UPDATE OF PEER REVIEW OF "COST OF CAPACITY FOR CALIBRATION OF BELGIAN CRM"

A report to Elia

OCTOBER 2022

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Making Future

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1 Executive summary

Following AFRY's review of cost assessment for selected technologies in Belgium in 2020 ("AFRY 2020 Report") for Elia to support its inputs for the calibration of the capacity remuneration mechanism, AFRY has been commissioned to realise an updated analysis of the review to provide:

- clarifications around what is included in the "fixed O&M" cost category;
- an update of the specific fixed O&M costs for OCGT and CCGT units in Belgium and how these have changed since the assessment realised by AFRY in the summer of 2020; and
- an update of the specific fixed O&M costs for pumped storage units in Belgium and how these have changed since the assessment realised by AFRY in the summer of 2020.

This Report is to be read in conjunction with the AFRY 2020 Report, which contains further details around the initial peer review assessment serving as the basis for this update.

Since the AFRY 2020 Report, energy markets have faced significant developments and challenges, the most recent of those following the events in Ukraine since February 2022. With Russia and Ukraine are leading the global production of metals such as nickel, copper, and iron which has repercussion on materials used in the energy industry. Both countries are also significant players in the export and manufacture of other essential raw materials like neon, palladium, and platinum. Russia's attack on Ukraine has caused significant escalation in the prices of these metals. Oil and gas prices have also significantly increased, impacting manufacturing and transportation.

This is impacting fixed operating and maintenance costs supported by market participants. However, there is currently limited public information in the form of publicly available studies or statements by power plant operators. However, based on AFRY's in-house project experience we know that cost increases are being supported by market participants through indexation formulas used in EPC quotes and LTSA contracts. While the exact details of such contracts are confidential by nature, we have used relevant public indices traditionally used in those to reflect the cost increases on materials and labour since the previous analysis.

Exhibit 1.1 presents the results of updating the specific fixed O&M cost for each OCGT unit in Belgium, which leads to **a 26-26.4%% increase on average across the OCGT fleet in Belgium compared to the AFRY 2020 Report**.

Exhibit 1.1 – Results of updated specific fixed O&M cost for all OCGT units

Unit	Capacity (MW)	Type	COD	Specific fixed O&M cost (€/kW/a)*			
				AFRY 2020 Report	AFRY 2020 (excl. grid charge)	AFRY 2022 Report	AFRY 2022 (excl. grid charge)
Angleur 3 - TG31	25	Frame type	1978	40.68	40.19	50.41	49.92
Angleur 3 - TG32	25	Frame type	1978	40.68	40.19	50.41	49.92
Angleur 4 - TG41	63	Aero	2012	19.08	18.59	24.69	24.19
Angleur 4 - TG42	63	Aero	2012	19.08	18.59	24.69	24.19
Ham - HAM31	56	Aero	2006	19.08	18.59	24.69	24.19
Ham - HAM32	56	Aero	2006	19.08	18.59	24.69	24.19
Cierreux	18	Turbojet	1960s	29.49	29.00	37.00	36.51
Beerse	32	Turbojet	1960s	23.07	22.58	28.94	28.45
Zelzate	18	Turbojet	1960s	29.49	29.00	37.00	36.51
Aalter	18	Turbojet	1960s	29.49	29.00	37.00	36.51
Zedelgem	18	Turbojet	1960s	29.49	29.00	37.00	36.51
Noordschote	18	Turbojet	1960s	29.49	29.00	37.00	36.51
Zeebrugge	18	Turbojet	1960s	29.49	29.00	37.00	36.51

* For OCGTs, the fixed O&M costs assume of 800 running hours.

Exhibit 1.2 presents the results of updating the specific fixed O&M cost for each CCGT unit in Belgium, which leads to **a 23-27% increase on average across the CCGT fleet in Belgium compared to the AFRY 2020 Report**.

Exhibit 1.2 – Results of updated specific fixed O&M cost for all CCGT units

Unit	Capacity (MW)	Type	COD	Specific fixed O&M cost (€/kW/a)			
				AFRY 2020 Report (8,000h)	AFRY 2020 Report (4,000h)	AFRY 2022 Report (8,000h)	AFRY 2022 Report (4,000h)
T-Power	425	1x1	2011	41.39	32.08	50.97	40.21
Seraing	485	2x1	1994	42.10	32.06	51.81	40.16
Amercoeur	451	1x1	2010	40.26	31.34	49.59	39.31
Marcinelle	405	1x1	2011	42.36	32.71	52.15	40.98
Saint-Ghislain	350	1x1	2000	45.52	34.74	56.01	43.47
Drogenbos	460	2x1	1993	43.22	32.77	53.17	41.03
Knippergroen	315	1x1	2010	48.06	36.36	59.11	45.45
Ringvaart	357	1x1	1998	45.07	34.46	55.46	43.12
Herdersbrug	480	2x1	1998	42.31	32.19	52.07	40.33
Zandvliet	384	1x1	2005	43.47	33.43	53.50	41.86
Inesco	138	1x1	2007	56.46	43.88	69.48	54.77

Exhibit 1.3 – Results of updated specific fixed O&M cost for all CCGT units

Unit	Capacity (MW)	Type	COD	Specific fixed O&M cost (€/kW/a)			
				AFRY 2020 Report (8,000h, no elec)	AFRY 2020 Report (4,000h, no elec)	AFRY 2022 Report (8,000h, no elec)	AFRY 2022 Report (4,000h, no elec)
T-Power	425	1x1	2011	36.46	29.62	46.04	37.75
Seraing	485	2x1	1994	37.16	29.59	46.87	37.69
Amercoeur	451	1x1	2010	35.32	28.88	44.65	36.84
Marcinelle	405	1x1	2011	37.42	30.24	47.21	38.51
Saint-Ghislain	350	1x1	2000	40.59	32.28	51.08	41.01
Drogenbos	460	2x1	1993	38.28	30.30	48.24	38.56
Knippergroen	315	1x1	2010	43.12	33.89	54.17	42.98
Ringvaart	357	1x1	1998	40.13	31.99	50.52	40.65
Herdersbrug	480	2x1	1998	37.38	29.73	47.13	37.86
Zandvliet	384	1x1	2005	38.53	30.96	48.57	39.39
Inesco	138	1x1	2007	51.52	41.42	64.54	52.30

Based on the various data sources used in our analysis, there is significant variation in reported O&M costs for PSP plants, ranging from €10/kW to €50/kW. Costs attached to major overhaul can have a strong impact on O&M costs. Maintenance may be done preventively or reactively which considerably impacts the cost side and in the latter case the availability of the plant.

Our review of different public data sources (from power utilities as well as authorities) combined with our in-house knowledge suggests annual fixed O&M for PSP in the range of €10-30/kW. There may, however, be a significant difference between small and large PSP plants. **We recommend the use of an updated average cost of €22/kW for the purpose of defining a typical annual fixed O&M value for a pumped storage plant in Belgium.** Larger facilities may however find themselves on the lower end of the spectrum.

2 Introduction

2.1 Introduction and background

With the introduction of a capacity remuneration mechanism in Belgium from 2025 onwards, Elia (along with CREG) commissioned Fichtner to provide cost estimates for new entrant technologies and for existing/operating technologies in Belgium ("Fichtner 2019 Report")[1]. The cost estimates were to be used to inform the inputs for the calibration of the capacity remuneration mechanism.

A peer review of the Fichtner cost estimates was completed by AFRY in October 2020 ("AFRY 2020 Report")[2]. As part of this work AFRY provided independent estimates of the specific fixed O&M costs for OCGT units, CCGT units and pumped storage units in Belgium.

Following this, Elia commissioned AFRY to provide an updated review to the AFRY 2020 Report and to provide:

- clarifications around what is included in the "fixed O&M" cost category;
- an update of the specific fixed O&M costs for OCGT and CCGT units in Belgium and how these have changed since the assessment realised by AFRY in the summer of 2020; and
- an update of the specific fixed O&M costs for pumped storage units in Belgium and how these have changed since the assessment realised by AFRY in the summer of 2020.

This Report is to be read in conjunction with the AFRY 2020 Report, which contains further details around the initial peer review assessment serving as the basis for this update.

[1] Fichtner Report entitled "Cost of Capacity for Calibration of the Belgian Capacity Remuneration Mechanism (CRM)" dated April 2020.
[2] AFRY report entitled "Peer review of "cost of capacity for calibration of Belgian CRM study", dated October 2020.

2.2 Structure of this report

This report is structured as follows:

- Chapter 3 clarifies the costs items considered in the fixed O&M category as part of the review.
- Chapter 4 provides an update of the specific fixed O&M costs for OCGT units in Belgium and how these have changed since the assessment realised by AFRY in the summer of 2020.
- Chapter 5 provides an update of the specific fixed O&M costs for CCGT units in Belgium and how these have changed since the assessment realised by AFRY in the summer of 2020.
- Chapter 6 provides an update of the specific fixed O&M costs for pumped storage units in Belgium and how these have changed since the assessment realised by AFRY in the summer of 2020.
- Annex A provides sensitivities around the 2022 fixed O&M assessment based on a range of different assumptions on CCGT running hours.

