WHY

Deliverable 6.2

Online Reference
Documentation of the WHY
Toolkit

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EXECUTIVE SUMMARY

The WHY project aims at developing a software toolkit (the WHY Toolkit) which can create more detailed consumption and generation information for residential households. This information includes data (load profiles) for thermal energy demand, electricity demand and hot water demand.

The WHY Toolkit can consider the actual living situation, the technical devices (TV, dishwasher, refrigerator, etc.) and the reactions of the inhabitants to external interventions. In case of the WHY-project external interventions are events such as new taxes, funds or technologies or even winning a lottery. Reactions to these events could be the investment into new technologies, refurbishing the building or changing the individual behaviour of the inhabitants.

Deliverable D6.2 is a reference document for the Universal Time Series Provider (UTSP). The UTSP works as a distributed job manager for time series generation tools. Which, basically, means that the UTSP allows to run multiple runs of the WHY Toolkit simultaneously. For a detailed description of the WHY Toolkit please refer to Deliverable D3.2.

The purpose of the WHY Toolkit is to create household load profiles for thermal and electrical energy as well as water consumption for different Use Cases. These Use Cases can consider single households or thousands and thousands of households, such as the European or Global Use Case in which the entirety of European or Global households are simulated.
In its initial form the WHY Toolkit can be used to simulate one single household, the simulation of multiple households can be done by calling the WHY Toolkit once at a time, which would result in a substantial effort to create the required data. To reduce the required effort the UTSP was created, which allows to run multiple House Infrastructure Simulator (HiSIM) or Load Profile Generator (LPG) runs simultaneously.

Figure 1 shows how the Deliverable D6.2 fits into the rest of the project environment of the WHY project. While the Deliverable is part of work package 6, it strongly refers to the work done in work package 3.
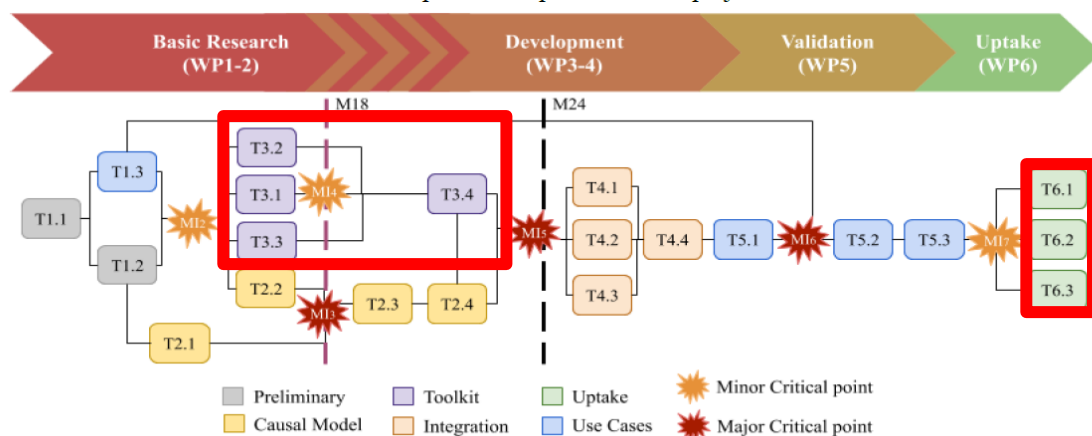

Figure 14: PERT diagram. Red points denote the major critical points and orange minor critical points.

Figure 1: Allocation of the Deliverable D6.2 in the Pert-Chart of the WHY project

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Long text
UTSP	Universal Time Series Provider
HiSIM	Household infrastructure Simulator
LPG	Load Profile Generator
REST	Representational State Transfer
Caching DB	Caching Database

1   Universal Time Series Provider (UTSP)

Role of the Universal Time Series Provider:
The UTSP is a server that works as a distributed job manager for time series generation tools. It is used to distribute many HiSIM calculation, Building Sizer or LPG evaluations, collect and filter the results, or even analyse them. The UTSP enables to user to run multiple HiSIM, Building Sizer and LPG runs simultaneously.

