

BIM parametric modeller

Deliverable Report D2.2



Deliverable D2.2, issue date 31 August 2017

P2ENDURE

Plug-and-Play product and process innovation for Energy-efficient building deep renovation

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BIM parametric modeller

Deliverable Report D2.2

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Colophon

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Publishable executive summary

The P2Endure parametric Modeller offers the user the possibility to plan his/her renovation project before the actual start. By adding or removing product solutions that the user finds on the P2Endure e-Marketplace, the parameters of the existing *as is BIM* model can be changed. The products, which can be added by the user to their respective *as is BIM* model, are described by parameters. As a result, the user gets an overview of the thermal, energetic and financial values that can be expected for his renovation project with the selected products.

The P2Endure parametric modeller consists of several components, which are combined into one system. The respective subsystems operate as micro services and are interconnected via interfaces. Due to the decoupling of the respective services, the partial processes of the P2Endure parametric modeller are easy to maintain, scalable and expandable. This makes the parametric modeller a modern and flexible software service that allows the user, based on the data of the *as is BIM* model and the added e-Marketplace products, to predict energy performance and life-cycle cost.

This report explains the process sequence of the parametric modeller and the interaction of the individual components. The individual processes are presented with regard to the entire system and are explained by means of illustrations. The report also provides information on the current state of research of the parametric modeller as well as the activities, which are necessary for the further development of the modeller.

List of acronyms and abbreviations

BIM – Building Information Model

CSV – Comma Separated Values

IDF – Intermediate Data Format

IFC – Industry Foundation Classes

PnP – Plug and Play

HVAC – Heating, Ventilation, and Air Conditioning

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1. Introduction

The P2Endure e-Marketplace is a platform for supply-chain integration and with the functionality as an information platform. This e-Marketplace contains, as one of its core elements, the BIM parametric modeller. This modeller allows the user to calculate real energy use and energy costs for several years. It also allows a validation of reduced use of net primary energy, lowered embodied energy, reduced renovation cost and time, replicability and scalability of PnP prefab solutions, improved indoor environment quality and reduced disturbance for inhabitants during renovation. The aim is to provide the user with an overview of the impact of renovation products on the energy balance and development of their building.

The P2Endure parametric modeller consists of several components, which are combined into one system. The respective subsystems operate as micro services and are interconnected via interfaces. Due to the decoupling of the respective services, the partial processes of the P2Endure parametric modeller are easy to maintain, scalable and expandable.

The goal of this documentation is to present the current state of the work in the development of the parametric modeller. The main focus of the report is to look at the way in which the modeller work and how they work. The individual elements are explained in detail. These explanations are accompanied by a general, introductory presentation of the P2Endure e-Marketplace web front end with the integrated modeller as well as an evaluation of the results and the consideration of future work. The demonstration is structured as follows:

Section two provides an overview of the P2Endure parametric modeller inside the e-Marketplace. The individual components and their mode of operation are explained here. The second section also presents the workflow of the parametric modeller as a graphic. This workflow is used to explain the individual components, their interfaces and the interaction with the user. In the third chapter the individual elements of the BIM parametric modeller are considered. The individual components interlock and form a process. Section 3 examines the individual process steps of the parametric modeller in greater detail and shows the interaction of the respective components.

The starting point is a flowchart, which shows the entire process. In the fourth section, the existing research results are evaluated. A presentation of the system elements, in which the implementation was successful or caused difficulties, is given. In the fifth chapter, results so far are discussed. Based on this, proposals are made to further improve the system. Also, an outlook on the outstanding research points will be given. The report is closed in the sixth section by a conclusion.

2. Overview of the parametric modeller

The following section illustrates the process structure of the BIM parametric modeller inside the P2Endure e-Marketplace. The operation of the parametric modeller is explained by the sequence of the individual processes. Figure 1 shows the individual system processes as well as their interaction. The graphic also illustrates the interfaces with the user. The incoming arrows indicate information that is provided (upload as is the BIM model) or generated (add e-marketplace products) by the user. The arrows pointing to the "User" field indicate information provided by the system to the user (e.g.: Present the as is BIM in the front end).

