OPTIMISED DESIGN METHODOLOGIES FOR ENERGY-EFFICIENT BUILDINGS INTEGRATED IN THE NEIGHBOURHOOD ENERGY SYSTEMS

*ee*Embedded – D6.3
Simulation Manager

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History

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Project of SEVENTH FRAMEWORK PROGRAMME OF THE EUROPEAN COMMUNITY		
Dissemination Level		
PU	Public	X
PP	Restricted to other program participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Abbreviations

MMC	Multi Model Container
LM	Link Model
ScM	Scenario Manager
3DTherm	3D Thermal CFD Analysis
3DWind	3D Wind CFD Analysis
SAS	Stochastic Sampling Service
NAS	Network Attached Storage
SAN	Storage Area Network
KPI	Key Performance Indicator
API	Advanced Programming Interface
BCF	BIM Collaboration Format
CFD	Computational Fluid Dynamics

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Executive Summary

The **objective** of Deliverable D6.3 "Simulation Manager" was to describe the approach of managing energy simulations as part of the workflow within all design phases identified in the eeEmbedded project.

The deliverable D6.3 is the successor of D1.5, and D6.1 and connected with D6.2. It is structured into **4 chapters:**

Chapter 1 contains an introduction of the objectives and the connections to other deliverables within the eeEmbedded project.

Chapter 2 explains the concept based on the requirements identified within D6.1. The chapter describes the needed capabilities of a simulation management. Tree main classes of capabilities will be introduced in a brief manner: (1) none-functional and (2) functional capabilities as well as (3) workflow-related capabilities.

Within **Chapter 3** the prototype implementation is described based on a computing environment which will be used within the validation and verification phase of the eeEmbedded project especially for processing building energy simulation.

In **Chapter 4** contains a brief summary about the simulation management and the intended implementation.

The deliverable was led by the Partners IET and SOF. Each of the involved partners has contributed from their expert viewpoint as follows:

TUD-CIB: provides input for chapter 4

TUD-IET: provides input for all chapters

SOF: provides input for all chapters as well.

1 Introduction

The content of this document is aligned with the subject of WP6 which covers the integration of the numerical investigations and simulations in the overall design process within all design phases.

The scope of this deliverable is the management of cloud-/cluster-based simulation analysis and the interdependencies of this service as a part of simulation and optimization framework which is used within all design phases identified and described within the eeEmbedded project. This work has been done within WP6 task T6.3 of the project and benefits from previous experiences of managing cluster-based parallelized simulation tasks.

The simulation management capabilities are superimposed on the simulation and optimization tools itself and aligned with the simulation mapping services as well as the result evaluation services for processing "AS-IS" KPIs and other visualization views.

In the eeEmbedded-context the simulation management acts as a layer on top of the operating system of each compute node within the available computing infrastructure. The simulation management is applicable on a single computing node as well as a larger cloud-based computing infrastructure.

The overall concept of managing simulations is intended to be applicable to every kind of simulation within the workflow especially focusing CFD wind and comfort analysis as well as thermal building and energy system analysis.

Main goal of this deliverable is the introduction of a common approach taking into account certain aspects of managing and monitoring the analysis jobs running within the computing environment as well as the simulation preparation, and post-processing steps.
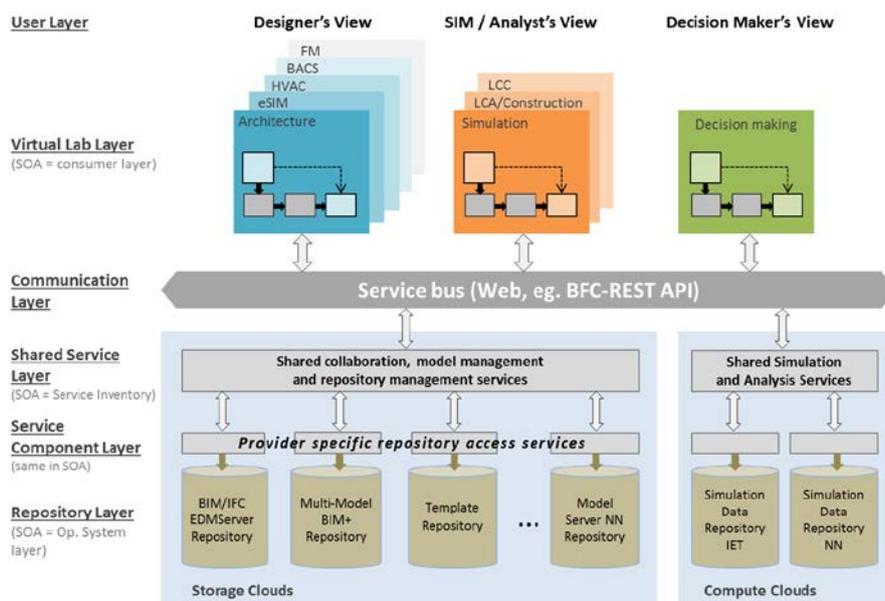

Figure 1: Overall architecture of the eeEmbedded framework [Zellner, 2015]

According to the introduction of the eeEmbedded framework given in deliverable D1.5 (Zellner, 2015), see Figure 1, the simulation management covers the "Simulation and Analysis Management

Services" with a strong relationship and interdependencies to the "Simulation and Analysis Services".