2.3 Conventions

All monetary values quoted in this report are in Euros (€) in real 2022 prices, unless otherwise stated.

Plant efficiencies throughout this report are defined at the Higher Heating Value (HHV) basis. Fuel prices are similarly quoted on a gross (HHV) basis.

2.3.1 Sources

Unless otherwise attributed the source for all tables, figures and charts is AFRY Management Consulting.

3 Cost items assumed under fixed O&M

3.1 Definition and clarification of fixed O&M costs included in the assessment

As per the "Explanatory note for the public consultation on the scenario's, sensitivities and data for the CRM parameter calculation for the Y-4 Auction with Delivery Period 2025-2026" issued by Elia in May 2020, the yearly fixed operation and maintenance (O&M) cost includes the following components:

- fixed operating costs including personnel costs, administrative costs, electricity and gas transmission charges (where applicable);
- the O&M insurance for general liability, machine breakdown and interruption of operation of a power plant; and
- fixed maintenance costs including intra-year maintenance and a provision for major overhauls that do not necessarily take place on a yearly basis.

As part of the scope of work agreed with Elia, clarifications have been made to which costs are included under the review of fixed O&M costs and those are discussed further below[3]. Another point was raised regarding portfolio management costs when looking at the fixed O&M costs. In our initial peer review, such estimates were based on literature reviews around fixed operating costs from Brattle, Pöyry, IEA and the Fichtner report. Trading and associated admin costs are bundled as a percentage estimate of the EPC contract price as per industry standards. We would not be able to comment on a detailed bottom-up view of portfolio management costs (Day-ahead power plant portfolio optimization, Dispatch team, Scheduling team, Intraday trading team, Forward trading team, Ancillary and TSO-activities team, Mid-term power plant portfolio management and partnership team (data quality management, asset representation, commodity management hedge strategy, maintenance planning, report on positions and results), Finance team, Settlement team) or its composition) as such activities may be grouped and dealt with through central functions within vertically integrated / large utilities or may be outsourced against a monthly fee by smaller Independent Power Producers.

[3] Please note that such clarification will not necessarily or specifically include a cost assessment for each of those.

3.1.1 OCGT and CCGT

The fixed O&M costs are costs which do not vary from year to year, generally increasing only in line with inflation and/or through contract indexation formulas.

The methodology and approach used in this Report is the same as the one used in the AFRY 2020 Report. To clarify the yearly fixed O&M costs considered for the OCGT and CCGT units in the AFRY 2020 report, and again in this updated 2022 review, include the following cost components:

- **Personnel costs.** Those assume the plant is operated and maintained by a third-party O&M company and cover salary and wages, bonus payments, shift premiums, pension contributions, social security contributions and O&M company profit.
- **Regular maintenance.** The regular maintenance cost covers routine and preventative maintenance activities including consumables (filters, fuses, bulbs, gaskets, pump mechanical seals, pump / motor bearings, lubricating oil changes, etc.). The routine or regular maintenance cost typically covers routine maintenance on the GT, generator, compressed air systems, cooling systems, fire protection, electrical equipment, C&I, site facilities and site support services. The gas turbine routine maintenance cost is expected to be the largest component and includes the cost associated with periodically replacing the gas turbine air intake filters.
- **Trading and admin costs.** Those include trading and settlement overhead costs, bank fees, security expenses, public relations, legal fees, freight and import duties, auditing fees, safety equipment, office equipment expenses, and other miscellaneous expenses.
- **Fixed electricity transmission charges.** The electricity transmission charge is highly country-specific and has been calculated based on tariff data published by Elia.
- **Fixed gas transmission charges.** For the OCGTs, the gas transmission charge has been set to zero on the basis that short-term gas capacity products are available and peaking units treat these as variable costs.
- **Plant operating insurance.** The annual insurance covers the O&M period insurances for general liability, machinery breakdown and business interruption for the power plant.
- **Annual accrual for future major overhauls.** This covers the annual accrual for future gas turbine major maintenance (often referred to as hot gas path inspections or major inspections). The trigger for carrying out such inspections is generally based on the gas turbine reaching the manufacturer's defined threshold in terms of operating hours or starts (e.g. 24,000 operating hours or 900 starts). As such the timing of inspections depends to a large extent on the plant running regime and consecutive inspections can be separated by many years.

Property taxes and land lease costs, which are eligible fixed O&M costs in Brattle 2018 and Pöyry 2018, are excluded from the above definition and have not been considered in the AFRY 2020 Report or this updated review.

For the avoidance of doubt, the yearly fixed O&M costs excludes the following cost components, which are considered to be included within the non-fuel variable O&M costs:

- **Chemicals cost.** The chemical cost covers chemicals for demineralised water production, water steam cycle chemical dosing, wastewater treatment (neutralisation) and any necessary cooling water treatment (anti-scalant, biocide).
- **Raw water cost.** The raw water will be used to satisfy the process water demands of the plant. In the case of a CCGT plant the municipal water will be treated on site to provide the high quality make up water that is required by the heat recovery steam generator when the plant is operating. For an OCGT plant the raw water consumption is relatively modest.
- **Wastewater discharge cost.** The wastewater discharge cost covers the cost of any process wastewater discharges to the local municipal sewerage network (e.g. treated boiler blowdown water or water treatment plant effluent).
- **Imported power.** Electricity is imported from the grid whenever a plant is shutdown (for planned maintenance or due to a forced outage). Given the strong correlation between the import amount and the plant running hours this is generally treated as a variable cost.
- **Contingency for unplanned maintenance.** The contingency for unplanned maintenance is an allowance to cover the cost of repairing unexpected equipment breakdowns which are not covered either by manufacturer's warranty or are below the threshold of the deductible under the insurance policy. Given the strong correlation between this cost and the amount of plant running hours / starts, this is generally treated as a variable cost.
- **Fuel for plant starts (i.e. after plant trips or maintenance).** Fuel for plant starts covers the cost of natural gas consumed during plant start-ups not requested by the transmission system operator (e.g. after a plant trip or after a shutdown for scheduled maintenance).
- **CO_2 emission costs.** The CO_2 emissions cost in any period depends on the amount of CO_2 emitted by the plant in that period (dependant on fuel use) and the prevailing CO_2 price level.

3.1.2 Pumped storage plant

Fixed O&M cost comprises the following three main cost components:

- **staffing costs** (manpower), required for the direct operation and maintenance of the plant;
- **third party and materials costs** (e.g. external companies being hired for specific O&M services), which are required to maintain and operate the plant including civil structures and electro-mechanical equipment; and
- **various O&M expenses** which are required for the operation (e.g. administration, back office, dispatching & control centre, etc.) but which are not directly linked to the civil or mechanical parts of the plant.

Costs for major overhaul normally are not included in the fixed O&M cost and are calculated separately.

Further clarification on what is included in the above costs is provided in Section 6.2.

4 Fixed O&M costs for existing OCGT units

4.1 Recap of fixed O&M cost calculation for Angleur 4 in AFRY 2020 Report

Exhibit 4.1 presents AFRY's calculation of the specific fixed O&M cost for the Angleur 4 facility taken from the AFRY 2020 Report. All costs are at 2019 price levels.

Exhibit 4.1 – AFRY calculation of specific fixed O&M cost for Angleur 4 – AFRY 2020 Report (2019 prices)

Parameter	Unit	Value	Remark
Plant	-	Angleur 4	
Gas turbine model		Trent 60	
Fuel type		gas/oil	
Rated output	MWe	63	
EPC cost			
Specific "Equipment supply" cost	€/kW	323	From GTW2019
Specific uplift for whole plant EPC cost	€/kW	258.688	80% of "equipment supply" cost
Specific EPC cost	€/kW	582	
Plant capacity	kW	63,000	
EPC cost	€	36,669,024	
Fixed O&M			
(a) Annual operating	€/a	696,711	1.9% of EPC cost
(b) Annual insurance	€/a	183,345	0.6% of EPC cost
(c) Annual fixed maintenance (excluding major maintenance)		183,345	0.5% of EPC cost
(d) Specific major maintenance	€/hour	173	Derived from Analysis 2020 report
(e) run hours /annum	-	800	Upper end of range for "utility peaker";

			Part 9 of ISO 3977: 1999
(f) annual major maintenance	€/a	138,749	(d) x (e)
(h) Total fixed O&M	€/a	1,202,150	(a)+(b)+(c)+(f)
Specific fixed O&M	€/kW/a	19.1	(h) divided by rated output

Source: AFRY 2020 Report

The above cost elements are discussed in more detail in the following sections, and commenting (where applicable) when an updated view has been made to reflect changes since the AFRY 2020 Report:

- either based on publicly available data; or
- AFRY's in-house knowledge of such cost items at the time this updated review is done (August 2022) witch such views not yet being reflected in public studies.