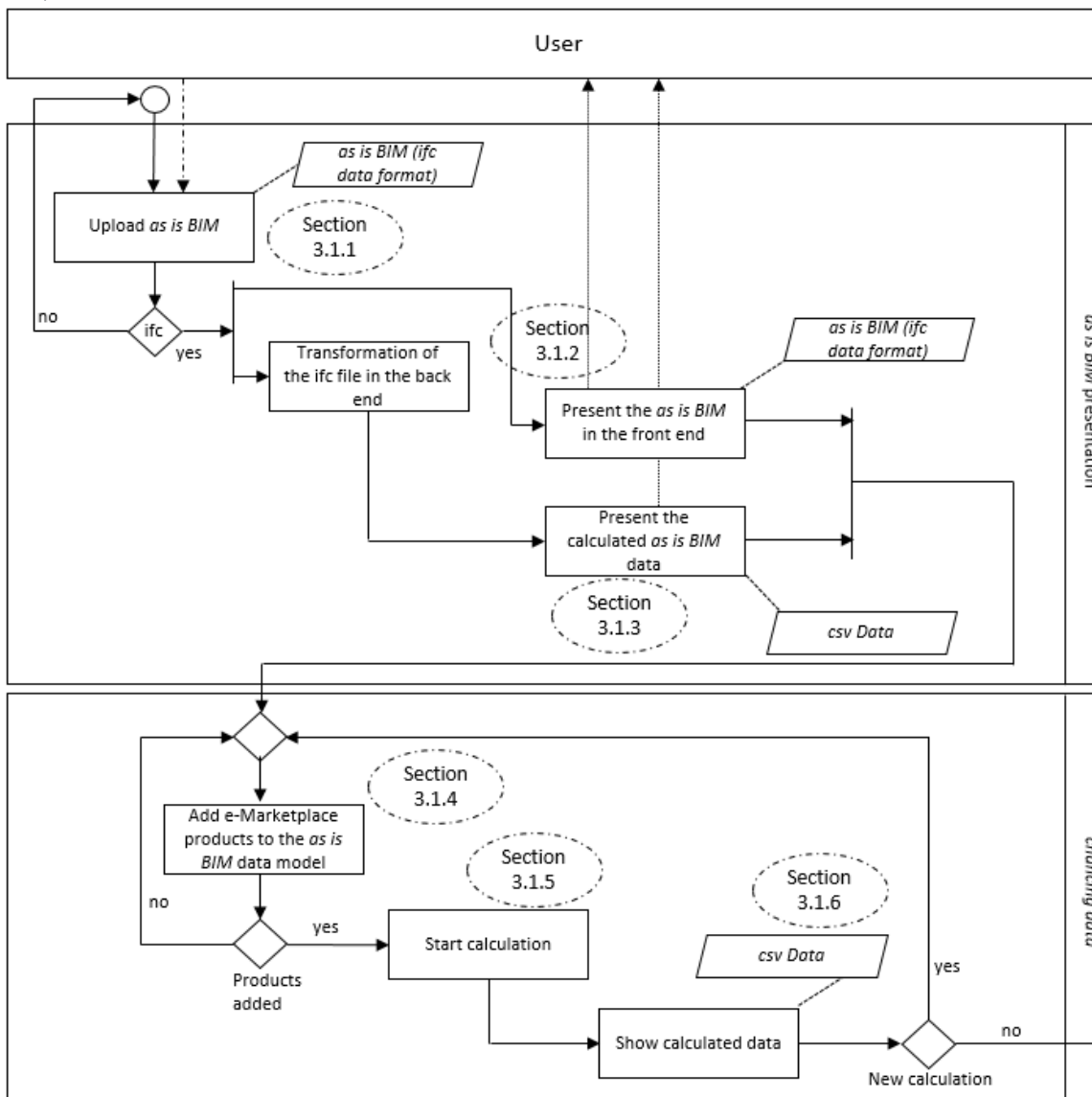


Figure 1: P2Endure e-Marketplace process structure

For the individual process elements, the data types are specified at the time of the respective process sequence (e.g.: as is BIM (IFC Data format)). These data types are explained during the report.

For reasons of clarity, the individual processes were divided into two process groups. The first group describes the *as is BIM* presentation. Within this group, the *as is BIM* is made available to the system by the P2Endure e-Marketplace user. This is followed by a transformation of the model data in the back-end of the system. The *as is BIM* is displayed in Industry Foundation Classes (IFC)¹ format in the front-end view of the e-Marketplaces and is visible to the user. The energetic and thermal data are extracted from the model and displayed in the front-end.

The second grouping is described by "changing data". Within these process steps, the user selects the products available on the P2Endure e-Marketplace and adds the *as is BIM* data. By adding these products, the calculation of the energetic and thermal in the back end can take place. The user can then view the result of this calculation in the front end.

In the following section, the individual steps are explained in more detail using illustrations and descriptions.

¹IFC data model is a format for describing building and construction industry data. IFC is platform neutral, open file format. IFC is common used collaboration file format for BIM (buildingSMART, 2017).