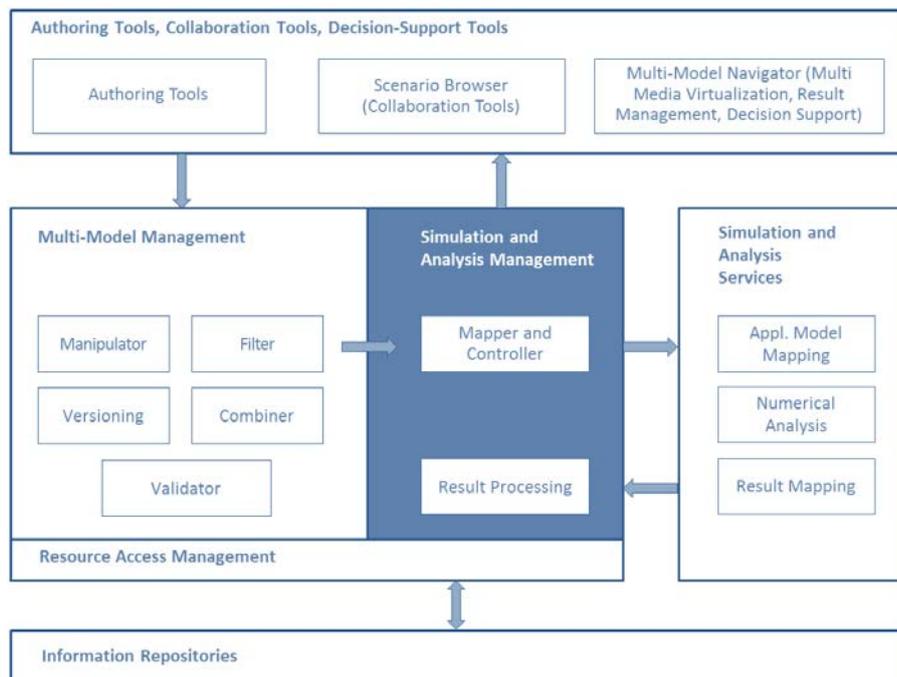*Figure 2: eeEmbedded framework structure – position of the "Simulation and Analysis Management"*
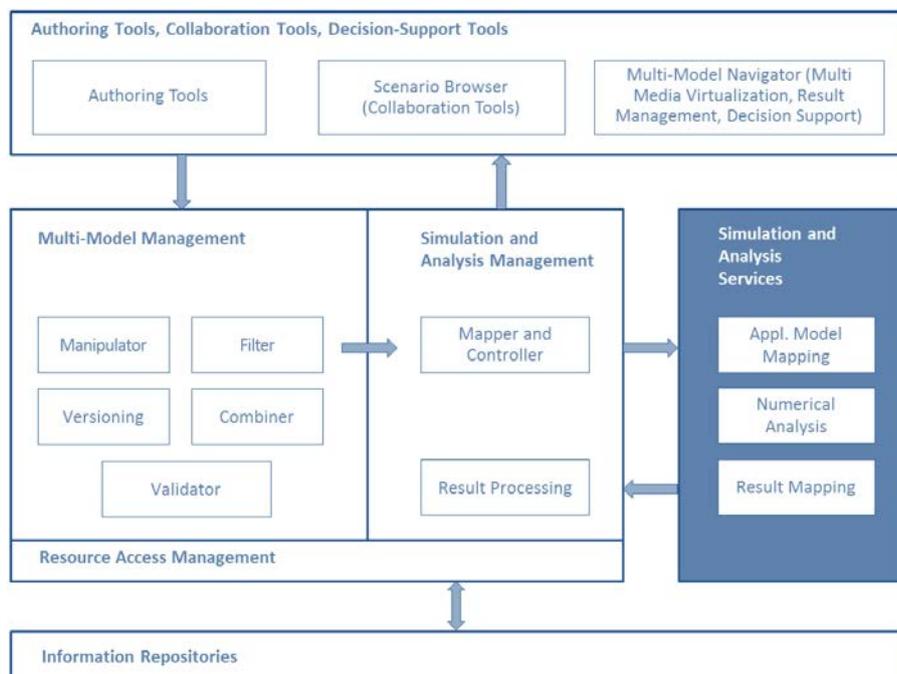*(Zellner, 2015)*

Figure 3: eeEmbedded framework structure – position of the "Simulation and Analysis Service"
(Zellner, 2015)

Following the description in (Zellner, 2015) the "Simulation and Analysis Management Services" handles the evaluation und transformation of the content related model data and additional

information as well as the process related data placed and transported within the multi-model container, see Figure 2. The simulation manager organizes the transformation of the input data produced within the design steps into an appropriate analysis model according to the design related questions which should be answered by the analysis.