4.1.1 Annual Operating Cost

The annual operating cost includes personnel costs, administrative costs, and network (electricity and gas) transmission charges:

- Personnel costs assume the plant is operated and maintained by a third-party O&M company and cover salary and wages, bonus payments, shift premiums, pension contributions, social security contributions and O&M company profit.
- Administrative costs include trading and settlement overhead costs, bank fees, security expenses, public relations, legal fees, freight and import duties, auditing fees, safety equipment, office equipment expenses, and other miscellaneous expenses.
- The electricity transmission charge is highly country-specific and has been calculated based on tariff data published by Elia. The gas transmission charge was set to zero on the basis that short-term gas capacity products are available and peaking units treat these as variable generation costs.

We have assumed annual operating costs at 1.9% of the EPC contract price, and this has not changed since the AFRY 2020 Report.

4.1.2 Annual Insurance Cost

The annual insurance covers the O&M period insurances for general liability, machinery breakdown and business interruption for the power plant.

We have assumed annual insurance costs at 0.6% of the EPC contract price, and this has not changed since the AFRY 2020 Report.

4.1.3 Annual Fixed Maintenance

The fixed maintenance cost covers routine and preventative maintenance activities including consumables (filters, fuses, bulbs, gaskets, pump mechanical seals, pump / motor bearings, lubricating oil changes, etc.).

The routine or regular maintenance cost typically covers routine maintenance on the GT, generator, compressed air systems, cooling systems, fire protection, electrical equipment, C&I, site facilities and site support services.

The gas turbine routine maintenance cost is expected to be the largest component and includes the cost associated with periodically replacing the gas turbine air intake filters.

We have assumed annual fixed maintenance costs at 0.5% of the EPC contract price, and this has not changed since the AFRY 2020 Report.

4.1.4 EPC Cost

In the AFRY 2020 Report, the EPC cost was set at 180% of the "equipment supply cost" published in the 2019 edition of the Gas Turbine Handbook (GTW, 2019).

The gas turbine installed at the Angleur 4 facility are of the Trent 60 WLE type capable of dual fuel operation (63MWe). The closest unit in the 2019 GT World Handbook was the SGT-A65 DLE (Trent), rated at 61.9MWe at ISO conditions. GTW 2019 quoted the equipment supply cost for this unit at $376/kW. Converting to Euros using an exchange rate of 0.86[4] gave a budget price of €323/kW, which is the figure used in Exhibit 4.1.

The 2022 edition of the GTW Handbook (GTW 2022) was published on 1 June 2022. GTW 2022 does not provide an equipment supply cost for the SGT-A65 DLE (Trent) gas turbine. The next closest gas turbine model for which an equipment supply cost is provided in both GTW 2019 and GTW 2022 is for a plant based on 2xFT8 SP60 (with output and efficiency ratings of 62,086kW and 36.8% respectively). The equipment supply cost is given as $362/kW in GTW2019 (fixed 2019 dollars) and $387/kW (fixed 2022 dollars). This corresponds to a 6.9% price increase.

This is a relatively modest price increase over a three-year period and is at odds with the real-life EPC cost escalation observed by AFRY over the last 12 months, especially because of the conflict in Ukraine since February 2022. Russia and Ukraine lead the global production of metals such as nickel, copper, and iron. Both countries are also significant players in the export and manufacture of other essential raw materials like neon, palladium, and platinum. Russia's attack on Ukraine has caused significant escalation in the

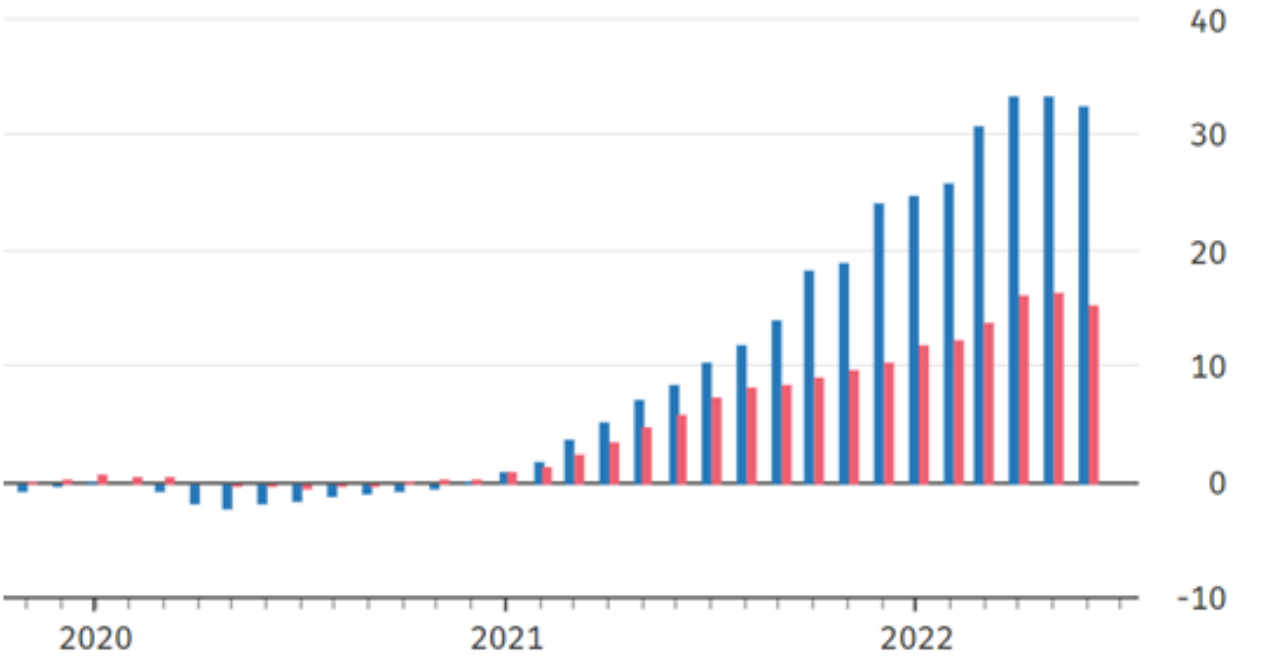
[4] This refers to the assumed exchange rate EUR per USD used in the AFRY 2020 Report. This figure is based on the monthly average USD to EUR exchange rate available via https://www.x-rates.com/average/?from=USD&to=EUR&amount=1&year=2019 for the year 2019 and was used, then, to convert USD EPC quotes from GTW 2019.

prices of these metals. Oil and gas prices have also significantly increased, impacting manufacturing and transportation[5].

The German Federal Statistic office recently reported that the Producer Price Index for Industrial Products in Germany increased by 30.9% from March 2021 to March 2022 (Exhibit 4.2).

Exhibit 4.2 – Evolution of PPI for Industrial Product since 2020

Producer Price Index for Industrial Products increase by around 30% between March 2021 and March 2022



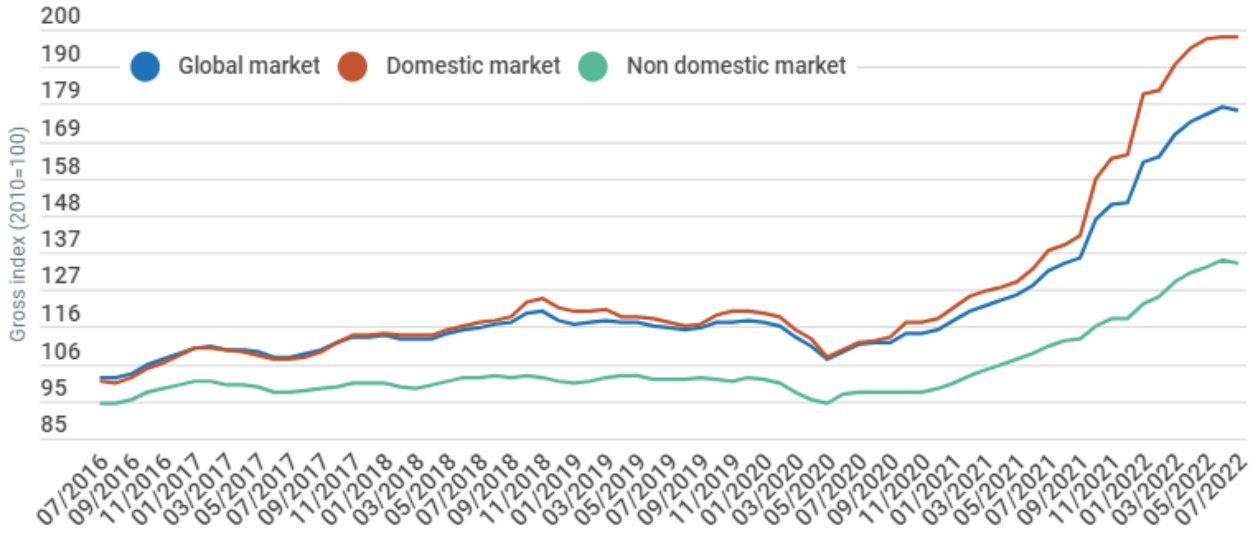
Notes: PPI for Industrial Products (change of previous year %)
Source: Statistiches Bundesamt, Destatis 2022

STATBEL, the Belgian statistical office, reported that the Producer Price Index for total industry excluding construction has increased by 34.4% between July 2021 and July 2022 (Exhibit 4.2).