3. Explanation of the system using a sample scenario

The P2Endure parametric modeller consists of several components, which are combined into one system. The objective of the modeller inside the e-Marketplace is to give the user an overview of the possible thermal, energetic and the resulting cost savings. The output data of the *as is BIM*, which are provided by the user, are compared with the parameters of the respective P2Endure e-Marketplace products which were added to the output model.

The following chapter explains the individual components as well as the process for the calculation and presentation of the data.

3.1 Upload the as-is BIM

Figure 2 shows the process elements with the sub process "as is BIM presentation" as well as the interactions between the system and the user. These elements will be considered in these as well as in the coming sections 3.1.2 and 3.1.3.

The process begins by providing the *as is BIM* by the user.

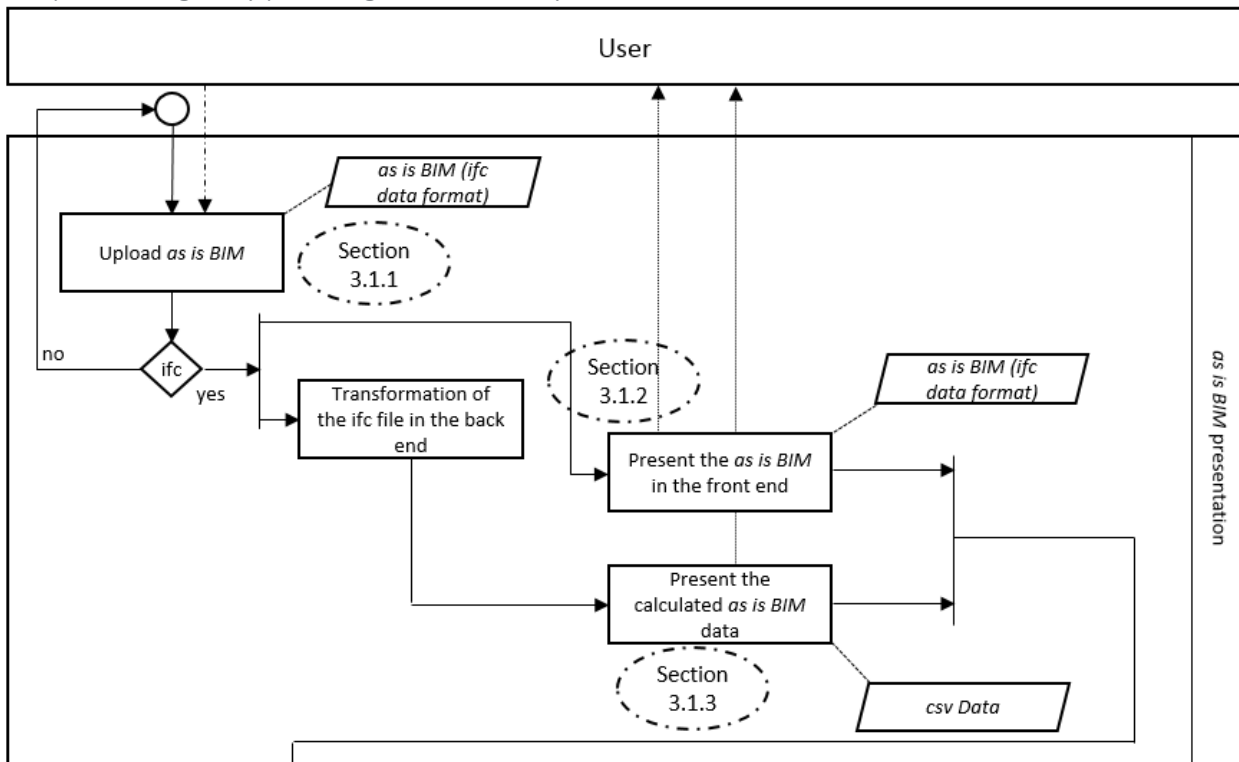


Figure 2: as is BIM presentation process

The user enters the home page of the P2Endure e-Marketplaces. Figure 3 shows the start page. The page is reduced to essential information and serves only to provide the upload of an IFC model. In the current structure of the P2Endure e-Marketplaces, this model must be available in an IFC data format. This IFC data model includes, in addition to geometric elements (walls, windows, floors, roofs), information about the HVAC or other electrical components.