The management of simulations is closely connected with the "Simulation and Analysis Services" introduced in Figure 3. In the general context of the eeEmbedded workflow the simulation service will **receive a set of input data, run a simulation and produce a set of output data,** see Figure 4.
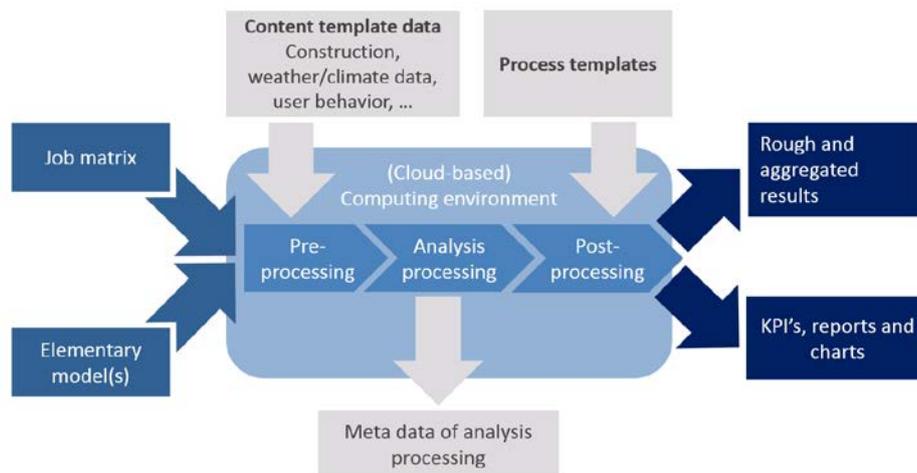

Figure 4: Schema of the main elements and tasks within the simulation management

Depending on the complexity of the analysis model and the type of analysis run as well as the involved analysis tools the processing time which is needed to produce results could be varying between a few minutes to certain hours. From the designers perspective a nearly synchronous availability of result (very short processing time, fast response of the analysis service on designer's requests) and asynchronous availability of results (longer processing time, slow response of the analysis service on designer's requests) can be classified. Caused by the usage of cluster or cloud based computing resources the time shift between formulation of the analysis request by the designer and the delivery of the related results will be reduced but will not disappear while using the state-of-the-art but cost-effective computing technology. Caused by this edge conditions the simulation manager need to cover **monitoring capabilities for the running analysis**.

The simulation management covers also the **handover of analysis results** to the downstream process steps via the Scenario Manager (ScM).

2 Simulation Management Concept

2.1 Requirements

Based on the common requirements introduced within eeEmbedded deliverable D6.1 (Protopsaltis, 2016) the simulation management concepts are an embedded part of the overall simulation and optimization framework. The simulation management is linked with the simulation model mapper described within eeEmbedded deliverable D6.2 (Heinzig, 2016).

According the described common requirements the simulation management offers certain capabilities to offer seamless integration into the eeEmbedded workflow taking into account a sophisticated model mapping and simulation generation processed within a flexible cloud-based computing environment. The required capabilities will be differentiated into non-functional, functional and workflow-related capabilities.

2.2 Non-functional Capabilities

The simulation management offers certain non-functional capabilities which will be introduced as follows:

Scalability	- Applicable within a minimalistic computing setup, e.g. one local multicore host incorporating simulation model-mapping, simulation management and analysis processing till to a cloud-based multi-node computing infrastructure; - Flexible integration of computing nodes into the analysis framework infrastructure
Maintainability	Easy maintainable due to script-based approach using basic functions provided by the operation system of the compute nodes
Adaptability	Handling of different analysis software, e.g. CFD simulation software as well as building energy solver including applications which are used for pre- and post-processing purposes
Applicability	Applicable in different computing environments, e.g. public and private cloud, cluster independent of the underlying hardware and the used virtualization technology

2.3 Functional Capabilities

The following aspects are identified as core tasks within the simulation management:

Infrastructure Management	- The simulation management acts as an application on top of a common used operation system (e.g. Linux or Microsoft Windows) installed on a local or cluster/cloud-based computing node. - A simulation manager script is able to administer (add, configure, suspend) further computing nodes as associated nodes of the

analysis processing infrastructure keeping currently running analysis jobs alive

- Managing availability status of computing nodes within the analysis processing infrastructure

User / Access Management	• Registering users to get access to the entry point of the processing infrastructure and to monitoring data
Job Management	• Initiate, monitor, kill, re-start, reject analysis jobs and sub-tasks like pre-processing, processing and post-processing
Software Management	• Verify pre-requisite's of analysis software on the associated computing nodes • Install missing pre-requisite software components
Self-Management	• The simulation manager is formed by several scripts which are distributed on the associated computing nodes; to roll-out updates and keep the distributed scripts in a consistent shape on all nodes capabilities for automated update-checking have to be implemented
Information Acquisition and Delivery	• Acquire or generate as well as aggregate and deliver information and statistical data explaining the behaviour of the associated computing nodes as well as the processed analysis jobs and the user-related activities