[5] As further detailed later in this Report, the update to the EPC and LTSA costs are escalated by the use of indices as the GTW 2022 prices are not yet reflecting the impact of the current situation in energy markets (especially linked to the invasion of Ukraine), and the known escalation within LTSAs given the use of a combination of indices.

Exhibit 4.3 – Evolution of PPI for Total Industry Excluding Construction since 2016

Producer Price Index for Total Industry excluding construction increase by around 34% between July 2021 and July 2022



Notes: PPI for Industrial Products (change of previous year %)
Source: Statbel (https://statbel.fgov.be/en/themes/indicators/prices/output-price-index-industry)

A typical breakdown of an EPC cost for an OCGT plant was provided in Table 5 of the AFRY 2020 Report where equipment and materials make up 79% of the overall EPC cost for an OCGT plant. To estimate the change in EPC cost from 2019 to 2022, AFRY considers it reasonable to apply the following formula:

- **2022 EPC cost = [2019 EPC cost] x [0.79 x 1.309 + 0.21 x 1.082]**
  - Where the index of 1.309 reflects the change in the Producer Price Index for industrial products from March 2021 to March 2022 as published by the German Federal Statistic office. **AFRY selected the index published by the German Federal Statistic Office rather than STABEL in view of Germany's strong position as equipment supplier to energy projects in Belgium**; and
  - The index of 1.082 reflects the labour cost index increase for "Electricity, gas, steam and air conditioning supply sector" for Belgium according to STATBEL..

According to the above formula **the 2022 EPC cost level for Angleur 4 is €46,251,740, which corresponds to a 26.1% increase** from the cost level reported in the AFRY 2020 Report (€36,669,024).

4.1.5 Specific Major Maintenance Cost

Major maintenance is assumed to be completed through a long-term service agreement (LTSA) with the original equipment manufacturer that specifies when to complete the maintenance based on either fired hours or number of starts. Each major maintenance cycle for a combustion turbine typically includes regular combustion inspections, periodic hot gas path inspections / major inspections. Since major maintenance activities and costs are spaced irregularly over the long-term, the LTSA cost in a given year represents an

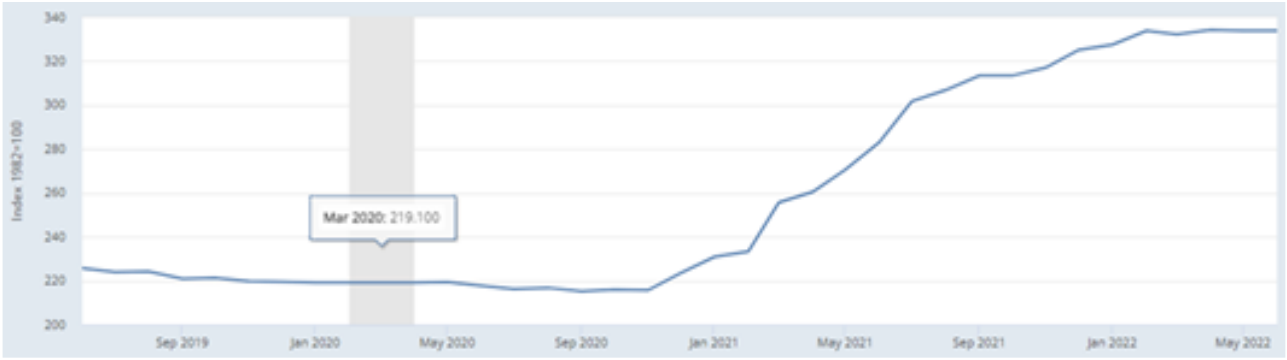
annual accrual for future major maintenance and can be considered as a financial provision taken in order to smooth overall fixed O&M cost rather than supporting these significant costs only in specific years.

The AFRY 2020 Report determined the LTSA cost for Angleur 4 to be €173/hour.

A typical LTSA will run for several years with the LTSA specific cost rates (€/hour) escalated annually according to a contractually agreed basket of indices, usually including a materials index and one or more labour indices.

The specific materials index used will vary according to LTSA provider and where the parts are made. For parts made in the United States an applicable index would be the producer prices index for "fabricated steel plate" published by the US Bureau of Labor Statistics (Series ID WPU 1076). In March 2022, this index increased by 29.9% compared with March 2021 (Exhibit 4.4). The reasons for this increase are already discussed in Section 4.1.4 of this Report.

Exhibit 4.4 – PPI for "fabricated steel plate"



Notes: PPI for "fabricated steel plate" code PPI 1076
Source: US Bureau of Labour Statistics (Series ID WPU 1076).

In AFRY's experience the materials index will typically make up 60% of the overall indexation factor, with the labour indices making up the remaining 40%. To estimate the change in LTSA cost for an OCGT plant from 2019 to 2022, AFRY considers it reasonable to apply the following formula:

- **2022 LTSA cost = [2019 LTSA cost] x [0.6 x 1.299 + 0.4 x 1.082]**
  - Where the index of 1.229 reflects the change in the PPI for "fabricated steel plate" index between March 2021 and March 2022 as published by the US Bureau of Labor Statistics; and
  - The index of 1.082 reflects the labour cost index increase for "Electricity, gas, steam and air conditioning supply sector" for Belgium according to STATBEL.

According to the above formula **the 2022 LTSA cost level for Angleur 4 is €210/hour, which corresponds to a 21.3% increase** compared to the 2019 cost level reported in the AFRY 2020 Report (€173/h).

4.2 Updated specific fixed O&M costs review for Angleur 4

Exhibit 4.5 presents the results of recalculating the specific fixed O&M cost for Angleur 4 using the updated EPC cost and LTSA cost numbers previously discussed. All costs are at 2022 price level.

Exhibit 4.5 – Updated AFRY calculation of specific fixed O&M cost for Angleur 4 – (2022 prices)

Parameter	Unit	Value	Remark
Plant	-	Angleur 4	
Gas turbine model		Trent 60	
Fuel type		gas/oil	
Rated output	MWe	63	
EPC cost			
EPC cost	€	**46,251,740**	**Updated**
Fixed O&M			
(a) Annual operating	€/a	**878,783**	1.9% of EPC cost
(b) Annual insurance	€/a	**277,510**	0.6% of EPC cost
(c) Annual fixed maintenance (excluding major maintenance)		**231,259**	0.5% of EPC cost
(d) Specific major maintenance	€/hour	**210**	**Updated**
(e) run hours /annum	-	800	Upper end of range for "utility peaker"; Part 9 of ISO 3977: 1999
(f) annual major maintenance	€/a	**167,783**	(d) x (e)
(h) Total fixed O&M	€/a	**1,555,336**	(a)+(b)+(c)+(f)
Specific fixed O&M	€/kW/a	**24.7**	(h) divided by rated output

The 2022 specific fixed O&M costs for Angleur 4 is €24.7/kW/a, which represents a 29.4% increase compared the reported cost level in the AFRY 2020 Report (€19.1/kW/a).

4.3 Updated specific fixed O&M costs review for all Belgian OCGTs

Exhibit 4.6 presents the results of updating the specific fixed O&M cost for each OCGT unit in Belgium.

The value from the AFRY 2020 Report (real 2019) is also shown for comparison purposed to the updated values from this 2022 analysis (real 2022).