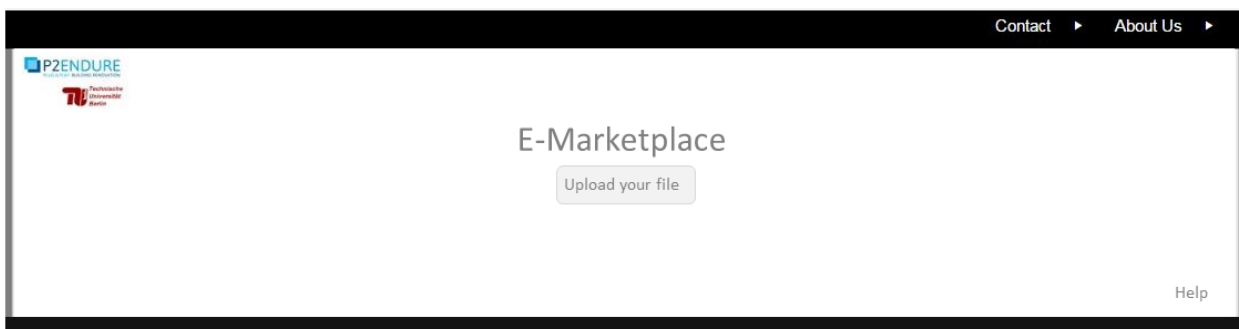


Figure 3: Landing page of the P2Endure e-Marketplace

After the user has selected his IFC model, the actual process and display area of the P2Endure e-Marketplace will appear in the next process step. Figure 4 illustrates this front-end representation.

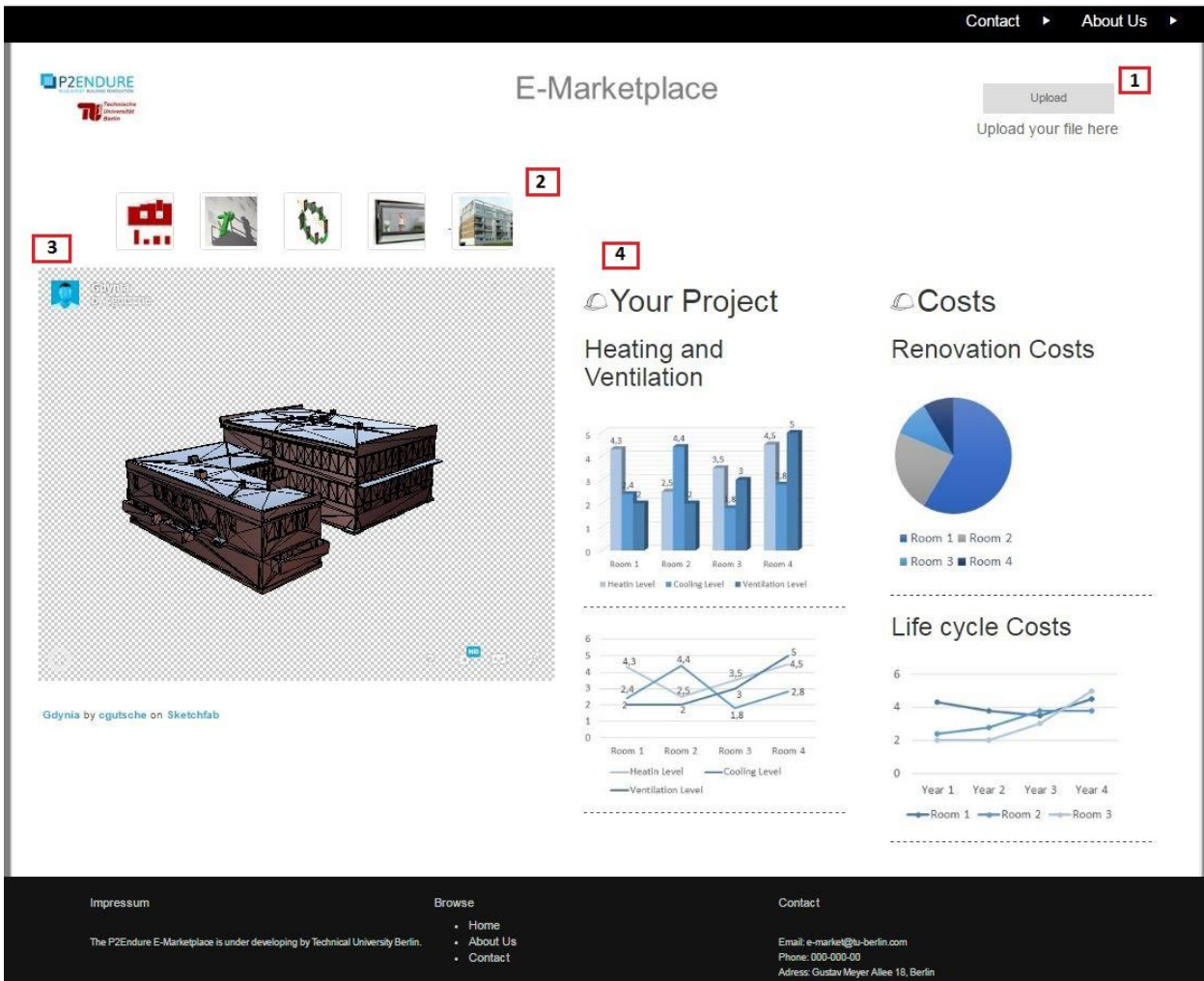


Figure 4: P2Endure front end

Within the front-end representation, four essential elements are recognizable.

