDZjLWQ4MmRlMzQ1ZDM3ZiIsImMiOjh9

A move towards an electricity cost/benefit calculator that is closer to a fully-fledged tool for the calculation of electricity costs could involve:

- Relaxing assumptions relating to the characteristics of the archetype household (members, square meters, energy efficiency certification) by:
    - including more types of representative households
    - allowing for direct editing of the characteristics of the household by the user
- Relaxing assumptions relating to the characteristics (frequency of use, electricity consumed per unit of use, seasonality) of the different electricity consumption categories by:
    - Including more types of electricity consuming devices
    - Allowing for direct editing of the characteristics of the electricity consuming activities

3.1.3 Communication of results

The communication of results through appropriate means of visualisation is as important as the quantification of electricity costs. Bar charts and line charts are best suited for a quick and accessible review of the risks and benefits of dynamic electricity prices by most users.

A good practice is starting from aggregated results – unidimensional – such as the comparison of the annual electricity costs between fixed price contract, dynamic price contract, and dynamic price contract with optimised energy consumption. This will give direction in the residual comparisons, as the user gradually introduces additional dimensions: time, electricity consumption category. Auxiliary graphs, such as prices and electricity consumption, are useful to better understand changes in electricity costs across time and categories, as well as to put into perspective the potential of savings through optimised consumption.

Another good practice when reviewing the risks and benefits of dynamic electricity pricing is relying on multi-year price time series. This will allow the user to identify time trends in electricity price and in the relationship between fixed and dynamic prices.

3.2 Dynamic pricing contracts

3.2.1 Data transparency

The estimates presented in this report are based on publicly available data and assumptions regarding the electricity consumption and electricity prices paid by households in the countries considered. While historical hourly day-ahead wholesale electricity prices can be obtained from the ENTSO-E Transparency Platform[10], historical hourly household electricity prices (and differences between electricity suppliers) are not.

In the absence of publicly available data, assumption-driven estimates have been made in this study. For dynamic prices charged by suppliers, the hourly dynamic household electricity prices have been estimated assuming the add-on to day-ahead wholesale prices are similar to the add-on for fixed prices. In practice, there can be differences between the add-ons between fixed and dynamic prices, as well as between different suppliers.

[10] https://transparency.entsoe.eu/

Equally for electricity consumption, in particular a breakdown by household activity and how this is distributed across time, data is sparse. Available data regarding electricity consumption by different types of households and household use / consumption category is still sparse for the countries considered in our analysis. Most publicly available data presents annual data on household electricity consumption at aggregate level only (all household activities), without providing a breakdown by household type or household activity, nor a distribution over time.

Without better (observed) data, it is hard for anyone to make accurate comparisons of the differences in electricity costs for households, for the households themselves or third parties. **There is clear scope for energy regulators to foment more transparency regarding dynamic retail prices charged by energy providers and electricity consumption (levels and hourly distribution) by category (washing, space heating, EV charging, etc) and make those publicly available.**

3.2.2 Consumer information

The data used in this study and the estimates made suggests that households should be clearly informed of the following aspects related to dynamic pricing:

- Seasonality: the data illustrates the seasonality of both electricity prices and electricity consumption. **Households should be well informed of these seasonal variations in prices, rather than being provided with annual averages or the price when signing the contract. Ideally, they should also be given information about how electricity demand and prices are regularly distributed throughout the day.** Simply multiplying a fixed number for daily, monthly or annual electricity consumption by an average variable price is not sufficient to provide an accurate picture of the potential risks and benefits to households considering a dynamic pricing contract.
- Flexible use: the electricity costs for a household with a dynamic pricing contract depends on the household's ability to adjust consumption during the day following information about upcoming price variations. **Households should be given sufficient information and tools that allow them to assess the extent to which they are able to use appliances flexibly, depending on appliances owned and household characteristics.** When the ability to use appliances flexibly is low, households should understand this and be aware that the benefits from managed use are likely to be small.
- Past prices and consumption: Households should not only have insight into upcoming prices to maximise demand-side responses, but those **households with a dynamic pricing contract should be informed of their past consumption levels and electricity prices with as much granularity as possible, for example, having access to historical consumption data from their smart meter, and how this would have compared with a fixed price contract.**

3.2.3 Price floors and ceilings

The price increases in 2021 illustrated by the data used in this study (although they are also common knowledge) illustrate that **the main risk of dynamic or variable pricing lies not primarily with intraday volatility, but the long-term volatility that can lead to sustained changes in electricity prices on the market.** Intraday volatility can to a certain extent be managed by a household if they have the necessary forward-looking information about upcoming price spikes in the short them (day ahead, same day), thus keeping the impact on total electricity costs within certain limits.

The main purpose of dynamic price contracts is to give households price signals that allow them to adjust their electricity demand within a day to minimise the costs, yet the longer-term volatility that we have seen in 2021 is hard to manage and exposes households with dynamic pricing contracts to considerable risks, particularly compared to households with a fixed pricing contract. **Placing ceilings and/or other restrictions to sustained price variation over time would mitigate the risk for households while the main objective of demand-side management within a day can still be met.** Such ceilings and/or floors can be designed in a way that they only apply in the case of sustained price changes over time, rather than intraday volatility.