Exhibit 4.6 – Results of updated specific fixed O&M cost for all OCGT units

Unit	Capacity (MW)	Type	COD	Specific fixed O&M cost (€/kW/a)	
				AFRY 2020 Report	AFRY 2022 Report
Angleur 3 - TG31	25	Frame type	1978	40.68	50.41
Angleur 3 - TG32	25	Frame type	1978	40.68	50.41
Angleur 4 - TG41	63	Aero	2012	19.08	24.69
Angleur 4 - TG42	63	Aero	2012	19.08	24.69
Ham - HAM31	56	Aero	2006	19.08	24.69
Ham - HAM32	56	Aero	2006	19.08	24.69
Cierreux	18	Turbojet	1960s	29.49	37.00
Beerse	32	Turbojet	1960s	23.07	28.94
Zelzate	18	Turbojet	1960s	29.49	37.00
Aalter	18	Turbojet	1960s	29.49	37.00
Zedelgem	18	Turbojet	1960s	29.49	37.00
Noordschote	18	Turbojet	1960s	29.49	37.00
Zeebrugge	18	Turbojet	1960s	29.49	37.00

5 Fixed O&M costs for existing CCGT units

5.1 Recap of specific fixed O&M cost calculation for T-Power CCGT in AFRY 2020 Report

Exhibit 5.1 presents AFRY's calculation of the specific fixed O&M cost for the T-Power facility taken from the AFRY 2020 Report. All costs are at 2019 price levels.

Exhibit 5.1 – AFRY calculation of specific fixed O&M cost for T-Power – AFRY 2020 Report (2019 prices)

Parameter	Units	Value	Remark
Plant	-	T Power	
Gas turbine model		SGT5-4000F	
Number of gas turbines		1	
Fuel type		gas only	
Rated output	MWe	425	
EPC cost			
EPC cost	€/kW	637	GTW2019
Plant capacity	kW	425,000	
EPC cost	€	270,764,480	
Fixed O&M			
(a) Annual operating costs	€	8,122,934	3.0% of EPC cost
(b) Annual operating insurance	€	1,624,587	0.6% of EPC cost
(c) Annual fixed maintenance (excluding major maintenance)		2,030,734	0.75% of EPC cost
(d) specific major maintenance cost (LTSA cost)	€/GT-hour	726.8	Derived from Pöyry 2018 report and applicable to F class technology
(e) run hours per annum	-	8,000	

(f) annual major maintenance cost	€	5,814,000	(d) x (e)
(h) Total fixed O&M cost	€	17,592,255	(a)+(b)+(c)+(f)
Specific fixed O&M cost	€/kW	41.4	(h) divided by rated output (in kW)

Source: AFRY 2020 Report

The above cost elements are discussed in more detail in the following sections, and commenting (where applicable) when an updated view has been made to reflect changes since the AFRY 2020 Report:

- either based on publicly available data; or
- AFRY's in-house knowledge of such cost items at the time this updated review is done (August 2022) witch such views not yet being reflected in public studies.

5.1.1 Update to Annual Operating Cost, Annual Insurance Cost, and Annual Fixed Maintenance

1. Annual Operating Cost.

Cost items under the Annual Operating Cost category are the same as those listed in Section 4.1.1 for the OCGTs.

We have assumed annual operating costs at 3.0% of the EPC contract price, and this has not changed since the AFRY 2020 Report.

2. Annual Insurance Cost.

Cost items under the Annual Insurance Cost category are the same as those listed in Section 4.1.2 for the OCGTs.

We have assumed annual insurance costs at 0.6% of the EPC contract price, and this has not changed since the AFRY 2020 Report.

3. Annual Fixed Maintenance Cost.

The fixed maintenance cost covers routine and preventative maintenance activities including consumables (filters, fuses, bulbs, gaskets, pump mechanical seals, pump / motor bearings, lubricating oil changes, etc.).

The routine or regular maintenance cost typically covers routine maintenance on the Gas Turbine, Steam Turbine, generator, Heat Recovery Steam Generator (HRSG), compressed air systems, air cooled condenser and cooling systems, water treatment plants, water analysis and chemical dosing plants, fire protection, condensate and feedwater systems, steam systems, electrical equipment, C&I, site facilities and site support services.

The gas turbine routine maintenance cost is expected to be the largest component. This includes the cost associated with periodically replacing the gas turbine air intake filters.

The other significant items are likely to be site support services, HRSG routine maintenance and C&I maintenance. The site support services

lagging, scaffolding, mobile cranes, painting etc.. The HRSG routine maintenance will cover control valves, instrumentation, level probes etc.. The C&I maintenance will cover technical support agreement, hardware maintenance and emissions monitoring systems routine maintenance.

We have assumed annual fixed maintenance costs at 0.75% of the EPC contract price, and this has not changed since the AFRY 2020 Report.

5.1.2 Update to EPC cost

In the AFRY 2020 Report, the EPC cost was derived from the 2019 combined cycle cost curve given in GTW 2019. Based on this cost curve, a 425MW capacity CCGT plant was estimated to have a specific EPC cost of $713/kW (fixed 2019 dollars). Converting to Euros gave an EPC cost of €637/kW (figure quoted in Exhibit 5.1).

The 2022 edition of the GTW Handbook (GTW 2022) was published on 1 June 2022. Based on the 2022combined cycle cost curve given in GTW 2022, a 425MW capacity CCGT plant is estimated to have a specific EPC cost of $725/kW (fixed 2022 dollars), which corresponds to a 1.6% price increase compared to the 2019 level.

Similar to the commentary around GTs (Section 4.1.4), This is a relatively modest price increase over a three-year period and is at odds with the real-life EPC cost escalation observed by AFRY over the last 12 months, especially because of the conflict in Ukraine since February 2022.

Applying a similar approach as for GTs in Section 4.1.4 and using the evolution of relevant global indices to estimate the change in EPC cost from 2019 to 2022, AFRY considers it reasonable to apply the following formula:

- **2022 EPC cost = [2019 EPC cost] x [0.7 x 1.309 + 0.3 x 1.082]**
  - Where the index of 1.309 reflects the change in the Producer Price Index for industrial products from March 2021 to March 2022 as published by the German Federal Statistic office. Similar to the approach for OCGTs, **AFRY selected the index published by the German Federal Statistic Office rather than STABEL in view of Germany's strong position as equipment supplier to energy projects in Belgium**; and
  - The index of 1.082 reflects the labour cost index increase for "Electricity, gas, steam and air conditioning supply sector" for Belgium according to STATBEL.

According to the above formula **the 2022 EPC cost level for T-Power CCGT is €333,717,221, which corresponds to a 23% increase** from the cost level reported in the AFRY 2020 Report (€270,764,480).

5.1.3 Specific Major Maintenance Cost (LTSA Cost)

Major maintenance is assumed to be completed through a long-term service agreement (LTSA) with the original equipment manufacturer that specifies when to complete the maintenance based on either fired hours or number of starts. Each major maintenance cycle for a combustion turbine typically includes regular combustion inspections, periodic hot gas path inspections / major inspections. Since major maintenance activities and costs are spaced irregularly over the long-term, the LTSA cost in a given year represents an annual accrual for future major maintenance and can be considered as a financial provision taken in order to smooth overall fixed O&M cost rather than supporting these significant costs only in specific years.

The AFRY 2020 Report determined an LTSA cost for T-Power to be €726.8€/GT-hour.

A typical LTSA will run for several years with the LTSA specific cost rates (€/hour) escalated annually according to a contractually agreed basket of indices, usually including a materials index and one or more labour indices. The specific materials index used will vary according to LTSA provider and where the parts are made. Using the same approach as for GTs in Section 4.1.4 and based on AFRY's real project experience the materials index will typically make up 60% of the overall indexation factor, with the labour indices making up the remaining 40%. To estimate the change in LTSA cost for an CCGT plant from 2019 to 2022, AFRY considers it reasonable to apply the following formula:

- **2022 LTSA cost = [2019 LTSA cost] x [0.6 x 1.299 + 0.4 x 1.082]**
  - Where the index of 1.229 reflects the change in the PPI for "fabricated steel plate" index between March 2021 and March 2022 as published by the US Bureau of Labor Statistics; and
  - The index of 1.082 reflects the labour cost index increase for "Electricity, gas, steam and air conditioning supply sector" for Belgium according to STATBEL.

According to the above formula **the 2022 LTSA cost level for T-Power is €881/GT-hour, which corresponds to a 21.2% increase** compared to the 2019 cost level reported in the AFRY 2020 Report (€726.8/h).

5.2 Updated specific fixed O&M costs review for T-Power

Exhibit 5.2 presents the results of recalculating the specific fixed O&M cost for T-Power using the updated EPC cost and LTSA cost numbers previously discussed. All costs are at 2022 price level.

Exhibit 5.2 – Updated AFRY calculation of specific fixed O&M cost for T-Power – (2022 prices)

Parameter	Units	Value	Remark
Plant	-	T Power	
Gas turbine model		SGT5-4000F	
Number of gas turbines		1	
Fuel type		gas only	
Rated output	MWe	425	
EPC cost			
EPC cost	€/kW	637	GTW2019
Plant capacity	kW	425,000	
EPC cost	€	**335,991,643**	**Updated based on EPC indexation formula estimate**
Fixed O&M			
(a) Annual operating costs	€	**10,079,749**	3.0% of EPC cost
(b) Annual operating insurance	€	**2,015,950**	0.6% of EPC cost
(c) Annual fixed maintenance (excluding major maintenance)		**2,519,937**	0.75% of EPC cost
(d) specific major maintenance cost	€/GT-hour	**881**	Derived from AFRY 2020 Report and applicable to F class technology
(e) run hours per annum	-	8,000	
(f) annual major maintenance cost	€	**7,048,354**	(d) x (e)
(h) Total fixed O&M cost	€	**21,663,991**	(a)+(b)+(c)+(f)
Specific fixed O&M cost		**50.97**	(h) divided by rated output (in kW)

The 2022 specific fixed O&M costs for T-Power is €50.97/kW/a, which represents a 23.1% increase compared the reported cost level in the AFRY 2020 Report (€41.39/kW/a).

