HydroEU Case

Part 1: Data Preparation and Analysis

Q1. Data Features summary

Variables **Latitude** and **Longitude** offer location information to map the hydro assets. Variable **installed_capacity_MW** provides information regarding the possible producible capacity of each power plant. This is crucial in understanding scale of installed energy in each plant. Furthermore, country **code** was selected to identify the name of the country of origin using a calculated field.

The **type** variable classified power plants into three important categories: Run of the River (HROR), Pumped Hydro Storage (HPHS), and Reservoir/Dam (HDAM). Variable **ID** provided unique identification for each asset. Matching **ID** with **name** variable enabled data cleanup process. These variables were chosen because they directly contributed to understanding the spatial distribution, capacity, and technological diversity of the portfolio, which are core to Hydro EU's operational strategy. Rest of the variables were not utilised owing to various data quality issues.

Q2. EDA and Data Quality

Approximately 50% of the variables were unsuitable for analysis due to completeness issues in the dataset as seen in the example image 1.

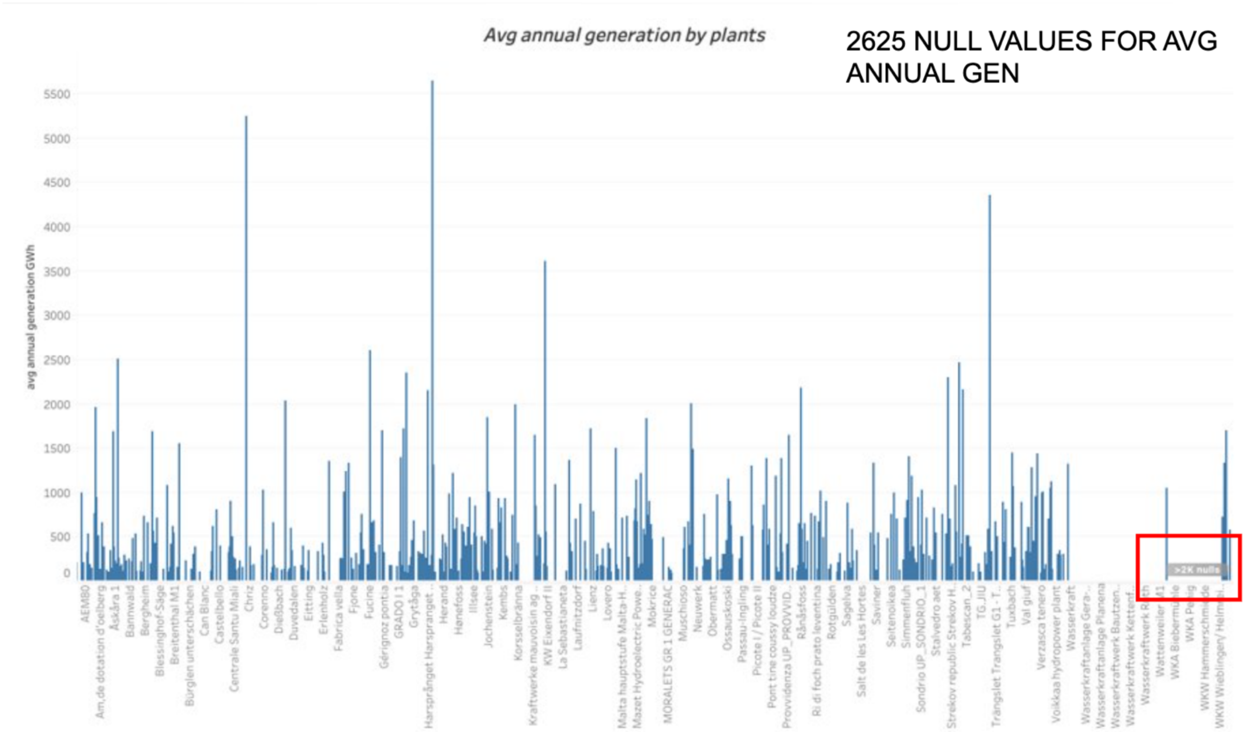

Image1: Avg Annual Generation (GWH) by Name of Plant

Two key variables, **pumping_MW and WRI**, had over **95% missing data**, rendering them unreliable for meaningful insights. Additionally, variables such as **storage_capacity_MWh** and **GEO** had over **80% missing values**, **volume_Mm3** had **72%**, while **avg_annual_generation_GWh**, **pypsa_id** and **dam_height_m** exhibited over **50%** missing data.

Additionally, there were issues with uniqueness in the dataset. The **name** variable contained **4033 unique values** out of **4178** records **(96.53%)**. Further analysis of **latitude** and **longitude** showed **95.24%** and **95.26%** uniqueness. These highlight issues of integrity and precision are also highlighted owing to these uniqueness issues.