- Upload new file
 - A new model can be uploaded by the user.
- Selection of the e-Marketplace products
 - The user can choose between the different products he wants to use for his renovation process.
 - The selection is required for the calculation of the data in the later process sequence.
- Presentation of IFC model
 - Presentation of the (as is) BIM of the user in the IFC format
- Presentation of the simulated performance data
 - Display of the simulated data. In the first process step (as is BIM presentation see Figure 1), the output data of the as is BIM model are displayed. After the product

has been added to the initial model and the calculation has been completed, the simulated performance values are displayed.

3.2 Presentation of the (as is) BIM model in the front end

After the *as is* BIM has been successfully loaded into the back end by the user via the front end of the P2Endure e-Marketplace the model is then presented to the user in the front-end. Figure 5 shows the *as is* BIM model in the front end.

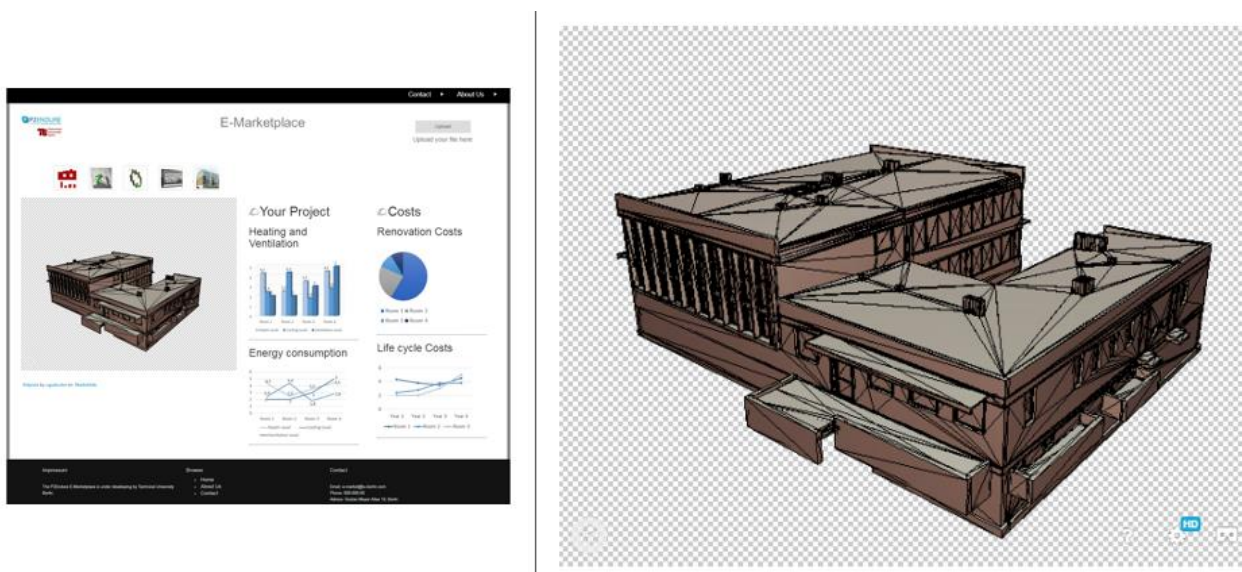


Figure 5: Presentation of the *as is* BIM model in the front end

The *as is* BIM contains physics as well as functional characteristics of the building. This model, provided by the user, serves as a starting point for the calculation of the energetic and thermal parameters. By adding the products available to the user on the P2Endure e-Marketplace, a recalculation is made by comparing the *as is* BIM data and the parameters added to the model (an explanation is given in section 3.1.4 and 3.1.5).

To represent the model in the front end, a transformation of the data format must take place. For this, the IFC data model must be converted into a JSON² format. The model is represented by three.js³. Via a three.js JSON loader, the JSON building information is then loaded and rendered in the front end⁴.

² JSON (JavaScript Object Notation) is a sleek data exchange format that is easy to read and write for people and easy to parse (machine data structures) for machines. It is based on a subset of JavaScript. (Marrs, 2017, S. 6 f.)

