Definition of Application Programming Interface

D4.2

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LOCALISED

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List of Abbreviations

API	Application Programming Interface
DSP	Data Sharing Platform
HTTP	Hypertext Transfer Protocol
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
MIDAS	Modular Integrated Decarbonisation and Adaptation Solver
NUTS	Nomenclature of Territorial Units for Statistics - the acronym stems from French: Nomenclature des Unités Territoriales Statistiques
RCP	Representative Concentration Pathway
WP	Work Package

Executive Summary

Deliverable 4.2 outlines the first version of the proposed Application Programming Interface (API) definition for the Modular Integrated Decarbonisation and Adaptation Solver (MIDAS) model Hypertext Transfer Protocol (HTTP) API in the LOCALISED project. In particular, this deliverable presents the results of the work in Task 4.4 regarding the definition of application programming interface. It serves as a comprehensive guide to integrating the MIDAS HTTP API into the website frontend developed in Work Package 8. The primary objective of this deliverable is to provide a comprehensive API structure for optimising and calculating solutions within the context of the LOCALISED project. The document also contains clear and detailed integration guidelines for the MIDAS HTTP API, focusing on API structure, API endpoints, data management and interactions between users and the MIDAS model. Additionally, this deliverable offers insights into data storage, job management and workload management.

Key Objectives of Deliverable 4.2:

- Define the structure and endpoints of the MIDAS API.

- Describe the functionalities of the Optimisation and Calculation APIs.

- Specify the request and response formats for both APIs.

- Provide an overview of user interactions with the API.

- Present the role of the Job Manager in managing requests.

1   Introduction

This deliverable is the first outcome of Task 4.4 (Definition of Application Programming Interface). This task supports the development of a part of Application Programming Interface (API) to connect the data and back-end code from Work Packages (WP) 2 to 7 with the frontends developed in WP8. The complete integration with the work packages will be delivered as part of WP4.

Modular Integrated Decarbonisation and Adaptation Solver (MIDAS) model is an optimisation model developed to assist in analysing, understanding and choosing optimal climate response solutions. The MIDAS HTTP API is designed to facilitate the interaction with the backend of the decarbonisation profiler with the MIDAS system which handles optimisation and calculation requests. Optimisation requests direct the MIDAS model to execute the entire optimisation process in order to locate a set of climate response solutions, based on the data contained in the Work Package 3 Data Sharing Platform (DSP) and Work Package 4 Measure Database. Alternatively, calculation requests direct the model to calculate the expected regional outcomes from a preprocessed set of measure capacities that are fed into the model.

The API provides two entry points: the Optimisation API for generating optimal sets of climate response measures and their parameters, hereinafter referred to as solution fingerprints and the Calculation API for calculation result requests. This document outlines the API's purpose, endpoints, request and response formats, as well as key functionalities.

Examples of the input JavaScript Object Notation (JSON) and output JSON files generated by the model can be found in Appendix 1, 2 and 3 of this report.
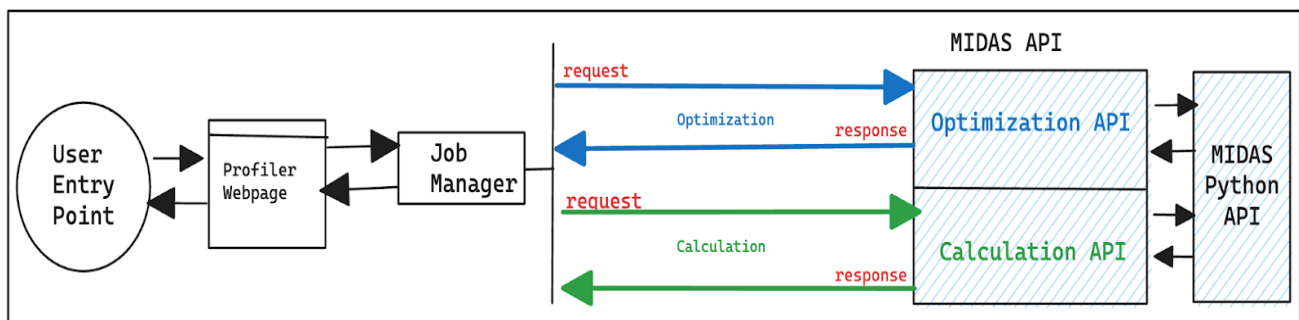

Figure 1: Front-End to API Flow

2 API Overview

The MIDAS HTTP API developed in Task 4.4 offers two entry points to access the model. The Optimisation API and the Calculation API. These APIs play pivotal roles in enabling users to harness the full potential of the MIDAS model.