Following (Canvas, 2024), the data must be standardised and exhibit uniqueness, completeness, integrity and precision. Furthermore, the root cause of these issues may be attributed to the capture process or combining multiple datasets.

Variables	Total Values	Missing Values	Unique Values	Percentage of Missing Values	Percentage of Unique Values
id	4178	0	4178	0	100%
name	4178	0	4033	0	96.53%
installed_capacity_MW	4178	0	1375	0	32.91%
pumping_MW	104	4074	90	97.51%	86.54%
type	4178	0	3	0	0.07%
country_code	4178	0	30	0	0.71%
lat	4178	0	3979	0	95.24%
lon	4178	0	3980	0	95.26%
dam_height_m	1856	2322	1068	55.58%	57.54%
volume_Mm3	1167	3011	747	72.07%	64.01%
storage_capacity_MWh	761	3417	665	81.78%	87.38%
avg_annual_generation_GWh	1553	2625	1120	62.83%	72.12%
pypsa_id	1472	2706	1471	64.77%	99.93%
WRI	37	4141	37	99.11%	100%
GEO	513	3665	512	87.72%	99.80%

Table 1

Here are the key underlying assumptions undertaken with the dataset to conduct the analysis:

1. **Data Accuracy**: The variables with complete values are correct and free from errors.
2. **Static Nature:** Since the dataset is static, it is assumed that no significant changes have occurred since data collection (e.g., plant closures or capacity upgrades).

3. **Comparability**: The classification of plants into types such as HROR, HDAM, and HPHS is assumed to be consistent and mutually comparable. The energy production metrics and plant types are assumed comparable across different countries. Despite potential differences in regulations and reporting standards.

4. **Handling of Missing Data**: It is assumed that not utilising variables with missing data, does not significantly alter the overall insights or skews the analysis.

Q3. Addressing data quality issues and preparation

As per lecture slides week 5 (Canvas, 2024), data cleaning involves five key steps. For HydroEU's dataset, the steps of standardising, matching and consolidating are important. To ensure clarity and consistency in the analysis, several variables were **standardised**. For instance, variables **Lat** and **Lon** were renamed **Latitude** and **Longitude**, and **installed_capacity_MW** was renamed to **Installed Capacity (MW)**. **Energy Type** field was derived from **Type** for easier understanding.

Furthermore, after conducting a thorough **missing values analysis,** it was determined that any variable with more than 50% missing data should be removed from the dataset. Datasets with large amounts of missing data may lead to skewed analysis and reduce the reliability of findings. As part of the matching process, the **count of ID (Unique)** and **count of Name (Unique**) led to uncovering possible duplicate values.

A **unique values analysis** was conducted to identify and remove **duplicate values**. These duplicates could result in an inaccurate representation of the asset portfolio. Matching the values with the same **name**, **installed capacity**, **latitude**, and **longitude** led to the identification of 89 entries with repeating values. Thus, these were removed as part of the data consolidation process.

Additional steps in preparation included the creation of calculated fields. This included deriving the **Country Name and number of countries** from the country code. As per the US Dept of Energy (2022), the installed capacity of the hydropower dam can be classified based on scale or size of energy production. A calculated **Scale** field was also introduced to classify plants by their production scale, such as micro, small, medium, and large.

Q4. Additional data to enhance analysis

For the analysis, additional data points would have been valuable but were not available. Time series data for energy production trends and maintenance/outage data could have improved operational efficiency analysis. Financial data on costs and revenue may aid in assessing economic performance, while environmental impact data like water usage and CO2 savings would enhance sustainability evaluations. Real-time energy production data can provide dynamic plant performance insights.