³ Three.js is a JavaScript-based library class for the representation of three-dimensional models (Dirksen, 2015, S. 8)

3.2.1 Presentation of the diagrams in the front end

In the *as is BIM* presentation sub process (see Figure 2), the thermal and energetic values of the model are presented alongside the *as is BIM* model. These values are based on a calculation of the *as is BIM* data and thus reflect the output values of the model. These initial values are used for later calculations, with additional use of data from the selected product data. Figure 6 shows the representation of these simulated output data.

The diagrams show the current thermal and energetic costs based on the components which are part of the *as is BIM*. An analysis of the energy costs can also be made using this initial data.

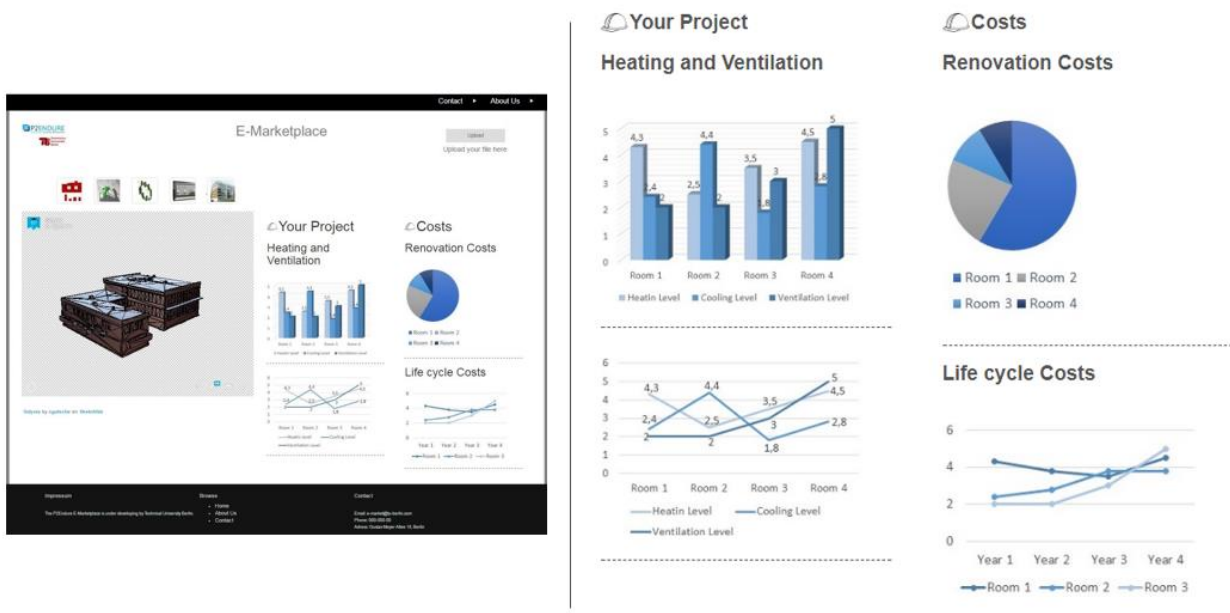


Figure 6: Presentation of the thermal and energetic data of the *as is BIM* model

The diagrams are displayed with the JavaScript library d3.js⁵. This library is well suited for the representation of three-dimensional data structures and models. The JavaScript library used has an interface for reading data records of the formats JavaScript Object Notation (JSON) as well as Comma Separated Values (csv)⁶. Thus, two widely used formats are used to describe database tables or to transfer data between (web) applications.

⁴ In the appendix, there is an example of the previous source code for loading and mapping the *as is BIM* model via three.js

⁵ D3.js is a JavaScript library for dynamic, interactive data visualisation (Amr & Stamboliyska, 2016, S. 6)

⁶ CSV files stores tabular data (numbers and text) in plain text. Each line of the file is a data record. Each record consists of one or more fields, separated by commas. CSV is often used to exchange data between differently similar applications.(BigCommerce, 2017)

3.2.2 Add the parametrically described Products to the as is BIM model

Figure 7 shows the process elements with the sub process "changing data". These elements will be considered in these as well as in the coming Sections 3.1.5 and 3.1.6.