2.1 Optimization API

The Optimisation API is instrumental in the MIDAS platform for providing optimal solutions, based on user-defined parameters and goals. Users can submit optimisation requests to this API, specifying key information such as:

- Calculation Properties: The parameters and constraints for the optimisation process, such as budget constraints, emission reduction targets or model objectives.(As described in T4.1)

- DSP Data: The Data Sharing Platform (DSP) data along with user data adjustments.(As described in D3.1)

- Regional Properties: The Nomenclature of Territorial Units for Statistics (NUTS3) region, Representative Concentration Pathway (RCP) scenario, and national decarbonisation pathway the user would like the model to consider in its calculations. (As described in D2.1)

The Optimisation API processes these inputs and passes them to the MIDAS model. The model applies these settings and generates a set of solution fingerprints that each outline a recommended set of measures and their associated parameters.

2.2 Calculation API

The Calculation API is designed to handle complex calculations using the MIDAS model. Users can submit solution fingerprints via this API, which specifies the measures and measure parameters used by the calculation. The API processes these requests, utilising the MIDAS model's capabilities, and returns detailed calculation results. These response from the API encompass a wide range of metrics such as, but not limited to:

- Aggregated measure capacities over time

- Resource consumption and KPI impacts

- Objective results (Calculation results from MIDAS model)

3 API Definition

The core of D4.2 is the definition of the MIDAS APIs. While the exact inputs and outputs are still under development, this section provides a clear framework for their structure. It defines the Optimisation API and the Calculation API, specifying their endpoints, request and response formats and primary purposes. These definitions serve as a foundation for further development.

The API is defined as follows:

Optimization API:

Functionality: The Optimisation API is a core component of MIDAS, enabling users to optimise their mitigation and adaptation strategies. It empowers users to find the most efficient combination of measures, aligning with predefined objectives and constraints.

- **Endpoint:** /api/v1/optimization

- HTTP request method: POST

- Request Structure: The request format is a JSON file and consists of measure database data, data sharing platform data and the request properties.

- Response Structure: The response format is a JSON file and consists of a set of solution fingerprints that list the recommended measures and parameters.

- Purpose: To receive optimisation requests and return optimisation results

- Input Parameters: Measure database data, DSP-data, and calculation and regional properties, organised in a structure to enable the MIDAS optimisation python function calls to process them.

- Output: A set of best-case solution fingerprints that contain a list of measures and instruments and the calculated parameters for each.

Calculation API:

Functionality: The Calculation API enables the MIDAS model to take optimised mitigation and adaptation strategies and translate them into regional impact results. It allows users to extract the resulting effectiveness of a solution fingerprint while aligning with the predefined objectives and constraints.

- **Endpoint:** /api/v1/calculation

- HTTP request method: POST

- Request Structure: The request format is a JSON file that specifies the input measure data and parameters (Solution fingerprint).

- Response Structure: The response format is a JSON file that contains detailed calculation results covering carbon emission reduction, energy efficiency, cost analysis and KPI evaluation.

- Purpose: To receive calculation requests and return calculation results

- Input Parameters: Solution fingerprint JSON, organised in a structure to enable the MIDAS optimisation python function calls to process it.

- Output: Calculation results comprising objective results and KPI impacts.

4 Data Storage and Management

This section outlines the strategies employed for data storage, focusing on solution fingerprints which are stored locally on the server's filesystem in a JSON file format, providing quick access for referencing.

4.1 Solutions Fingerprint

The use of hash keys to store optimization request parameters directs any API request first to the stored solution fingerprint files and returns a result if it is available, ensuring the rapid retrieval of relevant data.

An implementation description of the above is described as follows: A hash key is generated based on the input optimization request parameters.