2.4 Workflow-related Capabilities

The following workflow-related aspects will be covered by or linked to the simulation management:

Input Management	• Integration of computing nodes into the framework infrastructure • Managing availability status of computing nodes
Job-Analysis-Tracking	• Applying an appropriate nomenclature for unique identification of jobs, used analysis applications, analysis runs and related results
Output Management	• Delivery of the processed analysis results in the appropriate output formats
Data Archiving	• Optional: archiving all job-related data including inputs, results, outputs, analysis software, meta data (timestamp, computing effort, used resources and other logging data), which could be used to track the workflow and process cost statements within a productive environment

3 Prototype Implementation

3.1 Overview

The simulation manager service fully utilizes the cloud abstraction layer that was developed according to D6.1, in order to support various cloud architectures.

Within the evaluation phase of the eeEmbedded project a prototype of the simulation manager is being implemented with adapters for the cluster environment provided and managed by the project partner TUD-IET as well as the HPC cluster system provided by SOF. The TUD-IET cluster environment is based on rack mounted computing nodes in conjunction with a storage area network on Fibre Channel basis and a NAS system for archiving purposes. To achieve maximum performance within for processing of energy simulations no virtualization is used within the cluster. The SOF cluster consists of a 5 node cluster with 136 cores interconnected with a 10Gb Ethernet.

A Linux derivate is used as operating system of all computing nodes. The Simulation Manager itself is implemented as collection of shell scripts on top of the operating system.

Figure 5 presents an overview to the interfaces, parts and steps which will be summarized as simulation management within the prototype implementation.
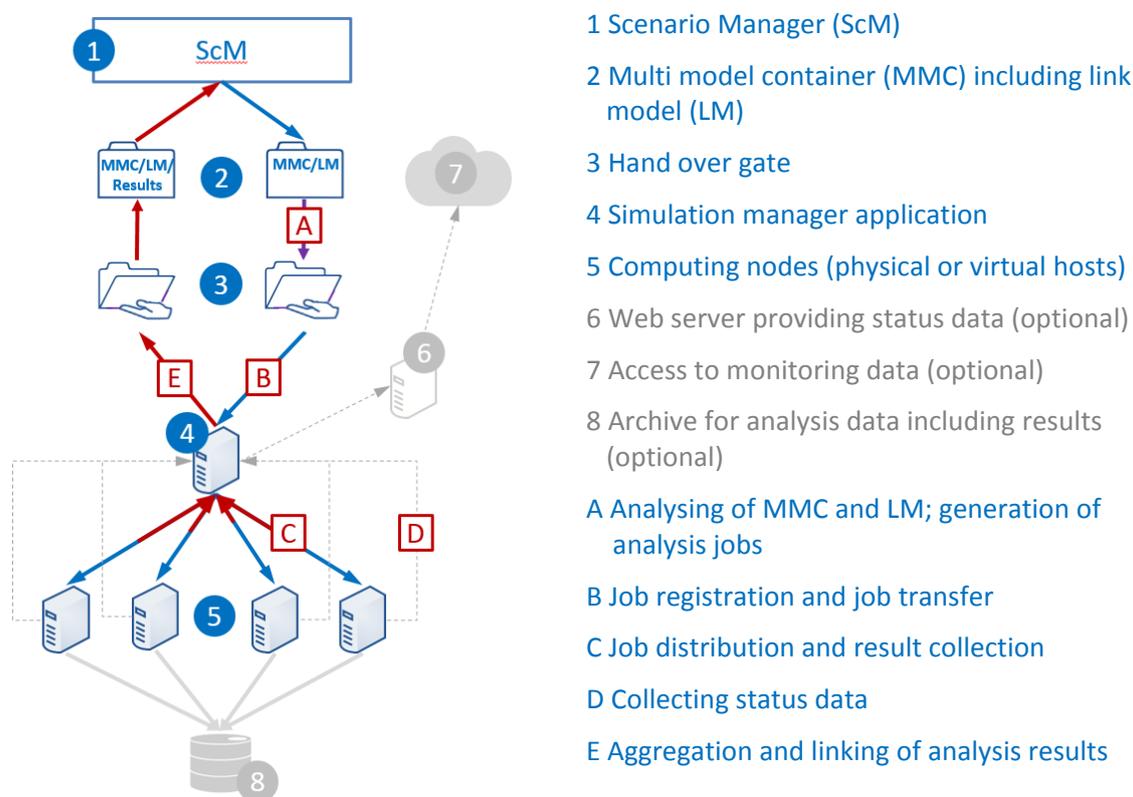

1 Scenario Manager (ScM)

2 Multi model container (MMC) including link model (LM)

3 Hand over gate

4 Simulation manager application

5 Computing nodes (physical or virtual hosts)

6 Web server providing status data (optional)

7 Access to monitoring data (optional)

8 Archive for analysis data including results (optional)

A Analysing of MMC and LM; generation of analysis jobs

B Job registration and job transfer

C Job distribution and result collection

D Collecting status data

E Aggregation and linking of analysis results

Figure 5: Overview of analysis processing infrastructure

Workflow Integration

The software of the Simulation Manager is integrated within and connected to the eeEmbedded workflow via the Scenario Manager, (1) in Figure 5. The ScM will deliver design data handled by the Multi Model Container (MMC) in conjunction with the Link Model (LM) approach (2).