5.3 Updated specific fixed O&M costs review for all Belgian CCGTs

Exhibit 5.3 presents the results of updating the specific fixed O&M cost for each CCGT unit in Belgium.

The value from the AFRY 2020 Report (real 2019) is also shown for comparison purposed to the updated values from this 2022 analysis (real 2022).

Exhibit 5.3 – Results of updated specific fixed O&M cost for all CCGT units

Unit	Capacity (MW)	Type	COD	Specific fixed O&M cost (€/kW/a)	
				AFRY 2020 Report	AFRY 2022 Report
T-Power	425	1x1	2011	41.39	50.97
Seraing	485	2x1	1994	42.10	51.81
Amercoeur	451	1x1	2010	40.26	49.59
Marcinelle	405	1x1	2011	42.36	52.15
Saint-Ghislain	350	1x1	2000	45.52	56.01
Drogenbos	460	2x1	1993	43.22	53.17
Knippergroen	315	1x1	2010	48.06	59.11
Ringvaart	357	1x1	1998	45.07	55.46
Herdersbrug	480	2x1	1998	42.31	52.07
Zandvliet	384	1x1	2005	43.47	53.50
Inesco	138	1x1	2007	56.46	69.48

The above estimates are based on a 'baseload' operation assumption.

A sensitivity on fixed O&M costs for CCGTs based on different assumptions around assumed running hours (8,000; 6,000; 4,000; 2,000; 1,000 and 500 hours) is presenting in Annex A.

The gas turbine major overhaul costs used in the calculation of fixed O&M costs assume the plant owner will enter into a Long-Term Service Agreement (LTSA) with the original equipment manufacturer. Whilst this is a reasonable assumption for a new build plant based on advanced gas turbine technology, we do recognise that the average age of the existing CCGTs in Belgium is over 16 years. By this time the original LTSA will have normally expired, as a typical LTSA term covers the first 100,000 equivalent operating hours. Once the original LTSA expires, a plant owner will be able to procure maintenance services competitively from a much wider range of third-party maintenance service providers. In this way a plant owner can typically realise gas turbine maintenance cost savings of between 10 and 15% when compared to an LTSA.

6 Fixed O&M costs for pumped storage

Based on the latest developments in the global hydropower market, which has been seen affected by the consequences of the COVID-19 pandemic as well as recently by the war in Ukraine (increased inflation, difficulties in supply chain, etc.), lead-times for purchasing spare parts and equipment for major overhauls considerably increased. Most notable for steel and copper intensive parts of the plants - namely for runners, generators, transformers and hydromechanical equipment - certain price increase could be observed during the last 2 years since the first review of O&M costs in the AFRY 2020 Report.

In particular, this development also gives an indication with respect to the fixed O&M cost as most of the material and services purchased to undertake the continuous operation and maintenance of the plants consist of the same component family and thus are affected by the same price increase. Furthermore, order books of main equipment suppliers are well filled resulting also in longer purchase times.

6.1 Approach to updating fixed O&M cost for hydropower plant

As of August 2022, there are publicly available, detailed updated figures from the literature to account for recent developments since the AFRY 2020 Report was published. However, industry specific indexes already show and underline the above-described market evolution. Due to the lack of newer and updated information from the industry or equivalent data from the European market, AFRY reassessed the data from 2020 based on the US PPI Industry Data (https://data.bls.gov/PDQWeb/pc) providing up to date indexations for various hydro power components, as this index is widely used in international hydropower contracts where indexation is applied.

Labour cost, which represent the biggest portion of the fixed O&M cost for hydropower plants as stated in the AFRY 2020 Report has been updated according to STATBEL (https://statbel.fgov.be/en/themes/indicators/labour/labour-cost-index#figures) applying the relevant index for the "Electricity, gas, steam and air conditioning supply sector".

As indicated in the AFRY 2020 Report, the estimation of operational expenditure for hydropower plants and, in particular, for pumped hydro plants are well known with respect to their different main cost components but may considerably differ between countries in Europe as the interpretations are not similar as to what should be included as fixed cost and what forms part of the variable part. The latter one is linked to the annual operating hours and usage of water.

Fixed O&M cost comprises the following three main cost components:

- **staffing costs** (manpower), required for the direct operation and maintenance of the plant;
- **third party and materials costs** (e.g. external companies being hired for specific O&M services), which are required to maintain and operate the plant including civil structures and electro-mechanical equipment; and
- **various O&M expenses** which are required for the operation (e.g. administration, back office, dispatching & control centre, etc.) but which are not directly linked to the civil or mechanical parts of the plant.

Costs for major overhaul normally are not included in the fixed O&M cost and are calculated separately. However, and for completeness, general assumptions based on international experience are shown in section 6.2.2.

6.1.1 Updated cost items

1. **Staffing costs (manpower)** in Belgium can be expected to have increased by 8.2% compared to 2020 (Q1 2020 to Q2 2022) based on the relevant STATBEL index for labour cost in the energy sector.
2. **Third party and materials costs** have been split according to AFRY's in-house project experience and corresponding cost increase as per US PPI Industry Data (Exhibit 6.1).

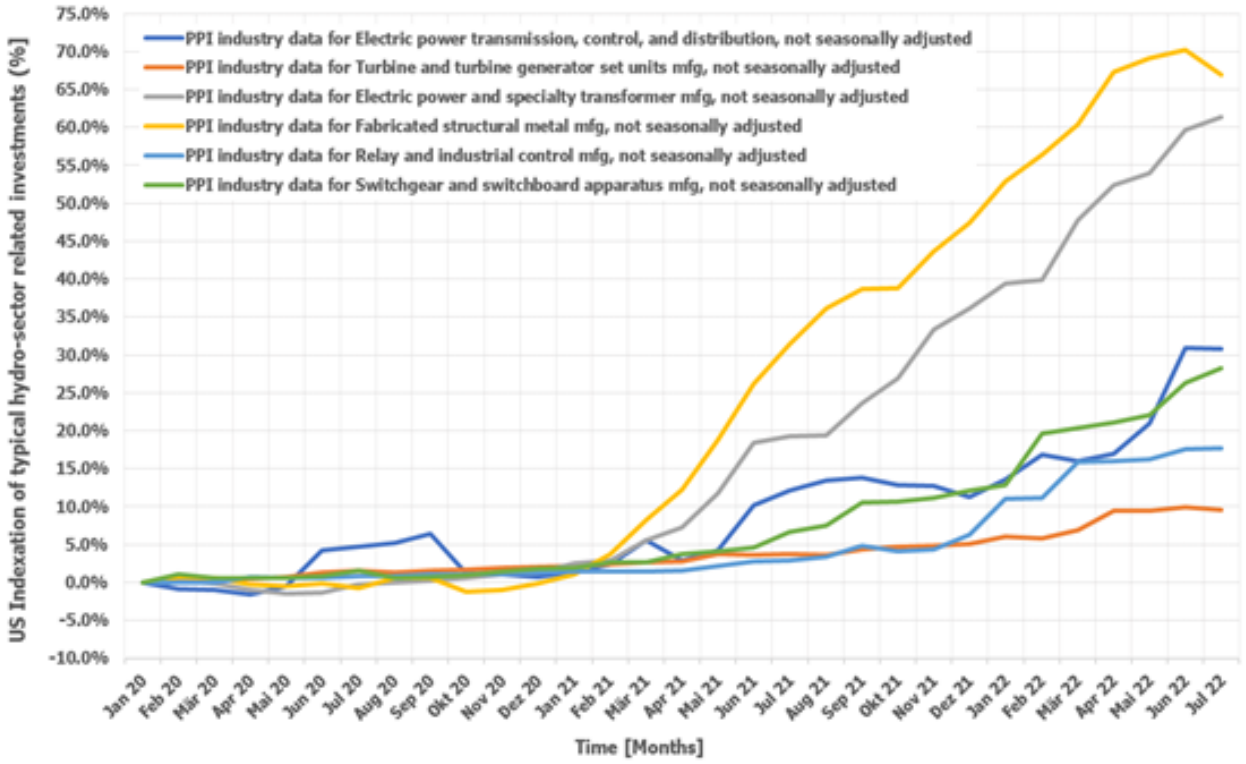
Exhibit 6.1 – Cost portions, NAICS code and cost increase for third party and material costs as per US PPI Industry Data

Materials & Service Purchase	Corresponding cost percentage share	NAICS code	Cost increase % compared to 2020
Turbine and generator	50%	333611	9.6%
Transformer	10%	335311	61.4%
Switchyard	10%	335313	28.3%
Control system	20%	335314	17.7%
Hydromechanical equipment	10%	332312	67.0%
Weighted average cost increase for Material and Service purchase (2020 to July 2022)			**24%**

3. **Various O&M expenses** are related to costs not directly linked to continuous maintenance of the equipment or staff needed to operate the facility. In this respect the index for the generation, transmission and distribution industry was used which showed an increase of 30.7% compared to January 2020.