This hash key is used as a reference to store the generated fingerprint data. When another request with the same parameters is made, the existing file can be retrieved, by calculating the hash key of the request parameter.

The generated solutions fingerprint data will be stored locally on the server's file system in a raw JSON file format.

Since the model's processing time for generating the solutions fingerprint data is expected to be longer compared to modern real-time web applications, we intend to implement result caching to optimize performance.

4.2 Calculation Results

Since the time taken by the model to process a Calculation API request is expected to be less than 1 second, the output of calculation results will not be stored.

5   API Interaction Flow, Job Manager and Workload Manager Overview:

The interaction between users and the model is a crucial aspect of its functionality. This section offers a brief view of how the API interacts within the system.

A detailed description of user interactions with the application will be described in WP8.
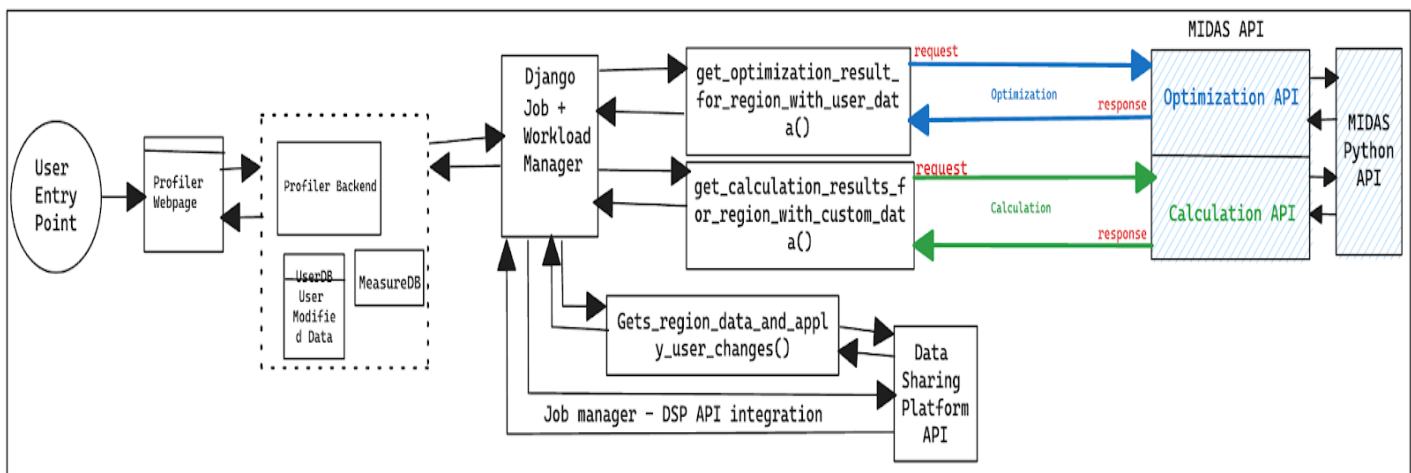
Figure 2: API Interaction Flow

- API Interaction: The API workflow begins with user interactions on the frontend, these interactions can include requests for calculation tasks and/or optimisation goals.

- Frontend Request Submission: When users initiate calculation or optimisation requests, these requests are first directed to the Job Manager. The job manager then interacts with the MIDAS system through the provided API endpoints to provide any necessary parameters and instructions.

- The output of the MIDAS HTTP API is sent to the frontend and the user through the job manager.

5.1 Job Manager

The Job Manager is a critical component of the system and is responsible for coordinating and managing the execution of user requests.

- The Job Manager first checks a local storage cache for previously calculated results before initiating a new calculation. If a cached solution is available, it is retrieved and returned to the user.

- The Job manager will also check the solution fingerprint filesystem for existing results before sending a request to the Optimization API.

- Additionally, the Job Manager checks the solution fingerprint filesystem which contains previously calculated solution IDs. This solution fingerprint file system serves as a valuable resource for quick reference, especially for recurring queries or optimisation requests.

- The Job Manager initiates a request to the Data Sharing Platform API to retrieve data and incorporates any user-customised data before sending a request to the MIDAS API.

- Integration with APIs: The Job Manager coordinates with the Calculation API, Optimisation API, Data Sharing Platform API and the Profiler frontend.