Universal Time Series Provider:
The Universal Time Series Provider (UTSP) is a distributed job manager that provides access to result data from different sources via a uniform Representational State Transfer (REST) interface.

The main feature of the UTSP is to provide easy utilization of distributed, unstructured, and non-uniform computing resources, using a simple client-server-architecture. The central access point consists of the UTSP server, which receives and queues incoming requests. Additionally, an arbitrary number of UTSP worker processes may be started on the same or other machines. These connect to the server and continuously ask for calculation tasks.

The actual calculations are performed by independent programs, so-called providers. Typically, these receive a configuration file and produce several output files, e.g., demand time series. For universal applicability, these tools are wrapped in a Docker container for the UTSP. All available provider containers are stored on the UTSP server and sent to the workers on demand.

Whenever a worker has finished calculating its request, it sends the resulting files back to the UTSP server which stores them in a caching database. From there, they can be retrieved by clients immediately in case the same request is sent again.

To send requests more easily, the open-source client library utspclient can be used. It provides simple blocking and non-blocking functions for sending requests and retrieving results for single or multiple requests at once.

Figure 2 shows the UTSP architecture, consisting of the following elements:

- **Client:** User that calls and activates the UTSP to perform the operations.
- **Provider:** Software that is used to make the calculations or simulations (Load profile generator, HiSIM, Building Sizer)
- **Worker**: Computer/Server that runs the Provider
- **Work Distributer**: Software that decides which worker will be used to run the provider in each setting. It distributes the work that needs to be done between the different workers.
- **Caching DB**: Database which acts as storage for results provided by the different workers. These results can be recalled later to prevent additional computation.
- **REST Server**: The server that accepts calculation requests from the client.
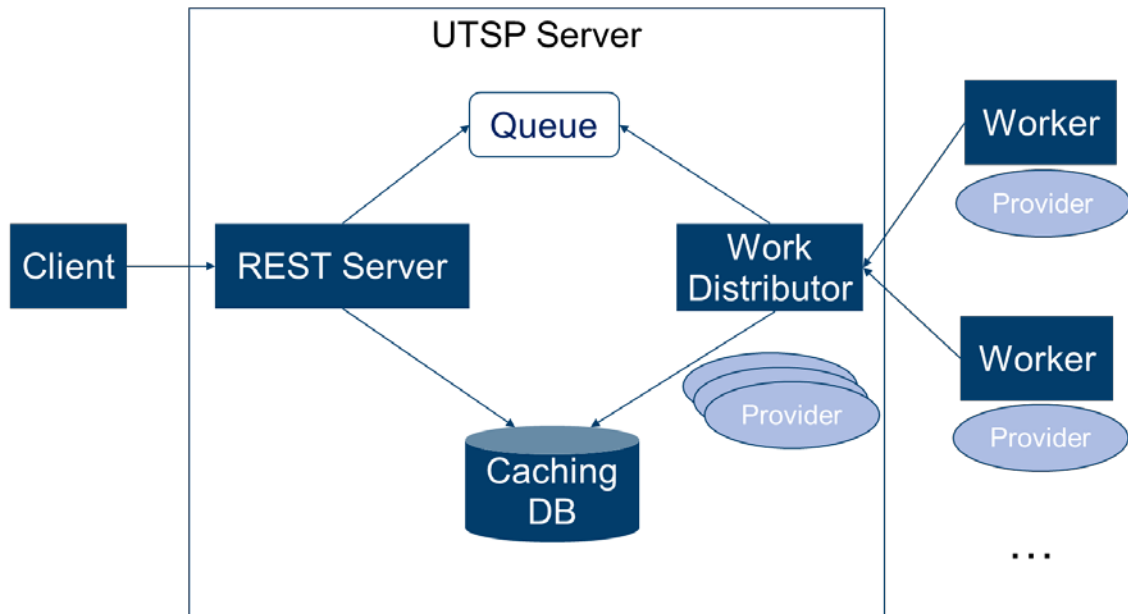- **Queue**: A data structure that stores all pending calculation requests until they are distributed onto the workers.