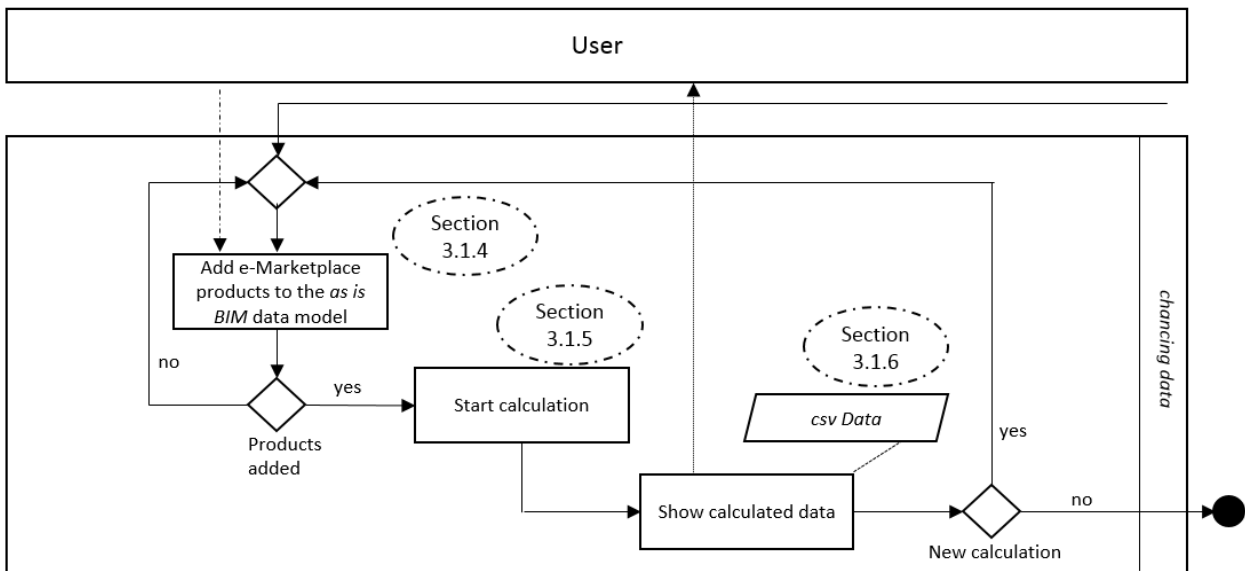


Figure 7: Second process part of the parametric modeller: changing data

The actual core of the P2Endure e-Marketplaces is the parametric modeller. This analyses the energetic and-thermal values of the output model and the values of the products which the user has selected and makes an analysis of the data.

On the P2Endure e-Marketplace the user can find products which he can add to the existing *as is BIM* model for his renovation project. By selecting the products, a calculation can be started which compares the values of the original model with the added parameters of the products. The information resulting from the calculation helps the user in the estimation of the thermal, energetic and financial properties and / or developments of his renovation project. Figure 8 shows the products that can be added to the model data. In the right part of the image, the products are displayed which the user has selected for its renovation projects (e.g.: On-side 3D printing).

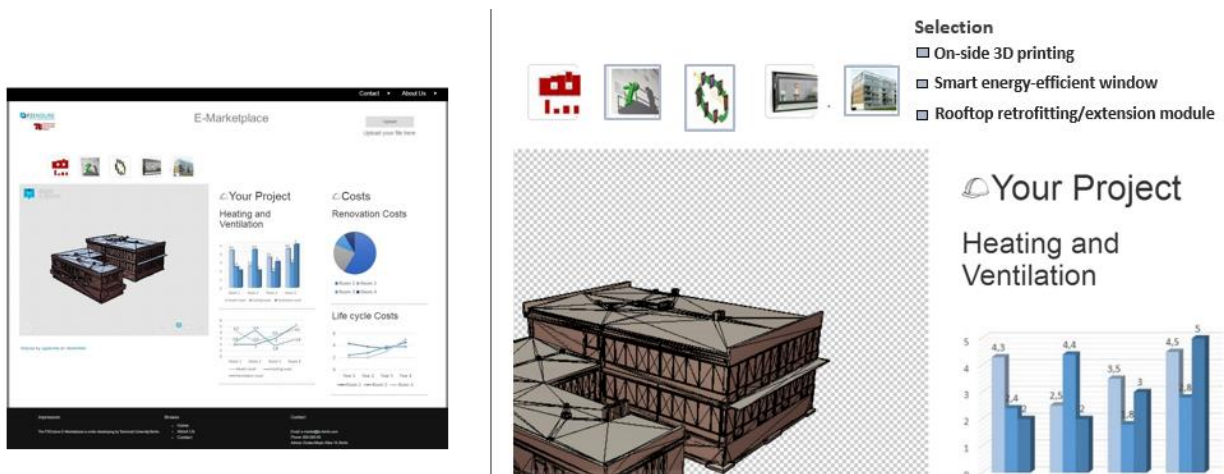


Figure 8: Selection of P2Endure e-Marketplace products

Calculation is also possible with just one added product. Depending on which products were selected, the values of the calculation change.