Business Insights and Recommendations

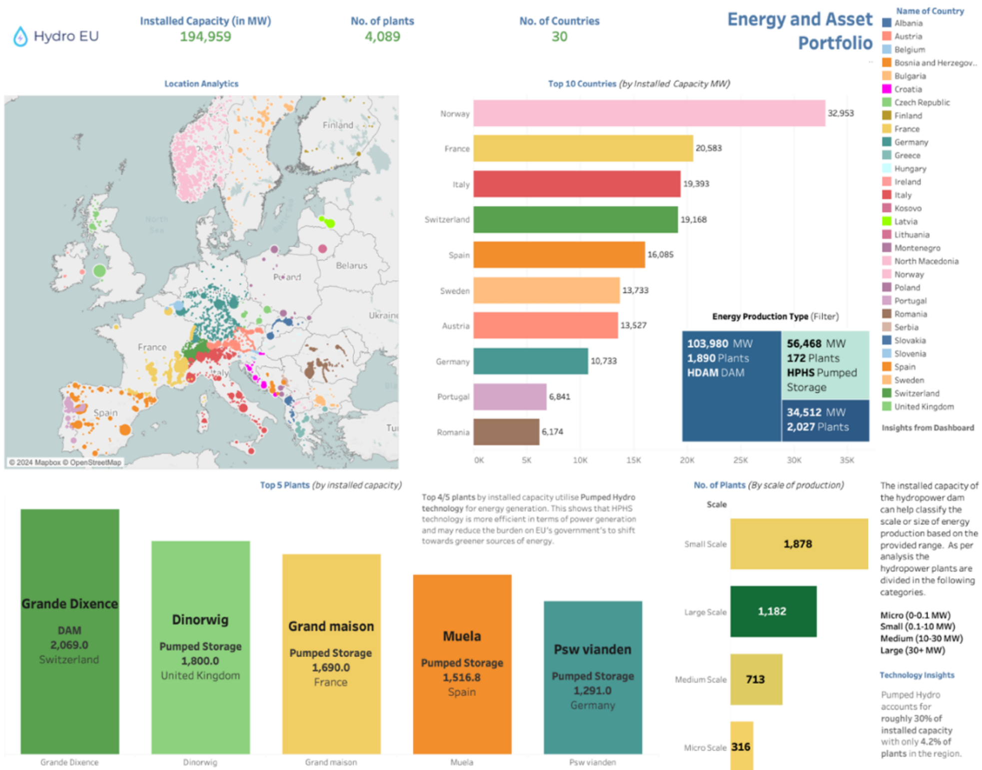

Image 2: Dashboard Energy and asset portfolio

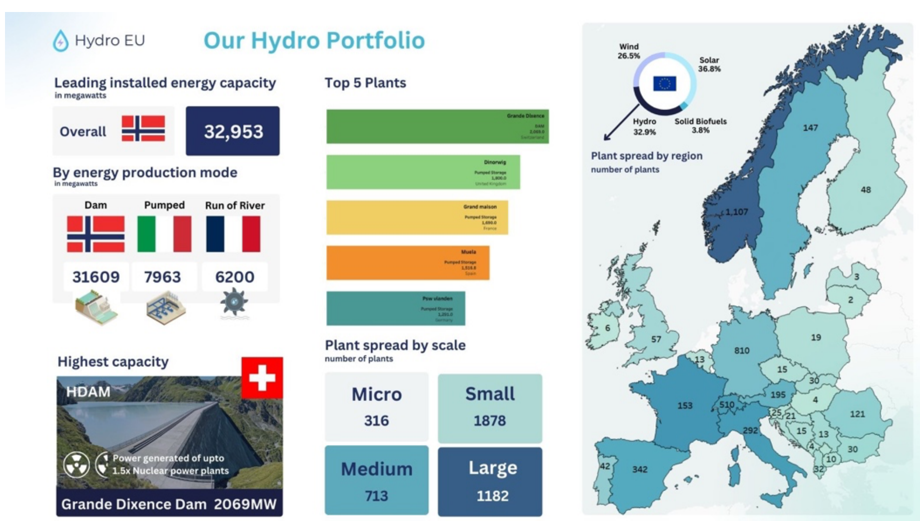

Image 3: Infographic on HydroEU's Portfolio

Q1. Value creation potential based on industry benchmarks and KPIs

The dashboard identifies key performance indicators for HydroEU as its spread of installed capacity, number of plants and presence in different countries of the region. Some top asset locations for the organisation are in Norway, with 32,953 MW as installed capacity. Additionally, the research (Pepe & Zanoli, 2024) identifies hydropower plants to be analysed based on their efficiency. Thus, a relevant KPI for a hydropower business can be a capacity factor, which evaluates whether the plant is being us any scope for further improvement. However, according to Eurostat (2022), electricity generation in the EU has remained relatively stable over the past five years, with a minor decline in 2020. Furthermore, the European Environment Agency (EEA, 2024) indicates that hydropower contributes 33% of the total renewable electricity output. Thus, HydroEU's portfolio requires utmost care. Please refer to Image for assumed business model of HydroEU.