5.2 Workload Manager

The Workload Manager handles the execution of the MIDAS model. It is responsible for load balancing across available computational resources. Workload manager also ensures an equitable distribution of tasks, preventing resource bottlenecks and optimising system efficiency.

6 Conclusions

In conclusion, Deliverable 4.2 serves as a vital resource for integrating the model to the frontends developed in WP8. It offers comprehensive insights into the API structure, data management and user interactions. While certain aspects, such as job management and data storage, will be reported in detail in other work packages, this document provides a solid foundation for leveraging the capabilities of the model.

7 References

Martínez Görbig, G., Flacke, J., Keller, M., Reckien, D. (2022), Database of current, planned and potential adaptation and mitigation measures (LOCALISED Deliverable 4.1)

Verstraete, J.; Patil, S.; Pflugradt N., Radziszewska W. (2023), Database for 3 EU countries with relevant data for the year 2020 (LOCALISED Deliverable 3.2)

8 Appendix

8.1 Input queries for MIDAS sample:

The results generated by the following queries are predominantly synthetic and do not accurately represent the model's output yet.

Calculation:

> Request_Type:"Calculation",
>
> Request_Region:"DE300",
>
> Pathway_Region:"Transformational pathways for climate neutrality. Technology mix",
>
> Climate Variant: "RCP8.5"

Optimization:

> Request_Type:"Optimization",
>
> Request_Region:"DE300",
>
> Objectives:"Pathway Error, Emission Reduction, Investment",
>
> Objective_Goal: "Minimization",
>
> Pathway_Variant: "Transformational pathways for climate neutrality. Technology mix",
>
> Climate Variant: "RCP8.5"