Handling analysis inputs: Multi Model Container and Link Model

At the entry point of the design data into the sphere of the Simulation Manager (3) the input data inside the MMC will be analyzed, transformed and pre-processed into simulation jobs (A) containing the analysis model as well as additional information and templates if needed.

When the analysis covers more than one simulation job e.g. when processing stochastic analysis, multiple simulations jobs will be created.

Job delivery

Step (B) covers the transfer of the pre-processed simulation jobs to the central component of the Simulation Manager (4). These components deliver the simulation jobs to the computing clients (5). The deliverance of the jobs to the clients (C) is factoring in the load as well as the health of the clients by analyzing appropriate information processed and delivered by the clients (D) to the manager (4).

Results management

After finishing a simulation the results will be delivered from the client back to the manager component (C). Before this data transfer is initiated the raw results of a single simulation will be aggregated and post-processed into KPI's if needed. This post-processing step will be handled on the client side.

In case of multiple simulation jobs related to one single design model the Simulation Manager (4) collects all the aggregated and post-processed simulation results while keeping the relationships between the model objects and the processed results before transporting these results to the hand over point (3). Within the last step the results will be integrated into the MMC.

Monitoring capabilities

The Simulation Manager is also responsible for observing the behavior of each single simulation run. The simulation manager is able to kill and re-start each single job if a simulation stops because of internal model-depending reasons or in case of unexpected behavior of the host system of the computing client.

For monitoring purposes the Simulation Manager collects status information and health-related data from both: the hosts and simulation clients as well as the simulations itself. The monitoring data will be delivered as files via the hand over point (3) and – optionally – provided via web server (6) and web pages (7). In the same manner certain analysis results can be delivered as the web pages too.

Archiving capabilities - optional

The archiving of simulation jobs and related analysis results is optionally available too (8).

3.2 Input Management

The simulation manager keeps the relationship between the input data, the analysis model entities and the analysis results (see Figure 6 and Figure 7).

The transfer and mapping of the design model into the analysis model will be done by based on the interpretation and analysis of the data included in the Multi Model Container (MMC) and analysis of the Link Model (LM). The model mapping is described in D6.2; see (Heinzig, 2016).
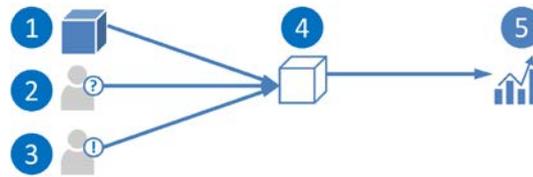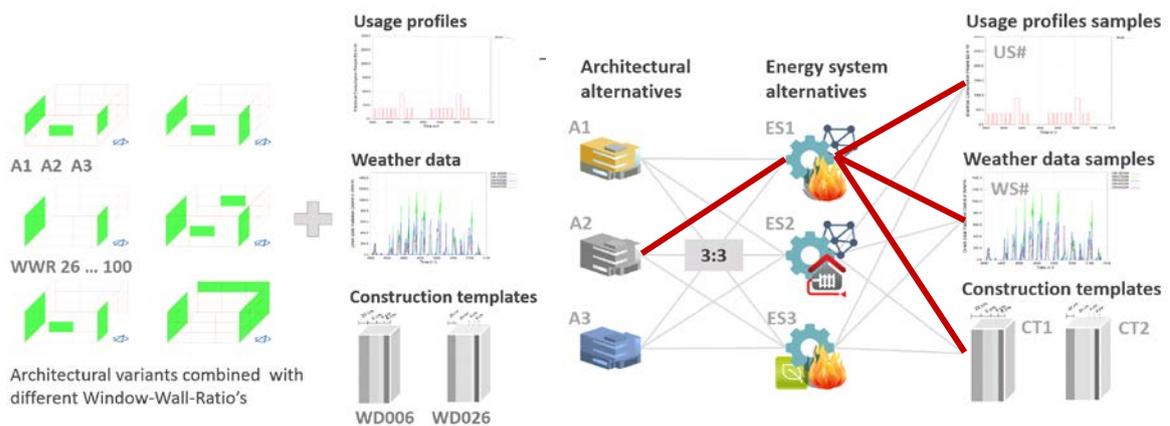

Figure 6: Relation between design entities (1), related questions (2) and requirements (3), analysis objects (4), and analysis results (5)

(a) Energy System Analysis

Weather data　　　　　　　　　　Architectural alternatives

Generation of analysis jobs example:

- **5** wind directions (W, SW, S, E, N)
- At least **3** reference wind velocities (2.7m/s, 4m/s, 8m/s)
- **15** simulations per variant -> **45** simulations per each alternative (for 3 alternatives and 3 variants per alternative)
- The simulations are assigned for execution on clients in the cloud.