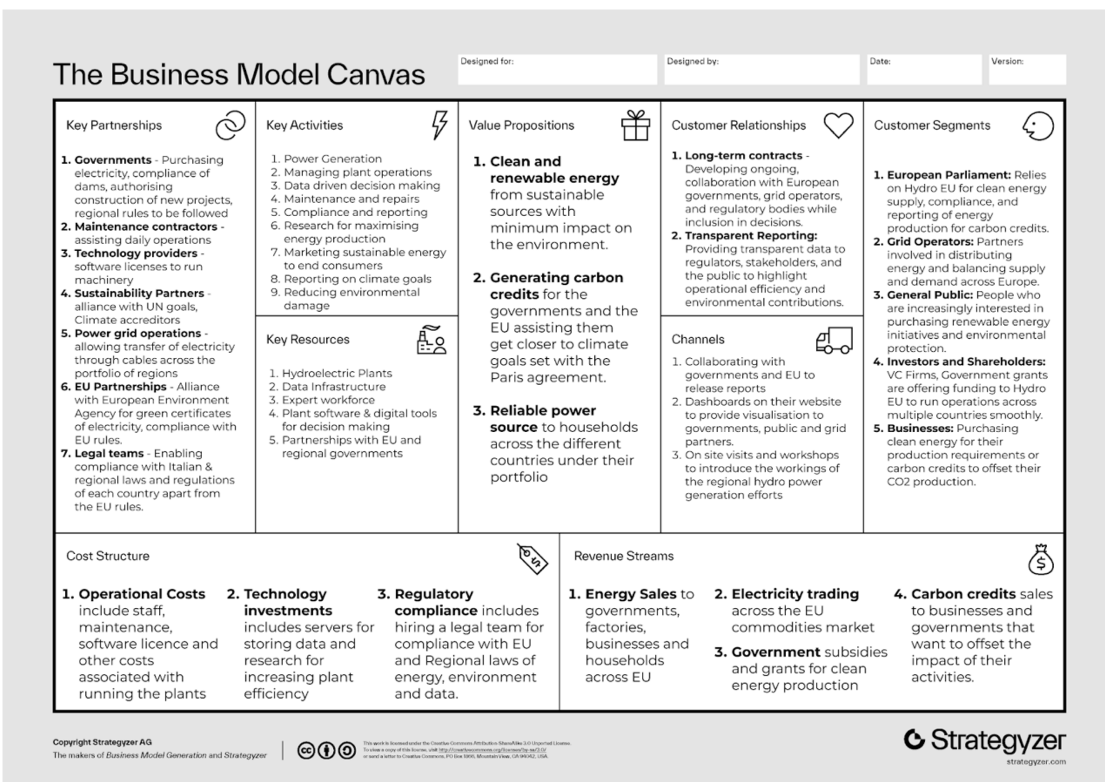

Image 4: BMC created using Strategyzer Template

As per the dashboard, differentiating plants based on the scale of installed capacity may help identify customer preferences for setting up new plants. Furthermore, the research (IHA, 2024) offers insights into the industry benchmarks for installed capacity, average generation and pumped storage capacity as seen in image 5.

Europe

Country/Territory	Total installed capacity including pumped storage (MW)	Pumped storage (MW)	Generation (TWh)
Albania	2,153	0	7
Andorra	46	0	<1
Austria	11,821	3,485	44
Belarus	96	0	<1
Belgium	1,494	1,308	2
Bosnia and Herzegovina	2,263	420	6
Bulgaria	2,916	1,403	3
Croatia	1,855	281	8
Cyprus	0	0	0
Czechia	2,285	1,172	3
Denmark	7	0	<1
Estonia	8	0	<1
Faroe Islands (Denmark)	41	0	<1
Finland	3,190	0	15
France	25,534	5,051	59
Germany	14,428	9,379	20
Greece	3,423	699	4
Greenland (Denmark)	91	0	<1
Hungary	61	0	<1
Iceland	2,114	0	14
Ireland	508	292	1
Italy	22,149	7,156	40
Kosovo	115	0	1
Latvia	1,558	0	4
Liechtenstein	35	15	<1
Lithuania	1,028	900	<1
Luxembourg	1,332	1,296	<1
North Macedonia	644	0	1
Malta	0	0	0
Moldova	64	0	<1
Montenegro	649	0	2
Netherlands	38	0	<1
Norway	33,897	1,441	137
Poland	2,506	1,591	4
Portugal	8,196	3,707	12
Romania	6,730	92	18
San Marino	0	0	0
Serbia	3,178	1,017	11
Slovakia	2,476	1,017	5
Slovenia	1,309	180	5
Spain	20,425	5,650	25
Sweden	16,391	91	66
Switzerland	17,533	4,055	37
Türkiye	32,529	0	66
Ukraine	6,600	1,963	10
United Kingdom	4,723	2,833	5
Total	**258,845**	**54,174**	**637**

Image 5: Industry benchmarks (IHA, 2024)

The variable installed capacity was compared with the industry benchmark (Image 5) to identify the difference in HydroEU's portfolio.