8.2 Solution Fingerprint JSON sample

```
[{
  "Region": "DE300",
  "MIDAS Version": "1.0.0"
},{
  "Period_Capacity": {
    "Integrate District Heating Networks: Non-Residential Biomass": [
      0.01873,
      0.01718,
      0.04761,
      0.04068,
      0.03336,
      0.02328
    ],
    "Install Geothermal Systems: Flash Steam": [
```

```
      0.003,
      0.003,
      0.003,
      0.003,
      0.003,
      0.003
    ],
    "Install Geothermal Systems: Binary Cycle": [
      0.00295,
      0.00295,
      0.00295,
      0.00295,
      0.00295,
      0.00295
    ],
    "Install Jacket Offshore Wind Farms": [
      1.03974,
      1.03012,
      1.02696,
      1.02048,
      1.014,
      1.00198
    ],
    "Utility PV-Single Axis Tracking in Germany": [
      0.33772,
      0.33369,
      0.33992,
      0.33842,
      0.33691,
      0.32833
    ],
    "Utility PV-No Tracking in Germany": [
      0.09454,
      0.09341,
      0.09516,
      0.09474,
      0.09431,
      0.09191
    ],
    "Freight Heavy Duty Vehicle Technology Shift: HDVH BEV": [
      73,
      1110,
      1939,
      1078,
      589,
      125
    ],
    "Freight Heavy Duty Vehicle Technology Shift: HDVH PHEV-D": [
      2,
      28,
      102,
      71,
      38,
      10
    ],
    "Freight Heavy Duty Vehicle Technology Shift: HDVL BEV": [
      25,
      578,
      1228,
      870,
      432,
      655
    ],
    "Freight Heavy Duty Vehicle Technology Shift: HDVL ICE-CNG": [
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      44,
```

```
      59
    ],
  "Freight Heavy Duty Vehicle Technology Shift: HDVL PHEV-D": [
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      68,
      60,
      32,
      43
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  "Freight Heavy Duty Vehicle Technology Shift: HDVM BEV": [
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      1748,
      1166,
      592,
      803
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  "Freight Heavy Duty Vehicle Technology Shift: HDVM FCEV": [
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      798,
      1429,
      906,
      454,
      637
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  "Freight Heavy Duty Vehicle Technology Shift: HDVM ICE-CNG": [
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      122,
      99,
      53,
      63
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  "Interior Water Way Vehicle Technology Shift: H2": [
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      0,
      0,
      0,
      0
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  "Freight Rail Vehicle Technology Shift: FCEV": [
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      712,
      1276,
      1097,
      884,
      758
    ],
  "2 Wheel Vehicle Technology Shift: BEV": [
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      16348,
      20571,
      5548,
      4335,
      1
    ],
  "Passenger Vehicle Technology Shift: BEV": [
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      177812,
      153996,
      0,
      0,
      592
    ],
  "Passenger Aviation Vehicle Technology Shift: ICE-H2": [
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      0,
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    223,
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    0,
    0,
    0,
    0,
    0
  ],
  "Passenger Rail Vehicle Technology Shift: BEV": [
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    3,
    3,
    1,
    0
  ],
  "Passenger Rail Vehicle Technology Shift: CEV": [
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    45,
    123,
    112,
    41,
    20
  ],
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    1567,
    821,
    452,
    89
  ],
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    142,
    98,
    52,
    14
  ],
  "Freight Heavy Duty Vehicle Technology Shift: HDVL FCEV": [
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    295
  ],
  "Freight Heavy Duty Vehicle Technology Shift: HDVM PHEV-D": [
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    38,
    46
  ],
```

```
  "Interior Water Way Vehicle Technology Shift: BEV": [
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    0,
    0,
    0,
    0,
    0
  ],
  "Freight Aviation Vehicle Technology Shift: ICE-H2": [
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    0,
    0,
    0,
    0,
    0
  ],
  "Freight Shipping Vehicle Technology Shift: ICE-H2": [
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    3,
    6,
    6,
    6,
    5
  ],
  "Passenger Vehicle Technology Shift: FCEV": [
    3513,
    76802,
    66615,
    0,
    0,
    254
  ],
  "Bus Vehicle Technology Shift: BEV": [
    59,
    957,
    1591,
    665,
    75,
    0
  ],
  "Bus Vehicle Technology Shift: PHEV-D": [
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    0,
    0,
    0,
    0,
    0
  ],
  "Passenger Tram Vehicle Technology Shift: Overhead Wire": [
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    0,
    0,
    0,
    2
  ],
  "Passenger Rail Vehicle Technology Shift: FCEV": [
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    38,
    76,
    58,
    27,
    15
  ],
  "Passenger Rail Vehicle Technology Shift: ICE-CNG": [
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    18,
    37,
    28,
```

```
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      7
    ]
  },
  "Objective_Resultants": {
   "path": [
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     9675.408,
     11895.863,
     12617.908,
     12028.308,
     12508.133
   ],
   "emissions": [
     51.458,
     50.095,
     49.538,
     49.269,
     49.077,
     48.965
   ],
   "investment": [
     4445.173,
     11247.433,
     10821.11,
     5047.756,
     2607.836,
     1470.402
   ]
  }
}]
```