Figure 2: UTSP Architecture

Source Code:

Online: https://github.com/FZJ-IEK3-VSA/UTSP_Client

Documentation:

Online: https://utsp-client.readthedocs.io/en/latest/

Examples and Tutorials:

Online: https://utsp-client.readthedocs.io/en/latest/generated/example_collection.html

2   Configuration Manual

The Documentation of the UTPS contains the relevant information on how to configure the UTPS and how to apply it. In this chapter, a short summary of the most important configuration parameters is presented.

The most relevant function for the use of the UTSP is the function *request_time_series_and_wait_for_delivery*[1] which uses the UTSP to create a single time series (result) using a defined provider. In the case of the WHY Toolkit this could be either the Building Sizer, Load Profile Generator or the HiSIM. Furthermore, the function *utspclient.client.calculate_multiple_requests*[2] will be of great importance, as it allows the user to run multiple simulations of different Providers and request the results.

Both functions use the following parameters that need to be defined by the user:

- **url**:
  string of the URL of the UTSP server. For the WHY project the server is running in Forschungszentrum Jülich.
  Example: http://134.94.131.167:443/api/v1/profilerequest

- **Requests**:
  This parameter represent the TimeSeriesRequest(s) that need to be handled by the UTSP. A TimeSeriesRequest is a class with a set of attributes, described below.
  Example: See below.

- **API_Key:**
  This optional string is the key for the API to access the UTSP.
  Example: PGI4RT5BZ1ND64C04BY8LFM3

- **raise_exceptions:**
  Optional Boolean parameter, that indicated whether failed request should raise exceptions. If the parameter is set to the default true, exceptions will be raised, otherwise exceptions will be added to the result list.

- **Quiet:**
  Optional Boolean parameter that indicates whether there should be console outputs or not. The default value for this parameter is "False", which will prevent the UTSP from creating console outputs.

Time Series Request Class:
The Time Series Request Class is another vital part of the UTSP configuration parameters, it describes what Time Series the UTPS should simulate/calculate. Furthermore, the Time Series Request Class

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[1]   https://utsp-client.readthedocs.io/en/latest/generated/utspclient.html#utspclient.client.request_time_series_and_wait_for_delivery
[2]   https://utsp-client.readthedocs.io/en/latest/generated/utspclient.html#utspclient.client.calculate_multiple_requests

functions as identifier. Sending the same identifier another time will prompt the UTSP to draw the already existing results from the Caching Data Base and thus preventing another use of the workers.

The following attributes are of relevance to the user:

- **Guid:**
  Optional String that acts as an identifier and can be used to force a recalculation of an already existing result.
  Example: "calculation-attempt-1"

- **input_files:**
  Dictionary of the names and contents of additional input files to be created in the provider container, if required.
  Example: {"input_data.csv": <base64-encoded file content>}

- **providername:**
  String that gives the UTPS the provider which shall process the request. As mentioned above, the provider is either the Load profile generator, HiSIM or the Building Sizer.
  Example: "hisim"

- **required_result_files:**
  Dictionary of the desired files that should be created by the provider that are sent back as result. Throws an error if one of these files is not created. If left empty all created files are returned.
  Example: { "kpi_config.json": ResultFileRequirement.REQUIRED}

- **simulation_config:**
  String with provider specific configurations, defining the results that are requested.
  Example: See Appendix I

Result Delivery Class:
The ResultDelivery Class works as a container for the results of a calculation requests that are sent back from the UTSP Server to the client.