(b) CFD analysis i.e. for Urban Design Purposes

Figure 7: Generation of several analysis jobs while combining several input data and templates for (a) Energy System Analysis (WWR – Window-Wall-Ratio; A1…3 – Architecture Models; WDxxx – Thermal Insulation; ES1…3 – Energy System; US# - Usage Profile Samples; WS# - Weather Data Samples; CT1…2 – Construction Template and (b) CFD wind analysis for urban design purposes (weather data, dominant wind directions and velocities as input conditions for each variant of the architectural alternatives)

The analysis of the simulation model will be processed using additional edge conditions and appropriate templates (a) for the Energy System Analysis at right hand side of the form presented in Figure 9 and (b) for the CFD analysis via a "Submit job" dialog in Figure 8b. All simulation parameter values are provided by the simulation manager but they may be modified according to specific user requirements.

Figure 8: Simulation manager example - simple example of alphanumeric building description and simulation parameters for Energy System analysis

Figure 9: Simulation manager example - simple example of alphanumeric building description and simulation parameters for CFD analysis

While generation of analysis jobs the consistent application of pre-defined naming convention and nomenclature of analysis job naming ensures the traceability of each sub-task within the analysis run.

3.3 Infrastructure Monitoring and Job Management

The following figures are containing certain selected aspects of the infrastructure monitoring and the job management which are delivered by the simulation manager as ASCII files.

```
Cluster 1 Status: Fr 16. Dez 18:37:49 CET 2016
24 Clients within the cluster
26 Clients available
10 Clients in use
16 Clients idle

11585 Number of processed simulations until now

Errors within host mtg16 hang over 61 min
```

Figure 10: Simulation manager example - Status of the computing environment

```
Start script:                  12. 12. 2016 11:17
Installed cores Kerne:         16
Idle cores:                    14
Storage usage real:            829 MB
Storage usage virtuell(max):   3520 MB
Disc space available:          179 GB
Simulation jobs waiting:       2
Simulation jobs processed:     4371

Simulation job currently running  ./wk/2_3_Lay_bruteS100_10kmaxV--20160725CEST153828...
Simulation time remaining         [wk-20160725CEST153828] (about) in h: 1.0

Simulation job currently running  ./wk/mit_mV100k--20160729CEST102835...
Simulation time remaining         [wk-20160729CEST102835] (about) in h: 1.0

SUMMARY
2   Simulation job currently running

0   Simulation jobs currently in preperation
2   Simulation jobs currently running
0   Simulation jobs successfull finished
0   Simulation jobs waiting with issues
```

Figure 11: Simulation manager example - Job statistic and prognosis for the duration of each analysis run

```
Statistic user: jens.kaiser
CALC_error:      ./40_DLY_OCCS000_test4-17--20161020CEST145201 START: 20. 10. 2016 14:52 END: 16. 12. 2016 18:34
CALC_ready:      ./20_HLD_1--20161017CEST181822                 START: 17. 10. 2016 18:18 END: 16. 12. 2016 18:34

First name:        Jens
Last name:         Kaiser
Jobs total:        2
Jobs aktiv:        0
Jobs finished:     1
Jobs with errors:  1
Jobs undefined:    0
```

Figure 12: Simulation manager example - user related statistic

Figure 13 presents an example for the web-based monitoring of the heartbeat of the analysis framework managed by the Simulation Manager.
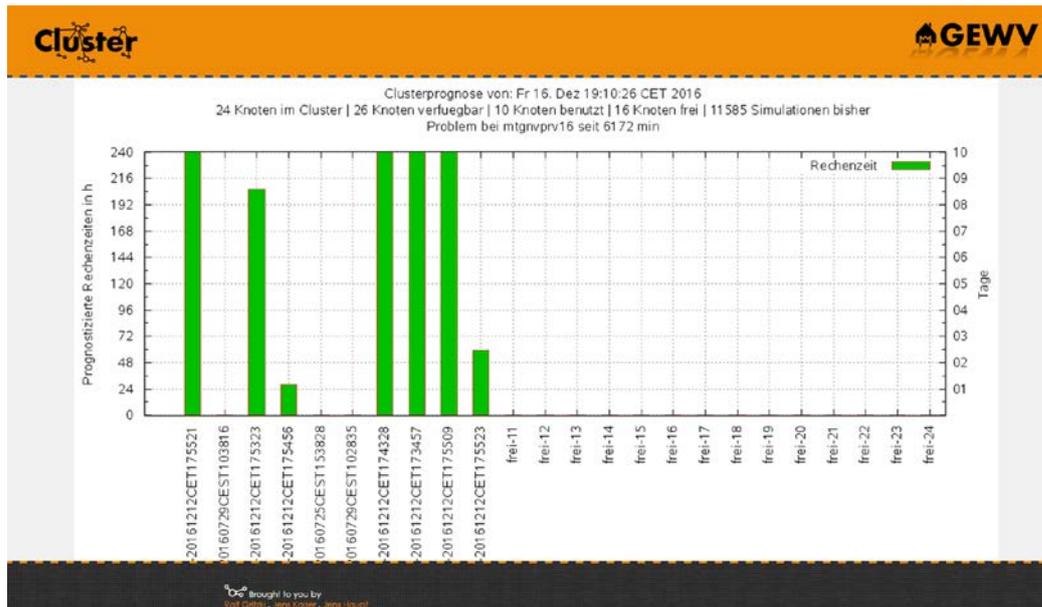
Figure 13: Simulation manager example - Web-based monitoring of simulation runs and the health of the computing nodes