8.3 Calculation Results JSON sample

```
[{
  "Region": "DE300",
  "MIDAS Version": "1.0.0"
},{
  "Objective_Resultants": {
   "path": [
     9790.878,
     9675.408,
     11895.863,
     12617.908,
     12028.308,
     12508.133
   ],
   "emissions": [
     51.458,
     50.095,
     49.538,
     49.269,
     49.077,
     48.965
   ],
   "investment": [
     4445.173,
     11247.433,
     10821.11,
     5047.756,
     2607.836,
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   ]
  },
  "Sector_Resultants": {
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     "path": [
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      33.82534,
      33.82534,
      33.82534,
      33.82534,
      33.82534
    ],
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      1.16955,
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      1.28249,
      0.71566,
      0.33993
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  },
  "climate impact": {
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    ],
    "emissions": [
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      0.0,
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      0.0,
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      0.0
    ],
    "investment": [
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      0.0,
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      8.46253,
      8.45201,
      8.44424,
      8.43833
    ],
    "investment": [
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      10159.66633,
      10155.45292,
      4647.25842,
      2366.17181,
      1326.84802
    ]
  },
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      ],
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        5.12318,
        4.87339,
        4.69598,
        4.59544
      ],
      "investment": [
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```
        1086.59674,
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        240.94856,
        143.21398
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        0.0
      ],
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        0.0,
        0.0
      ]
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        0.0
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      "investment": [
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        0.0,
        0.0
      ]
    },
    "carbon capture": {
     "path": [
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        0.0,
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        0.0
      ],
      "emissions": [
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      "investment": [
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    },
    "environmental and biodiversity": {
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        0.582,
        0.57335,
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      "investment": [
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  "Integrate District Heating Networks: Non-Residential Biomass": [
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    0.12421,
    0.13883,
    0.02328
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  "Install Geothermal Systems: Flash Steam": [
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    0.00601,
    0.00901,
    0.01201,
    0.01501,
    0.003
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  "Install Geothermal Systems: Binary Cycle": [
    0.00295,
    0.00589,
    0.00884,
    0.01178,
    0.01473,
    0.00295
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  "Install Jacket Offshore Wind Farms": [
    1.03974,
    2.06987,
    3.09682,
    4.1173,
    5.13131,
    1.00198
  ],
  "Utility PV-Single Axis Tracking in Germany": [
    0.33772,
    0.6714,
    1.01133,
    1.34974,
    1.34894,
    0.32833
  ],
  "Utility PV-No Tracking in Germany": [
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    0.18795,
    0.28311,
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    0.37762,
    0.09191
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  "Freight Heavy Duty Vehicle Technology Shift: HDVH BEV": [
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    1939,
    1078,
    589,
    125
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  "Freight Heavy Duty Vehicle Technology Shift: HDVH PHEV-D": [
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    28,
    102,
    71,
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  "Freight Heavy Duty Vehicle Technology Shift: HDVL BEV": [
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    128,
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    2914,
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  "Freight Heavy Duty Vehicle Technology Shift: HDVM FCEV": [
    49,
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    2227,
    2335,
    1360,
    637
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  "Freight Heavy Duty Vehicle Technology Shift: HDVM ICE-CNG": [
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    35,
    154,
    221,
    152,
    63
  ],
  "Interior Water Way Vehicle Technology Shift: H2": [
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    1,
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    264,
    976,
    2252,
    3349,
    4233,
    758
  ],
  "2 Wheel Vehicle Technology Shift: BEV": [
    888,
    17237,
    36919,
    26119,
    9884,
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  ],
  "Passenger Vehicle Technology Shift: BEV": [
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  6875,
  184686,
  331807,
  153996,
  0,
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"Passenger Aviation Vehicle Technology Shift: ICE-H2": [
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],
"Bus Vehicle Technology Shift: FCEV": [
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  340,
  855,
  756,
  248,
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],
"Bus Vehicle Technology Shift: ICE-CNG": [
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  4,
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],
"Passenger Rail Vehicle Technology Shift: BEV": [
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  4,
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  8,
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],
"Passenger Rail Vehicle Technology Shift: CEV": [
  5,
  50,
  173,
  285,
  326,
  20
],
"Freight Heavy Duty Vehicle Technology Shift: HDVH FCEV": [
  65,
  1004,
  1567,
  821,
  452,
  89
],
"Freight Heavy Duty Vehicle Technology Shift: HDVH ICE-CNG": [
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  41,
  142,
  98,
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  14
],
"Freight Heavy Duty Vehicle Technology Shift: HDVL FCEV": [