An overview of the percentage evolution of the different price components (compared to January 2020) is shown in Exhibit 6.2 and clearly illustrate a noticeable escalation in costs.

Exhibit 6.2 – Prices indices for different fixed O&M components for hydropower plants



Source: US PPI Industry Data

Furthermore, referencing to IRENA[6] database as well as World Energy Council[7] operation and maintenance costs are mentioned in the rather wide range of 10 to 50 €/kW (in real 2020 money terms). Taking the indexation for the "(02) Third party and materials costs" as a basis, this range can be translated to 12 to 62 €/kW for real 2022 money terms.

[6] RENEWABLE ENERGY TECHNOLOGIES: COST ANALYSIS SERIES, IRENA 2012 & also on https://www.irena.org/

[7] World Energy Perspective - Cost of Energy Technologies, World Energy Council 2013

6.2 General assumptions

6.2.1 Maintenance cost of installations (excluding major overhauls)

The annual O&M cost (without major overhauls) covers the following items:

- general maintenance of major E&M equipment, such as:
  - minor moving parts like guide vane cylinders, small bearing rings, packers but also painting, cooling oil, etc.;
  - consumables like carbon brushes, small cooling pumps, isolators, etc.;
  - HVAC – equipment; and
  - switchyard components of minor priority and function.
- general maintenance of major H&M equipment, such as:
  - minor parts of gates; and
  - annual maintenance of the penstock.
- general maintenance of the civil structures, including:
  - roads;
  - riverside & reservoir;
  - powerhouse structure (roof, windows, heating); and
  - dam and reservoir structures as well as monitoring facilities.
- general maintenance of transmission line & substation, as far as they belong to the plant operator:
  - towers and cables; and
  - switchgears.

Based on information from USBR (Estimation of Economic Parameters of U.S. Hydropower Resources[8]), where more than 380 hydropower plants in operation are assessed, as well as in-house AFRY experience, **updated** annual refurbishment cost of the plant can be calculated as function of capacity with:

- materials, parts and services for routine operation and maintenance in the range of **€1,120-1,500/MW** (compared to €900-1,200/MW in the AFRY 2020 Report);
- repair or minor repair of civil in the range of **€1,250-1,800/MW** (compared to €1,000-1,300/MW in the AFRY 2020 Report);
- repair or minor repair of hydro-mechanical equipment estimated at **€1,200-1,800/MW** (compared to €750-1,100/MW in the AFRY 2020 Report);

[8] Estimation of Economic Parameters of U.S. Hydropower Resources, Douglas et al. - Idaho National Engineering and Environmental Laboratory, June 2003

- repair or minor repair of E & M equipment with costs of **around €2,750/MW (Pelton) and around €2,950/MW (Francis)** (compared to €2,500-2,700/MW in the AFRY 2020 Report); and
- maintenance of transmission line in the order of 0.25% of TL-invest.

The origin of the E&M equipment manufacturer has a certain impact on the annual expenditure. The overall maintenance philosophy (predictive or reactive) can also influence the expected annual operation and maintenance costs.

6.2.2 Annual cost of operation and maintenance: major overhauls

These costs reflect the periodical maintenance of the E&M equipment as well as the control units. Within the first 10 to 20 years of operation no major overhaul shall be required and hence annual fixed costs at the beginning of the lifetime of a PSP are normally lower than compared to older plants. Cost items to be included in major overhauls are as follows:

- major overhaul (exchange) of major E&M equipment, like:
  - turbine (runner, guide vanes, etc.), which is done in general after 20 to 50 years;
  - generator (windings, bearings, erection, etc.), which is done in general after 20 to 60 years; and
  - substation components (switches, transformers, etc), which will be done in general after 25-35 years.
- major overhaul (exchange) of the H&M equipment, including:
  - gates (in general this is done after 40 years or more);
  - cranes (in general this is done after at least 25 years); and
  - penstock (in general this is done after 40 years or more).
- major overhaul (exchange / reconstruction) of the civil structures, including:
  - spillway & intake (in general this is done after 80 years or more); and
  - steel constructions (in general this is done after 40 years and more).

6.3 Fixed annual specific O&M cost assessment

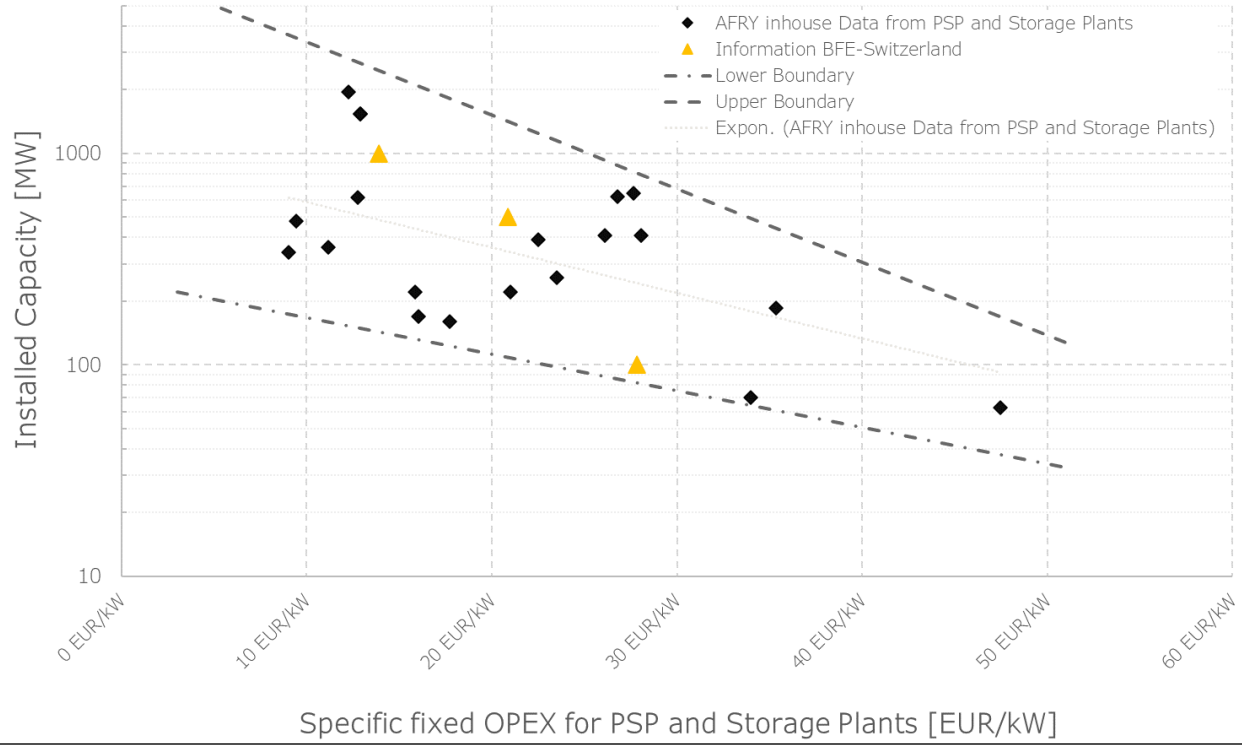
Based on AFRY's internal database updated fixed annual costs for PSP and storage plants are in the range of €10-47/kW (compared to a €10-40/kW range in the AFRY 2020 Report).

The cost range is based on more than 20 different PSP plants in Germany, Austria and Switzerland with capacities from ~60 to ~1,700MW. Data from

the Swiss and German Ministry for Energy (BFE and BMWI)[9],[10], which undertook a survey concerning the profitability of the Swiss hydropower industry in 2018 as well as an assessment on how to achieve contribution margins for pumped storage schemes, are also included. In the later reference the fixed operation and maintenance cost are reported as €16/kW and €0.1/kWh stored energy.

Furthermore, the storage scheme Linth-Limmern including the 1,000MW Linth-Limmern pump storage scheme, which recently became operational is included based on the detailed information available from the annual fiscal report[11]. Data from Swiss hydropower plants were adjusted and updated in terms of manpower cost based on relationships stated on Eurostat[12] between Switzerland and Belgium. Cost for third parties and material is not seen to be affected by a notable distortion between Belgium and Switzerland.