	Installed capacity (Total)			
	Hydro EU	Industry Benchmark	Difference	Difference
Country name	In MW	In MW	%	In MW
Albania	2,071	2,153	-4%	(82)
Austria	13,527	11,821	14%	1,706
Belgium	1,380	1,494	-8%	(114)
Bosnia and Herzegovina	2,000	2,263	-12%	(264)
Bulgaria	2,921	2,916	0%	5
Croatia	2,125	1,855	15%	270
Czech Republic	1,924	2,285	-16%	(361)
Finland	2,635	3,190	-17%	(555)
France	20,583	25,534	-19%	(4,951)
Germany	10,733	14,428	-26%	(3,695)
Greece	3,395	3,423	-1%	(28)
Hungary	48	61	-22%	(13)
Ireland	509	508	0%	1
Italy	19,393	22,149	-12%	(2,756)
Kosovo	65	115	-43%	(50)
Latvia	1,526	1,558	-2%	(32)
Lithuania	1,001	1,028	-3%	(27)
Montenegro	675	649	4%	26
North Macedonia	575	644	-11%	(69)
Norway	32,953	33,897	-3%	(944)
Poland	2,132	2,506	-15%	(374)
Portugal	6,841	8,196	-17%	(1,355)
Romania	6,174	6,730	-8%	(556)
Serbia	2,800	3,178	-12%	(378)
Slovakia	2,472	2,476	0%	(4)
Slovenia	1,239	1,309	-5%	(70)
Spain	16,085	20,425	-21%	(4,340)
Sweden	13,733	16,391	-16%	(2,658)
Switzerland	19,168	17,533	9%	1,635
United Kingdom	4,277	4,723	-9%	(446)
Total Additional Capacity Added				20479

Table 2: Analysis (IHA, 2024)

As per table 2, HydroEU can increase its capacity in its existing countries by 20,479 MW.

	Installed Capacity	Avg annual generation	Capacity factor
	Industry Benchmark	Industry Benchmark	Calculated
Country name	In MW	In GWH	%
Albania	2,153	7,000	37%
Austria	11,821	44,000	42%
Belgium	1,494	2,000	15%
Bosnia and Herzegovina	2,263	6,000	30%
Bulgaria	2,916	3,000	12%
Croatia	1,855	8,000	49%
Czech Republic	2,285	3,000	15%
Finland	3,190	15,000	54%
France	25,534	59,000	26%
Germany	14,428	20,000	16%
Greece	3,423	4,000	13%
Hungary	61	1,000	187%
Ireland	508	1,000	22%
Italy	22,149	40,000	21%
Kosovo	115	1,000	99%
Latvia	1,558	4,000	29%
Lithuania	1,028	1,000	11%
Montenegro	649	2,000	35%
North Macedonia	644	1,000	18%
Norway	33,897	137,000	46%
Poland	2,506	4,000	18%
Portugal	8,196	12,000	17%
Romania	6,730	18,000	31%
Serbia	3,178	11,000	40%
Slovakia	2,476	5,000	23%
Slovenia	1,309	5,000	44%
Spain	20,425	25,000	14%
Sweden	16,391	66,000	46%
Switzerland	17,533	37,000	24%
United Kingdom	4,723	5,000	12%

Table 3: Capacity factor based on industry benchmarks

Additionally, the analysis in Table 3 identifies that most countries are currently operating their hydro plants at less than 50% efficiency. Insights into this will allow HydroEU's maintenance engineers to assess underperforming assets and take up preventive measures. The capacity factor was calculated using the formula:

$$Capacity\ Factor\ (\%) = \left[\frac{Actual\ Energy\ Output\ (Gwh)}{\frac{(Installed\ capacity\ (Mwh)\ X\ 8760\ hours)}{1000}}\right] * 100$$

Problem Statement: HydroEU needs to gain insights into its diverse portfolio of assets spread across the EU region. It manages operations across 30 countries with numerous hydropower plants utilising different technologies. Thus, it needs a system to monitor and track its assets that will lead to high-impact strategies for continuous improvement.

Q2. Value creation opportunities and areas for improvement

1. Installed capacity: HydroEU has a significant proportion of France, Spain, Germany, Italy's market share of hydro capacity as seen from the dashboard. However, Table 2 shows there's significant opportunities to get more installed capacity in these regions. For instance, Germany exhibits a huge gap of 26% which may be capitalised on by Hydro EU. Additionally, France, Spain and Sweden are great candidates to expand HydroEU's installed capacity.

2. Number of countries: The research (IHA, 2024) includes 46 countries within their analysis of the Europe region. However, as per the dataset from HydroEU, their plants are limited to only 30 countries. This shows that there's opportunities for HydroEU to expand its presence into 12 more countries. This includes major players such as Turkey, Netherlands, Luxembourg, and Belarus, which are in close proximity to their existing portfolio.

3. Improve reporting: As per the research (IHA, 2024) and analysis, we can identify the utilisation of plants' energy generation using capacity factors. However, HydroEU lacks accurate data on its current plants for average annual generation capacity. Thus, they must invest in infrastructure overhauls that will improve reporting on sustainability metrics and calculating plant efficiency (capacity factor). These insights can be shared with key partners/customers as per the BMC, i.e. investors and governments.