  12,
  267,
  804,
  943,
  590,
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    295
  ],
  "Freight Heavy Duty Vehicle Technology Shift: HDVM PHEV-D": [
   1,
   23,
   108,
   157,
   108,
   46
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  "Interior Water Way Vehicle Technology Shift: BEV": [
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   1,
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   1,
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   66615,
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  "Bus Vehicle Technology Shift: BEV": [
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   2548,
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  "Bus Vehicle Technology Shift: PHEV-D": [
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  ],
  "Passenger Tram Vehicle Technology Shift: Overhead Wire": [
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   2,
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   2,
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  ],
  "Passenger Rail Vehicle Technology Shift: FCEV": [
   2,
   40,
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      116,
      174,
      201,
      15
    ],
    "Passenger Rail Vehicle Technology Shift: ICE-CNG": [
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      19,
      56,
      85,
      98,
      7
    ]
  },
  "KPI_Resultants": {
    "dhg_energy-demand_added-district-heat_gas-ff-natural": [
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      0.61583,
      0.56822,
      0.52754,
      0.49418,
      0.4709
    ],
    "dhg_energy-demand_added-district-heat_solid-ff-coal": [
      0.3675,
      0.35031,
      0.35031,
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      0.35031,
      0.35031
    ],
    "elc_energy-production_fossil_coal": [
      3.69878,
      2.23561,
      1.80053,
      1.36738,
      0.93615,
      0.51591
    ],
    "elc_energy-production_fossil_gas": [
      5.82123,
      5.82123,
      4.78832,
      3.76189,
      2.74194,
      1.73401
    ],
    "tra_vehicle-fleet_freight_HDVH_ICE-diesel": [
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      6920.0,
      3170.0,
      1103.0,
      0.0,
      0.0
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    "tra_vehicle-fleet_freight_HDVL_ICE-diesel": [
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      11218.0,
      9811.0,
      9107.0,
      8056.0
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    "tra_vehicle-fleet_freight_HDVM_ICE-diesel": [
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      6582.0,
      5446.0,

      3896.0
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    "tra_vehicle-fleet_freight_IWW_ICE": [
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      26.0,
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    "tra_vehicle-fleet_freight_aviation_ICE": [
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    "tra_vehicle-fleet_freight_marine_ICE": [
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      141.0,
      135.0,
      129.0,
      123.0,
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    "tra_vehicle-fleet_freight_rail_ICE-diesel": [
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      305.0,
      0.0,
      0.0,
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    "tra_vehicle-fleet_passenger_2W_ICE-gasoline": [
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      258465.0,
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      232345.0,
      228010.0,
      228009.0
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    "tra_vehicle-fleet_passenger_LDV_ICE-gasoline": [
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      1035913.0,
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    "tra_vehicle-fleet_passenger_aviation_ICE": [
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    "tra_vehicle-fleet_passenger_bus_ICE-diesel": [
      3210.0,
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    "tra_vehicle-fleet_passenger_bus_ICE-gasoline": [
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      55.0,

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     0.0
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   "tra_vehicle-fleet_passenger_metro-tram": [
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   "tra_vehicle-fleet_passenger_rail_ICE-diesel": [
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   "permanently irrigated land cover": [
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    0.13584,
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    0.13777,
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    0.12742
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   "non-irrigated arable land cover": [
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    0.13584,
    0.13838,
    0.13777,
    0.13278,
    0.12742
   ],
   "rice fields cover": [
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    0.13584,
    0.13838,
    0.13777,
    0.13278,
    0.12742
   ],
   "vineyards cover": [
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    0.13584,
    0.13838,
    0.13777,
    0.13278,
    0.12742
   ],
   "olive groves cover": [
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    0.13584,
    0.13838,
    0.13777,
    0.13278,
    0.12742
   ],
   "fruit trees and berry plantations cover": [
    0.14457,
    0.13584,
    0.13838,
    0.13777,
    0.13278,
    0.12742
   ],
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"pastures cover": [
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  0.13838,
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"permanent crops cover": [
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],
"agriculture with natural vegetation cover": [
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],
"complex cultivation patterns cover": [
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"agro-forestry areas cover": [
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"broad-leaved forest cover": [
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  0.12742
],
"coniferous forest cover": [
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  0.13278,
  0.12742
],
"mixed forest cover": [
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  0.13584,
  0.13838,
  0.13777,
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  0.12742
],
"natural grasslands cover": [
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  0.13584,
  0.13838,
  0.13777,
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      0.12742
    ],
    "moors and heathland cover": [
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      0.13584,
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    ],