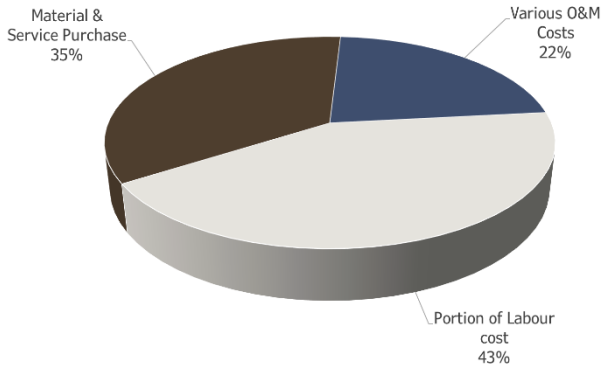
Exhibit 6.3 – Specific OPEX cost for Pumped Storage Plant as a function of installed capacity



[9] Profitability of Swiss hydropower, BFE 2018, https://pubdb.bfe.admin.ch/de/publication/download/9012.
[10] Potential to achieve contribution margins for pumped storage power plants in Switzerland, Austria and Germany, BFE 2014, https://www.bmwi.de/Redaktion/DE/Downloads/S-T/trilaterale-studie-zu-pumpspeicherkraftwerken-deutschland-oesterreich-schweiz-gutachten.html.
[11] Kraftwerke Linth-Limmern AG – Annual report 2018/19, https://www.axpo.com/content/dam/axpo19/master/files-master/about-us/investor-relations/publications---dates/2005_Axpo_KLL_Gesch%C3%A4ftsbericht_18_19_DE.pdf.
[12] https://ec.europa.eu/eurostat/databrowser/view/earn_ses_annual/default/table?lang=de

Exhibit 6.4 shows the distribution of the three main categories included under fixed OPEX.

Exhibit 6.4 – Distribution of cost items for annual fixed O&M cost



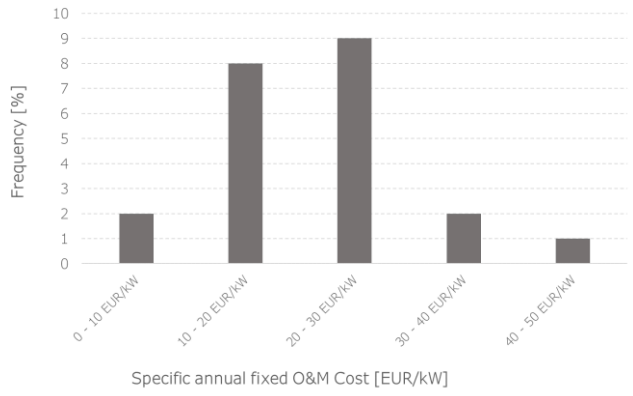
Almost 50% of the annual fixed costs is linked to manpower costs whereas material and third-party costs represent only ~1/3 of the entire fixed annual OPEX cost.

Cost items related to the energy generation, such as:

- water usage or royalty fees;
- grid usage fees;
- energy cost for pumping; and
- taxes for purchase and delivery of energy are **excluded** from this assessment.

1. **Updated costs for major overhauls** are also excluded, as are costs linked to depreciation and financing. Based on the recent developments as well as depending on the magnitude of the overhaul and the age of the plant this cost can be easily **in the range of €12-30/kW** (compared to €10-20/kW in the AFRY 2020 Report), which shall be added to the annual fixed costs.
2. The **majority of the annual OPEX cost** of the hydro pumped storage plants **are in the range of €10-30/kW** (range unchanged compared to the AFRY 2020 Report).
3. **The average value is €21.5/kW** (with a median of €20.9/kW), **a 17.5% increase compared to the AFRY 2020 Report**, but which remains within a reasonable range with data presented in BFE 2014[10] ($€_{2022}$19.7/kW).

Exhibit 6.5 – Distribution of specific annual fixed O&M cost



6.4 Conclusions

Based on the various data sources used in our analysis, there is significant variation in reported O&M costs for PSP plants, ranging from €10/kW to €50/kW. The lower end of the range is more representative of PSP plants integrated in a pool of hydropower plants allowing the utility to optimize resources – most notably manpower. On the other end of the spectrum, smaller PSP plants tend to have a higher O&M cost – a similar sized team is needed to operate the plant when compared to larger PSP plants.

Costs attached to major overhaul can have a strong impact on O&M costs. Maintenance may be done preventively or reactively which considerably impacts the cost side and in the latter case the availability of the plant.

Our review of different public data sources (from power utilities as well as authorities) combined with our in-house knowledge suggests annual fixed O&M for PSP in the range of €10-30/kW. As already discussed, there may, however, be a significant difference between small and large PSP plants. **We recommend the use of an updated average cost of €22/kW for the purposes of defining a typical annual fixed O&M value for a pumped storage plant in Belgium.** Larger facilities may however find themselves on the lower end of the spectrum.

This value excludes any royalty or water usage fees, major overhauls, and fees related to the plant operation in terms of grid usage, pumping energy or taxes in connection with the generation or purchase of energy.

Annex A Sensitivity of fixed O&M costs based on assumed running hours

Exhibit A.1 – Fixed O&M sensitivity depending on running hours assumptions (1/2)

Unit	Capacity (MW)	Type	COD	Specific fixed O&M cost (€/kW/a)					
				AFRY 2022 Report (8,000h)	AFRY 2022 Report (6,000h)	AFRY 2022 Report (4,000h)	AFRY 2022 Report (2,000h)	AFRY 2022 Report (1,000h)	AFRY 2022 Report (500h)
T-Power	425	1x1	2011	50.97	45.59	40.21	34.83	32.14	30.80
Seraing	485	2x1	1994	51.81	45.98	40.16	34.34	31.43	29.97
Amercoeur	451	1x1	2010	49.59	44.45	39.31	34.17	31.60	30.31
Marcinelle	405	1x1	2011	52.15	46.57	40.98	35.40	32.60	31.21
Saint-Ghislain	350	1x1	2000	56.01	49.74	43.47	37.21	34.07	32.50
Drogenbos	460	2x1	1993	53.17	47.10	41.03	34.96	31.92	30.40
Knippergroen	315	1x1	2010	59.11	52.28	45.45	38.62	35.21	33.50
Ringvaart	357	1x1	1998	55.46	49.29	43.12	36.95	33.87	32.32
Herdersbrug	480	2x1	1998	52.07	46.20	40.33	34.46	31.52	30.05
Zandvliet	384	1x1	2005	53.50	47.68	41.86	36.04	33.13	31.67
Inesco	138	1x1	2007	69.48	62.12	54.77	47.41	43.73	41.89

Exhibit A.2 – Fixed O&M sensitivity depending on running hours assumptions (2/2)

Unit	Capacity (MW)	Type	COD	Specific fixed O&M cost (€/kW/a)					
				AFRY 2022 Report (8,000h, no elec)	AFRY 2022 Report (6,000h, no elec)	AFRY 2022 Report (4,000h, no elec)	AFRY 2022 Report (2,000h, no elec)	AFRY 2022 Report (1,000h, no elec)	AFRY 2022 Report (500h, no elec)
T-Power	425	1x1	2011	46.04	41.89	37.75	33.60	31.53	30.49
Seraing	485	2x1	1994	46.87	42.28	37.69	33.10	30.81	29.66
Amercoeur	451	1x1	2010	44.65	40.75	36.84	32.93	30.98	30.00
Marcinelle	405	1x1	2011	47.21	42.86	38.51	34.16	31.99	30.90
Saint-Ghislain	350	1x1	2000	51.08	46.04	41.01	35.97	33.46	32.20
Drogenbos	460	2x1	1993	48.24	43.40	38.56	33.72	31.30	30.09
Knippergroen	315	1x1	2010	54.17	48.58	42.98	37.39	34.59	33.19
Ringvaart	357	1x1	1998	50.52	45.59	40.65	35.72	33.25	32.01
Herdersbrug	480	2x1	1998	47.13	42.50	37.86	33.22	30.90	29.75
Zandvliet	384	1x1	2005	48.57	43.98	39.39	34.80	32.51	31.36
Inesco	138	1x1	2007	64.54	58.42	52.30	46.17	43.11	41.58

TABLE OF EXHIBITS

Quality control

Roles	Name	Date
Authors	Sean Daly Alexander Arch Matthieu Mollard	7 October 2022
Approver	Gareth Davies	7 October 2022

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Version	Date	Comments
v100	19 August 2022	DRAFT version
V200	8 September 2022	Updated version following feedback from Elia
V300	7 October 2022	Updated version following feedback from Elia

ÅF and Pöyry have come together as AFRY. We don’t care much about making history.

We care about making future.

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