The following attributes are of relevance to the user:

- **data:**
  A dictionary containing the names and contents of all generated result files
  Example: {"result_file.csv": <file content as bytes>}

- **original_request:**
  The TimeSeriesRequest object that was originally sent to the UTSP Server
  Example: see description of the TimeSeriesRequest class above

3 Examples

The following chapter provides a set of examples[3] that explain the use of the UTSP. Furthermore, links for examples of the HiSIM, Building Sizer and Load Profile Generator are provided.

- **Build a new Image:**
  This example shows how to send a tar file containing the build context for a docker image to the server, so that the server builds the new provider image. This is done because the build context is usually significantly smaller than the built docker image file.

  Example: *https://github.com/FZJ-IEK3-VSA/UTSP_Client/blob/main/examples/build_new_image.py*

- **HiSIM sensitivity analysis:**
  This next example allows the user to run multiple HiSIM runs to perform a sensitivity analysis, the requested results are then stored locally for post processing. There are multiple ways to use this example:

  Example: *https://github.com/FZJ-IEK3-VSA/UTSP_Client/blob/main/examples/example_hisim_sensitivity_analysis.py*

  - o **Boolean Parameter Test:**
    Varies all indicated Boolean Parameters of the system configuration, simulates it by sending the HiSIM requests to the UTSP and saves the results. The HiSIM configuration of the reference technology/building should be in examples/input data/

  - o **Variation of different building codes and heating systems**:
    This example creates HiSIM requests for various buildings with different heating systems. The following parameters are required to run the simulation:

    - ▪ building_codes:
      List of strings that contains all building types that should be calculated by the HiSIM.
      Example: " AT.N.AB.01.Gen.ReEx.001.001"
    - ▪ heating_systems:
      List of strings that Contains all heating systems to be calculated in combination with the indicated building types.
      Example: "DistrictHeating"

  - o **Multi-Parameter Sensitivity Analysis:**
    This example can be used to execute a sensitivity analysis for multiple different parameters. For each of the parameters a curve with the variation of the parameter and the resulting KPI is generated, which results in a "star plot". Each of the parameters use the same base configuration file, for which the path needs to be provided by the user. Within the example, the value of only one of the parameters is changed at a time.

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[3]   https://utsp-client.readthedocs.io/en/latest/generated/examples.html

- base_config_path:
  String that describes the path to the base configuration file.
  Example: "examples/input data/hisim_config.json"
- Parameter_value_ranges:
  Dictionary with the value ranges for all the parameters that are being investigated.
  Example: {"battery_capacity": [5, 10, 15]}

  o **Sensitivity analysis:**
  In this example, a variation of all indicated discrete parameters that are mentioned in the system configuration is made. The corresponding HiSIM-request is sent to the UTSP, and the results saved.
  The HiSIM configuration of the reference technology/building should be located in examples/input data/

- **Get the HiSIM KPIs:**
  This simple example provides the user with the KPIs generated by the HiSIM.

  Example: *https://github.com/FZJ-IEK3-VSA/UTSP_Client/blob/main/examples/example_hisim.py*

- **Multiple HiSIM requests:**
  This example can be used to send multiple HiSIM calculation requests to the UTPS. The following parameters are required:

  o hisim_configs
  This list of strings contains the HiSIM configurations that need to be calculated.
  Example: [<simulation_config_1>, <simulation_config_2>, …]
  o return_exceptions:
  Optional Boolean Parameter, which defines whether exceptions should be caught and returned in the result list. The parameter defaults to "False".
  Example: False

  Example: *https://github.com/FZJ-IEK3-VSA/UTSP_Client/blob/main/examples/example_multiple_hisim_requests.py*

- **Load Profile Generator:**
  This example requests for one simulation of the load profile generator to be made.
  Example: *https://github.com/FZJ-IEK3-VSA/UTSP_Client/blob/main/examples/example_lpg.py*

- **SME Load Profile Generator:**
  By using this example, an exemplary load profile for a small or medium sized enterprise (SME) can be created.
  Example: *https://github.com/FZJ-IEK3-VSA/UTSP_Client/blob/main/examples/example_smelpg.py*

- **Mean Load Profiles:**
  This example shows how to send multiple long requests to the UTSP. When being called once, the example finishes without collecting results. After all requests have been calculated, the example can be run again to collect the results and calculate average profiles from them.