3.4 Output Management

In the context of the eeEmbedded workflow the visualization of analysis results will be provided by two applications: (1) the decision supporting tool and (2) the Multi Model Navigator (MMNav). Selected results of each analysis will be accessible via a web-based framework for monitoring purposes only. As an example certain results and web-pages will be resented within the following figures (for the Energy System analysis in Figs13-18 and for the CFD analysis in Figs 19-20).
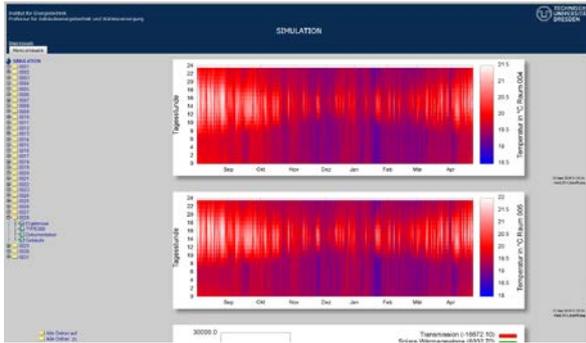
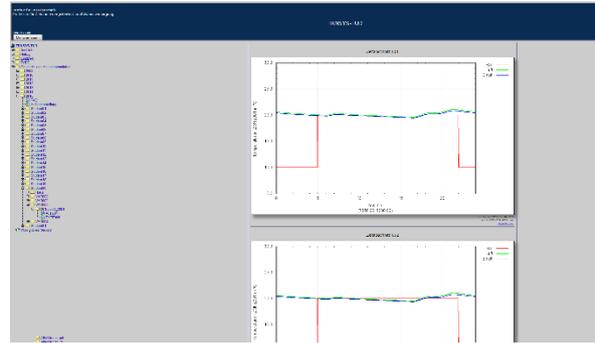*Figure 14: Thermal building simulation - example results – heat map*

Figure 15: Thermal building simulation - example results - space temperature

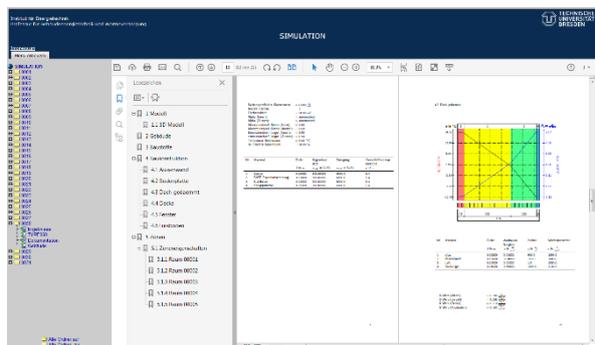*Figure 16: Example results - Energy consumption*

Figure 17: Automatic processed documentation of simulation parameter
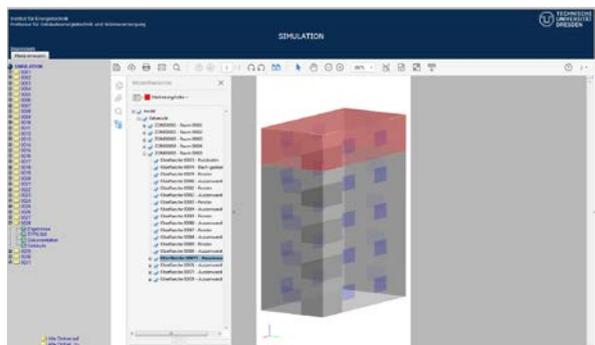

Figure 18: Example results

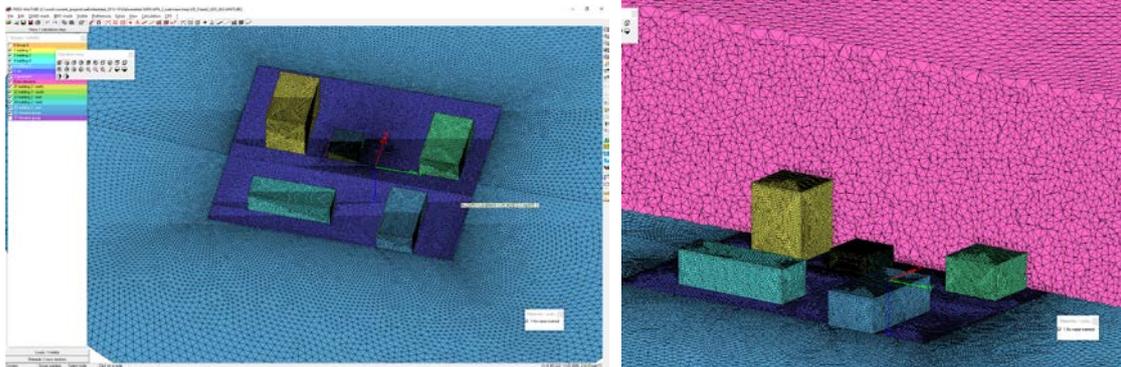*Figure 19: Model of the building geometry as a part of the processed documentation*