Q3 & 4 High-Impact strategies and implementation recommendations

1. Predictive Maintenance: HydroEU should invest in IoT sensors to monitor equipment performance in real-time and predict equipment failures before they occur. This can improve the overall efficiency and reliability of the plant by reducing downtime by 50%, maintenance cost by 10-40%, and extending the lifetime of equipment by 3-5% (element 61, n.d.).

Implementation: Deploy IoT sensors on equipment to monitor real-time performances and integrate predictive AI-based maintenance platforms.

2. Modernise Aging Infrastructure: The average life span of a hydropower installation is up to 100 years, with maintenance and upgrading turbines and generators that could increase annual energy production by up to 5% (DTEC, 2024). Improved efficiency reduces the carbon footprint per unit of electricity generated.

Implementation: Upgrading turbines and generators to modern, energy-efficient models. Conduct regular energy audits to fix inefficiencies.

3. Invest in Pumped Storage: The dashboard highlights the efficiency of pumped storage to have more capacity with fewer plants. Furthermore, Pump storage plants account for approximately 29% of net hydropower additions through 2030 (IEA, 2021).

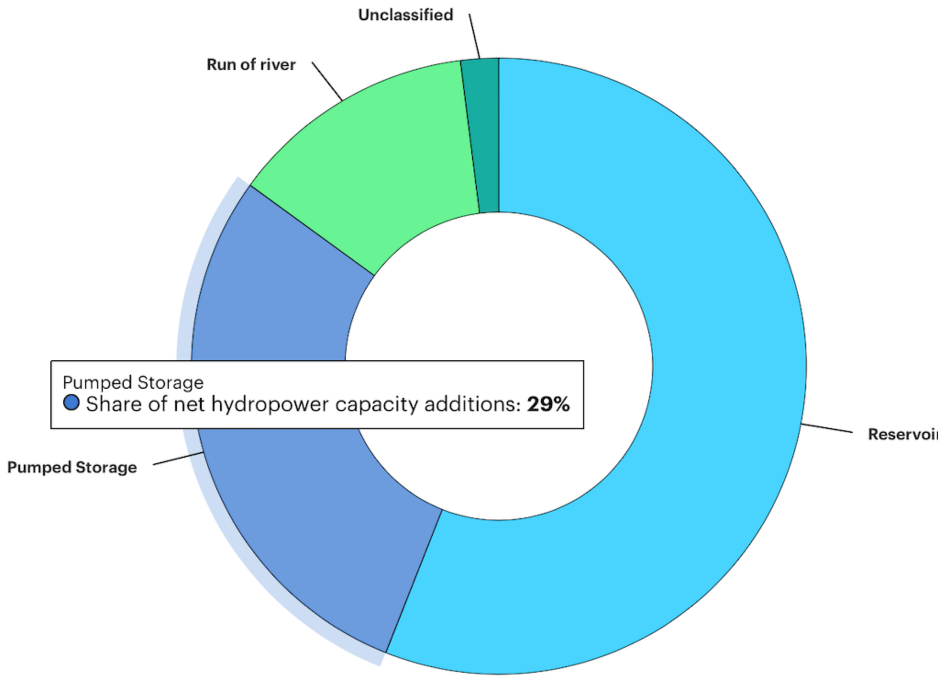

Image6 (IEA, 2021)

Implementation: Collaborate with government and private entities to secure funding and Conduct studies to identify potential sites for pumped storage facilities.

4. Optimise water flow management: Using real-time monitoring systems, advanced hydrological forecasting, and water management tools allows for better prediction of water inflow this may be crucial for HROR and HDAM plants. This can add to annual revenue without incurring additional infrastructure investment costs.

Implementation: Real-time monitoring to keep track of water inflows. Predictive risk mitigation for weather-related issues.

5. Leveraging Green Financing: As per BloombergNEF (2022), achieving net-zero emissions by 2050 requires an annual investment of $7 trillion globally. HydroEU should monitor government policies and laws to attract ESG-focused investors. As per research (Douglas, 2023), implementing the Return on Sustainability Investment (ROSI) framework and communicating the financial benefits of sustainable practices through ESG reporting is possible.

Implementation: Align Hydro EU's ESG reports with international sustainability framework and implement the ROSI framework.

6. Create Job Opportunities: HydroEU should emphasise technology-focused hiring for its power plants with different capabilities such as pumped, dam, and run-of-river. As per research (Calocouras, 2022), a single large project can employ over 1500 workers during peak construction phases, boosting local economies.

Implementation: Partner with local government to develop training programs for hydro technology-oriented roles.