This avoids having to keep the example running during the lengthy calculations of the requests.

Example: *https://github.com/FZJ-IEK3-VSA/UTSP_Client/blob/main/examples/example_mean_load_profiles.py*

- o **Main:**
  This function is meant to be run multiple times manually. It requests multiple electricity load profiles for all predefined LPG households to ultimately calculate a mean profile for each household. The function checks if all results have been created by the UTSP already, and only then retrieves the result data and calculates the mean profiles.

4   Recommendations for the Use of the WHY Toolkit

The WHY Toolkit has different applications as shown in the WHY Use Cases, see chapter 5. In this chapter different examples of users and how they can apply and use the WHY Toolkit optionally in combination with the UTSP are shown.

Technical Experts or Consultants on a local level:
This user group consists of experts that use the WHY-Toolkit to consult a wide range of customers when it comes to questions on small scale energy systems. Their customers can range from decision makers on city level over city lead energy consultancy agencies up to individual homeowners.
The group consists of technical bureaus, city planners, etc. who have a profound technical knowledge and expertise and facilitate other technical tool to create their consultation materials.

This User Group can apply different components of the WHY Toolkit for different purposes:

- Energy analysis of residential buildings:
  Depending on what type of analysis is made either the **LPG** or the **HiSIM** will be used.
  - o If only consumption of electricity in combination with water consumption is of interest, the use of the **LPG** is recommended. This would be the case if the User has a more sophisticated tool to calculate the thermal energy demand of the building.
  - o If the User wants to simulate the building under consideration of the load flexibilities of the building, the use of **HiSIM** is recommended. In that case **HiSIM** will generate the algorithms for controlling the flexibilities of the building while generating the required outputs.
  - o If the User wants to simulate the entire building, considering the thermal load behaviour in addition to the electricity demand and the water consumption the use of **HiSIM** is recommended.

- Developing recommendations for individual households:
  In this case, which basically represents the Maintal Use Case, the User will apply the WHY Toolkit to simulate a multitude of different households in for instance a new district that needs to be evaluated. Since in that case not a single building is simulated the application of the WHY Toolkit will depend on the number of households to be simulated and the required information that needs to be considered. The use of the WHY Toolkit is defined by the number of buildings to be calculated:

- o If only a small number of houses/households are to be considered the **LPG** or **HiSIM** can be used individually. The user can either define simulation parameters themselves or use pre-processed results for their analysis,
- o If a large number of buildings are to be considered, the use of the **UTSP** is recommended, as it will allow simulating multiple houses/households simultaneously.

  If the results that are required only consider the uncontrolled and not time shifted electricity demand or the warm water demand of the building, **HiSIM** can be replaced using the **LPG**.

- • Building recommendations:
  Another use would be to provide customers with recommendations on how to optimise their building from an energy perspective and which investments to make. In this case it is recommended, that the user applies the **UTSP** and activating the **Building Sizer**, as the evolutionary algorithm of the Building Sizer will require multiple runs of the same simulation. This can be handled by the **UTSP**.

Energy System Modellers:

The next User Group is part of the research community and consists of experts in energy system modelling. These energy systems can vary substantially in size, ranging from an individual household/house to complex energy system for countries or continents. In opposition to the User Group of Technical Experts this group will most likely implement the WHY Toolkit directly within their models, either via the interfaces provided or by using the open-source code directly. The following recommendations can be made:

- • Simulation of small-scale systems:
  For small scale energy system simulation, for instance single buildings- or households the use of the **LPG** or the **HiSIM** are recommended. Depending on the type of simulation the temporal resolution of the created data needs to be adapted to the requirements of the User. The use of the **HiSIM** should be preferred, as it provides a wider range of results.