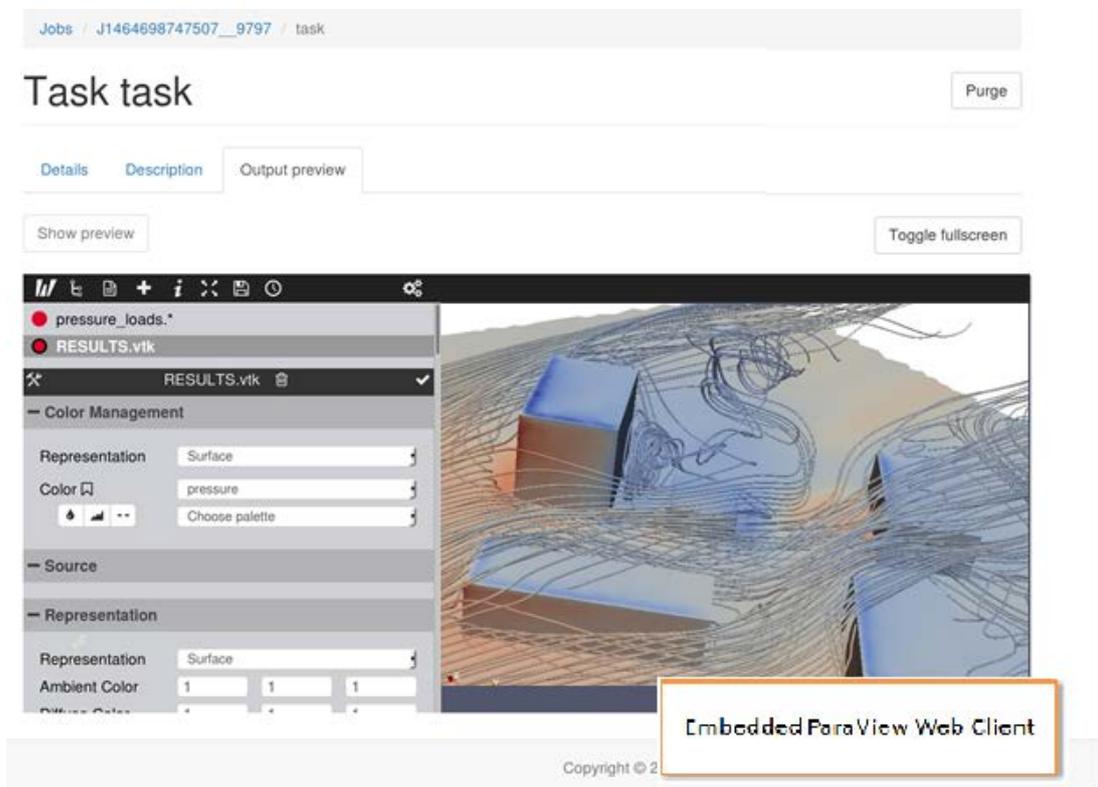*Figure 19: CFD model details*

Figure 20: CFD example results, mean field steam lines for one of the examined flow conditions

4 Conclusions

This deliverable summarizes the functionalities and the role of the simulation management services as a part of simulation and optimization framework which is used within all design phases in the context of the eeEmbedded project. The simulation manager assigns analysis and optimization simulations for efficient execution in the cloud. It enriches simulation data received from the simulation model generator (D6.2) with configuration run time parameters and additional edge conditions and appropriate templates in order to submit optimization simulations in the cloud.

It relies on the achievements of D6.1 and D6.2 and is based on the framework designed in the context of D1.5.

5 Reference

Baumgärtel K. & Guruz R. (2016); eeEmbedded Deliverable D8.3: Orchestration Manager © eeEmbedded Consortium, Brussels.

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Heinzig F., Katranuschkov P., Kadolsky M., Kaiser J., Protopsaltis B. (2016): eeEmbedded Deliverable D6.2: Multimodel mapper – Simulation model generator, © eeEmbedded Consortium, Brussels.

Protopsaltis B., Pappou T., Rekouniotis T. (2016); eeEmbedded Deliverable D6.1: Cloud-based simulation and optimization framework © eeEmbedded Consortium, Brussels.

Zellner, R., Guruz, R., Mosch, M., Katranuschkov, P., Tøn, A. & Kaiser, J. (2015): eeEmbedded Deliverable D1.5: System Architecture of the virtual holistic design lab and office © eeEmbedded Consortium, Brussels.