Conclusions and lessons learnt

The analysis identifies data quality issues in Hydro EU's dataset, incorporates cleaning methods, and provides reliable insights while highlighting the significance of additional information that enhances Hydro EU's evaluation of performance and operational insights. Further, it finds quantified value-creation opportunities for Hydro EU by comparing the important drivers and performance indicators with the Hydropower industry benchmark. Finally, practical strategies and recommendations are provided to capitalise on those identified opportunities.

Part 2: Reflection on KDDV with Generative AI

Q1. LIDA in comparison to traditional tools

LIDA is a unique tool for creating visualizations that function differently from traditional tools like Tableau or Power BI. Traditional tools offer many ways to customize, with point-and-click interfaces that let users adjust almost every visual element. While these options provide flexibility, they often require familiarity with intricate settings, adding complexity. In contrast, LIDA's streamlined, AI-using, web-based platform provides a more user-friendly approach to creating visualizations. It offers a range of predefined templates and visual types, enabling users to quickly create basic charts without the need for in-depth knowledge of the tool or the data. The user simply prompts what they want, and LIDA creates the graph or makes the necessary changes. It should be noted that LIDA still uses the outdated GPT 3.5 version, whereas ChatGPT is currently utilising GPT 4. Additionally, LIDA’s simple interface can be limiting for more complex visualizations. For example, advanced customisations, such as multidimensional filtering or drill-down features, are challenging to implement with LIDA. Traditional tools offer precise control over visualization aspects, making them well-suited for complex datasets and in-depth analysis. Overall, LIDA offers a range of automated features that streamline setup time and enhance accessibility. However, it may not fully meet the needs of users engaged in extensive data exploration. Therefore, it is best regarded as a complementary tool rather than a replacement for traditional platforms.

Basis of comparison	LIDA	Traditional Tools
Customization	Limited customization with predefined templates	Extensive customisation with point-and-click interfaces
User Interface	Streamlined, AI-driven, and web-based	Requires familiarity with tool-specific interfaces
Learning Curve	Easy to use with minimal training	Steeper learning curve settings
Automation	Uses prompts to automate visual creation	Manual setup and adjustments required
Visual Complexity	Limited support for complex visualisations	Supports advanced visualisations with multidimensional filters
Suitability for Advanced Analysis	Less suitable for deep data exploration	Highly suitable for detailed and complex analysis
Complementary Role	Best used alongside traditional tools	Can function as standalone tools for complex projects
Setup Time	Quick setup with predefined templates	More time-consuming
Target Audience	Casual users, quick insights	Data analysts, business intelligence teams

Table 4

Q2. LIDA Strengths and Weaknesses

LIDA proves particularly valuable in situations where rapid analysis is needed. Its “summariser” and “goal explorer” modules play a key role in quickly identifying patterns and trends. For example, when exploring correlations within a dataset, the tool efficiently generates relevant visualizations, such as scatter plots and graphs, streamlining the discovery process.

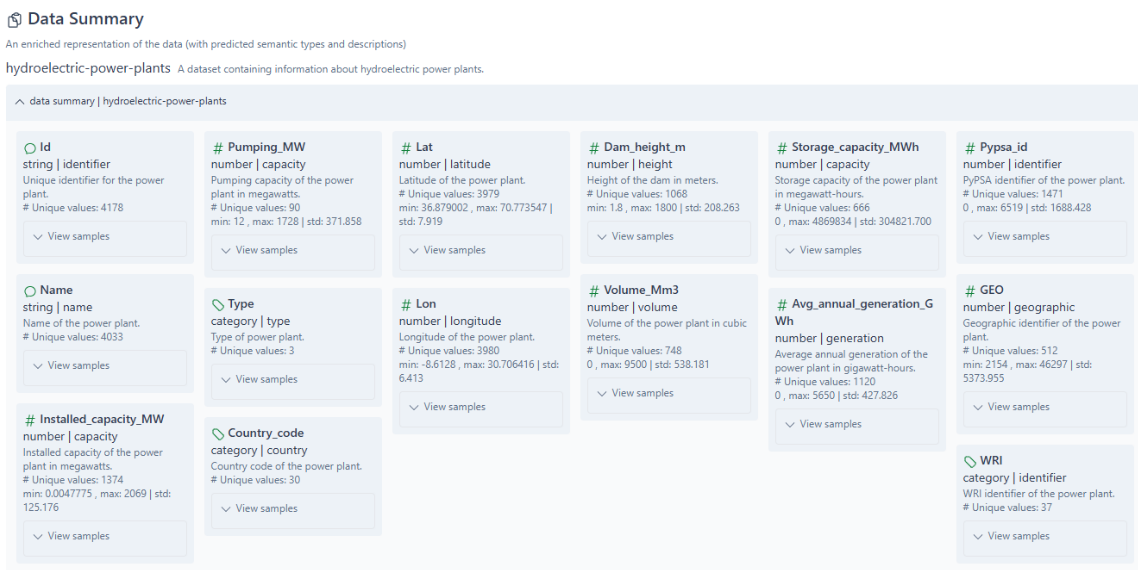

Image7 – Data Summary Generated by LIDA

What sets LIDA apart is its interface. It recommends specific areas for further exploration.