    "sclerophyllous vegetation cover": [
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    ],
    "transitional woodland-shrub cover": [
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      0.13584,
      0.13838,
      0.13777,
      0.13278,
      0.12742
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    "bare rocks cover": [
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      0.13584,
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      0.13777,
      0.13278,
      0.12742
    ],
    "sparsely vegetated areas cover": [
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      0.13584,
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      0.13777,
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      0.12742
    ],
    "burnt areas cover": [
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      0.13584,
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      0.12742
    ],
    "glaciers and perpetual snow cover": [
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      0.13584,
      0.13838,
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      0.12742
    ],
    "bld_energy-demand_alluses_solid-bio": [
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      0.01602,
      0.01369,
      0.01122,
      0.00783
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    "tra_energy-demand_freight_diesel": [
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    "tra_energy-demand_freight_electricity": [
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    "tra_energy-demand_freight_hydrogen": [
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    ],
    "tra_energy-demand_freight_natural-gas": [
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    ],
    "tra_energy-demand_passenger_diesel": [
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    ],
    "tra_energy-demand_passenger_electricity": [
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      0.0,
      0.0,
      0.0
    ],
    "tra_energy-demand_passenger_hydrogen": [
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      2e-05,
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      0.0,
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      0.0
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    "tra_energy-demand_passenger_metro-tram": [
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    "tra_energy-demand_passenger_natural-gas": [
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      0.0,
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      0.0,
      0.0
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```
  ],
  "tra_energy-demand_passenger_rail_electricity": [
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  ],
  "tra_energy-demand_passenger_rail_hydrogen": [
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    0.0,
    0.0
  ],
  "tra_energy-demand_passenger_rail_natural-gas": [
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    0.0,
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    0.0,
    0.0
  ]
},
"Warnings": {
  "Warning_1": "This is a test warning!",
  "Warning_2": "Equity is highly uncertain!"
}
}]
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8.4 MeasureDB sample

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[
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    "Name": "Utility PV-Single Axis Tracking in Germany",
    "ID": "M153.12",
    "Activation_Flag": true,
    "Definition": "Replace fossil fuel power generation with utility scale (>1MW) solar PV systems, with an integrated single axis tilt. It can be with or without battery storage",
    "Response_Type": "Mitigation",
    "API_KPI": "elc_energy-production_RES_pv_solar-power",
    "Sector": "energy",
    "Complementary_Sectors": null,
    "Origin": null,
    "Effectiveness_Mitigation": 1.0,
    "Effectiveness_Adaptation": null,
    "Unit": "TWh",
    "Barriers": [
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        "KPI": "utility PV potential capacity",
        "Type": "Technical"
      }
    ],
    "Application": null,
    "Secondary_KPIs": [
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        "KPI": "cover",
        "Tags": {
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            "land use"
          ],
          "resource": [
            "land area"
          ]
        },
        "Unit": "km2/TWh",
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        "Values": [
          6.8874,
          6.5743,
          6.5743,
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          6.2885
        ],
        "Scalar": null,
        "Method": null
      }
    ],
    "Investments": [
      {
        "Type": "CAPEX",
        "Values": [
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          598.37,
          531.93,
          467.81,
          427.44,
          388.44
        ],
        "Stakeholder": [
          "National government",
          "Subnational government"
        ]
      },
      {
        "Type": "OPEX",
        "Values": [
          8.709,
          7.657,
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          5.986,
          5.478,
          4.97
        ],
        "Stakeholder": [
          "National government",
          "Subnational government"
        ]
      }
    ],
    "Preconditions": [
      {
        "KPI": "country",
        "Tags": null,
        "Type": "Geophysical",
        "Values": "DE",
        "Method": "Equal"
      },
      {
        "KPI": "elc_energy-production_fossil",
        "Tags": {
          "sector": [
            "energy"
          ]
        },
        "Type": "Technical",
        "Values": 0.0,
        "Method": "Greater"
      },
      {
        "KPI": "cover",
        "Tags": {
          "sector": [
            "land use"
          ],
```

```
                "resource": [
                    "land area"
                ]
            },
            "Type": "Geophysical",
            "Values": 0.0,
            "Method": "Greater"
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    ],
    "Lifetime": 25,
    "Installation_Period": 1,
    "Confidence": {
        "emissions": "good",
        "equity": "bad",
        "risk": null
    },
    "Comments": "CAPEX is between 580-875€/KW installed in 2020. Expected to decrease to a range of
250-375€/KW installed in 2050. OPEX is between 11-15€/KW installed per year in 2020. Expected to decrease to a
range of 11-7,5€/KW installed per year in 2050. Source: https://doi.org/10.3390/su13063238",
    "Instruments": "I20;I47;I49;I52;I54;I55;I58;I62;I66;I75;I94;I100;I117;I122;I124;I126;I149;I196;I202",
    "SOIs": "K15;K25;K27;K28;K29;K30;K31;K46;K75;K86"
    }
]
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