- • Simulation of Medium to large scale energy systems:
  For medium to large scale energy systems the use of the **UTSP** is recommended, as is the case for the European and Global Use case of the WHY project. The WHY Toolkit comes with a built-in interface for large scale energy system models, that can be used.

The WHY Toolkit can run temporal resolutions up to 15 minutes, which sets a limit for the use in analysis of dynamic processes in energy systems.

System Analysts and Consultants:

This User Group can be compared to the technical experts, when it comes to the way they use the WHY Toolkit, but their customers differ. They address policy and decision makers on a larger scale. These could be policy and decision makers on country or cross-country level. As such, the level of detail in the data considered will likely be lower but more data points need to be addressed. These types of analysis are comparable to the European or Global Use Case, of the WHY Toolkit.

Due to the large scale and number of houses/households to be considered, the use of the **UTSP** is recommended.

5   WHY Use Cases

Table 1 shows the different Use Cases of the WHY project.

Table 1: WHY Use Cases

Use Case	Size	Resolution	ESM	Objective
Positive Energy District	City	Quarter-hourly /Yearly	HiSIM	Sizing energy positive district / energy cooperatives to operate under normal and blackout operations
Energy Community	Neighbour-hood	Hourly /Yearly	HiSIM	Create tool to define the business and governance models of energy communities
Energy Cooperative O&P	Regional	Hourly /	-	Assess the impact of new tariff on behaviour
2030 & 2050 European energy strategy	European	Yearly	PRIMES	Create different load profile under different interventions to foster EE, DG, DR and ES
Global energy scenario	Worldwide	2030 / 2050	TIAM-ECM	Assess the impact of different EE campaigns

6   Conclusion

The WHY Toolkit allows the user to make very detailed simulations for household energy (thermal and electrical) and water consumption, considering the effects of external interventions on individual decisions.

The WHY Toolkit consists of three main elements, the HiSIM, the LPG and the Building sizer, which can be operated to calculate single buildings. The issue with that is that as soon as the Building Sizer is used, computation time will increase substantially due to the nature of the evolutionary algorithm.

To address this issue the Universal Time Series Provider was developed, which allows the users to run multiple simulations of the WHY Toolkit in parallel, meaning that the Building Sizer can be run more efficiently but also that multiple instances of the WHY Toolkit an its components can be run in parallel. This will allow large scale simulations to be made, which require the data from a multitude of different houses/households.

Within this deliverable, the basics on how to apply the UTSP were explained and the corresponding links and sources presented. Furthermore, recommendations on when to apply the WHY Toolkit were presented.

Annex I

Exemple of HiSIM config file.

```json
{
    "system_config_": {
        "pv_included": false,
        "pv_peak_power": 10000.0,
        "smart_devices_included": false,
        "buffer_included": false,
        "buffer_volume": 1.0,
        "battery_included": false,
        "battery_capacity": 10.0,
        "heatpump_included": false,
        "heatpump_power": 1.0,
        "chp_included": false,
        "chp_power": 12,
        "h2_storage_included": true,
        "h2_storage_size": 100,
        "electrolyzer_included": true,
        "electrolyzer_power": 5000.0,
        "ev_included": false,
        "charging_station": {
            "Name": "Charging At Home with 03.7 kW",
            "Guid": {
                "StrVal": "38e3a15d-d6f5-4f51-a16a-da287d14608f"
            }
        }
    },
    "archetype_config_": {
        "occupancy_profile_utsp": null,
        "occupancy_profile": "AVG",
        "building_code": "ES.ME.TH.03.Gen.ReEx.001.003",
        "absolute_conditioned_floor_area": null,
        "water_heating_system_installed": "DistrictHeating",
        "heating_system_installed": "DistrictHeating",
        "mobility_set": null,
        "mobility_distance": null,
        "url": "http://134.94.131.167:443/api/v1/profilerequest",
        "api_key": ""
    }
}
```