Additionally, it accelerates the analytical workflow and leads to effortless extraction of insights.

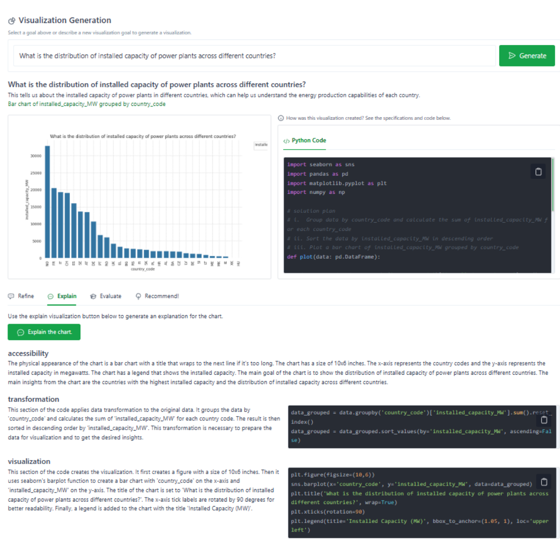

Image8– Example visualisation LIDA

Although LIDA has limits when dealing with complex data. For example, LIDA struggled to create clear and accurate visualizations when we tried to integrate multiple variables or use advanced filtering. When trying to add one of the recommended visualisations with 'Ion', 'Iat', and 'types' as variables, LIDA couldn't create the chart, and there is no capability to further customize the visualizations. Because of that, LIDA is not ideal for exploratory data analysis. In these areas, traditional tools with their user-directed modification are still the best choice.

Q3. NLI’s impact on visualisation

LIDA’s natural language interface (NLI) made it easy for anyone to create visualizations. With the ability to communicate visualization requests in dialogue, such as “show sales by quarter” or “highlight highest values”, the NLI reduces the barriers often associated with more complex interfaces. This ease of interaction allows users to focus on the analytical aspects of the visualisation rather than the technicalities, creating a more fluid experience. The NLI simplified straightforward adjustments like changing chart types, adding trend lines, or modifying data series with minimal friction.

However, the NLI had problems with more complex modifications. Unlike traditional tools that provide users with a full range of customization options, LIDA's NLI sometimes struggles with nuanced requests. For example, when adjusting specific visual elements or detailed data manipulations, the system occasionally misinterprets instructions, resulting in outputs that don't meet expectations. While in Tableau, it’s possible to directly select and apply specific variables, but with LIDA, it is necessary to rephrase variables multiple times to achieve the desired results, which slows down the process. Consequently, while the NLI was beneficial for basic visualisations, it's not for more complex ones. This shows that it needs to be improved to support complex data analysis. Nevertheless, the NLI in LIDA shows that AI-driven interfaces could make data visualization easier for more people by removing technical obstacles.

Q4. Role of LIDA in analysis and future outlook

AI-driven tools like LIDA are set to transform how organizations engage with data, streamlining workflows and making data analysis accessible to a broader audience. By automating certain tasks, these tools reduce the need for advanced technical skills, allowing users without deep expertise in visualization to create meaningful insights. This is especially valuable in industries where data-informed decisions are crucial, but access to specialized data analysts is limited. Through features like automated pattern detection, anomaly identification, and visualization recommendations, AI tools can accelerate analysis while improving accuracy and insight discovery.

Looking ahead, AI-driven visualisation tools could become more interactive and adaptable, supporting multi-turn dialogues and iterative refinements based on user feedback. In this role, AI functions as a data assistant, helping users explore their data by suggesting relevant questions, visualizations, or statistical methods based on emerging patterns. As these systems mature, they may incorporate domain-specific knowledge, enabling them to meet industry-specific standards, such as regulatory requirements in sectors like finance or healthcare.

However, the growing role of AI in data visualization brings new challenges. Transparency, accountability, and ethics will be essential to ensure trust in AI-generated outputs. Integrating explainable AI features, tools that clarify how insights are derived, will be critical in balancing automation with human oversight.

Conclusions and lessons learnt

In summary, tools like LIDA provide a glimpse into a future where data visualization is intuitive, efficient, and broadly accessible. It excels in quick insights but struggles with complex visualisations. While traditional tools offer more customisations, LIDA highlights the ongoing developments in AI-driven data insights. Improving the analysis and visualisation capability will make tools like LIDA indispensable in data-driven decision-making across industries. This approach will foster confidence in the results and ensure that users remain engaged in the analytical process.

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