For the calculation to be made, the products must be described as detailed as possible by the respective manufacturers. Table 1 and table 2 are used as an example for describing the products. Within these tables windows (of the P2Endure partner BGTech) as well as panels (EASEE) are described.

These parameters must be described by the manufacturers. The TU Berlin has developed a UML diagram for the orientation of the product description in which the necessary attributes of the respective product group can be found. Such a product description is necessary since no calculation can take place without this. The parameterized description of the data is stored in a product catalog. The data is in a .csv data format. These data are loaded from the back end via an interface. The interface is created as a jsx⁷ file. The parameters of the products are integrated into the IDF model of the as is BIM by means of an interface. By integrating these values, a calculation can be made between the "old" as is BIM model parameters and the new model (with added e-Marketplace products).

Table 1: Value for the calculation (BGTech window)

	Light		Solar radiant heat				Glazing u-Value	Window u-Value
	transmittance	reflectance	Direct transmittance	Reflectance	Absorptance	g-value (total transmittance)		
Suncool 50/52								

⁷ JSX is statically typed, object oriented programming language for web browser (DeNA, 2013).

double glazing								
summer mode	50	18	24	33	43	27	1,0	1,3
Triple glazing								
summer mode	45	20	22	33	45	24	0,7	1,0
Optitherm S1								
double glazing								
summer mode	70	21	41	41	18	45	1,0	1,3
triple glazing								
summer mode	56	31	30	48	22	32	0,7	1,0

Table 2: Value for calculation (EASEE panel)

Name	TRC Layer	EPS250	TRC Layer
Thickness (cm)	1,4	10	1,4
Conductivity (W/mk)	2	0,034	2
Emissivity	0,9	0,9	0,9
Volumetric mass (kg/m ³)	2400	28	2400
Specific heat (J/ kgK)	1000	1400	1000
Breathability μ	130	130	130

The product catalogue, which is located on the front-end view of the P2Endure e-Marketplaces, serves the user to plan his renovation intentions. To date, only products from the P2Endure project have been implemented. In the final e-Marketplace, all suppliers providing products for the renovation of buildings can offer them on the online marketplace. As a basis for the energetic, thermal and financial calculation, the user can then choose between the various products and read their effects on the planned renovation project based on the simulated data.

3.2.3 Configuration of the (as is BIM) data file for the energetic, thermal and financial calculation

The BIM model provided under the first process step must be processed for further processing of the data. The EnergyPlus software is used to calculate the data. This software requires an Intermediate Data Format (IDF)⁸ format to evaluate the data. In the ideal case, a consistent exchange of information must ideally implement seamless communication under various software, making manual and repeated data input unnecessary.

The *as is BIM* model data, provided by the user, are in an IFC data format. For a calculation of the data, a transformation into the IDF data format must be carried out. The aim of these microservices is to integrate a transformation concept which converts the geometry of the building in such a way that the EnergyPlus⁹ calculation software can read and evaluate the data. These transformed, geometric building data contain the information of the building material as defined in the original data.

However, EnergyPlus cannot process the complex building structure. Therefore, data must be simplified during transformation. The data transforming concept of the TU Berlin therefore initially presents walls, windows, façades and zones. With the successful conversion of the data formats the calculation of the energetic data based on the building information, can be initiated.

Figure 9 shows the process of transformation. The flowcharts "as is BIM presentation" and "changing data" are inserted above and below this process representation. They are intended to illustrate the transformation of the data in relation to the parametric model process sequence.

The starting point is the *as is BIM* model in the IFC data format. The IFC model is converted into an IDF data format by a data transformation which takes place in the back-end. This IDF format is read by the software EnergyPlus. Based on these data the thermal and energetic calculation is carried out. The generated calculation data are transferred to the front end as JSON or CSV data and are displayed graphically using d3.js. After the users has added products from the P2Endure e-Marketplace to their renovation project, the data transformation proceeds in the same way. The data are converted into an IDF format and are thus available to the calculation software. In addition to the data of the existing system, the software now also calculates the parameters of the products. The results are passed to the front-end. This process of calculation is possible both for the acquisition of one product as well as for several products.

⁸ The IDF data format is originally used for exchanging data between electrical and mechanical CAD/CAE systems for use in 3D design (Kehmeier, 1996, S. 1).

⁹ EnergyPlus is a building energy simulation program for calculating energy consumption (heating, cooling, ventilation, lighting) and water use in buildings (EnergyPlus, 2017).

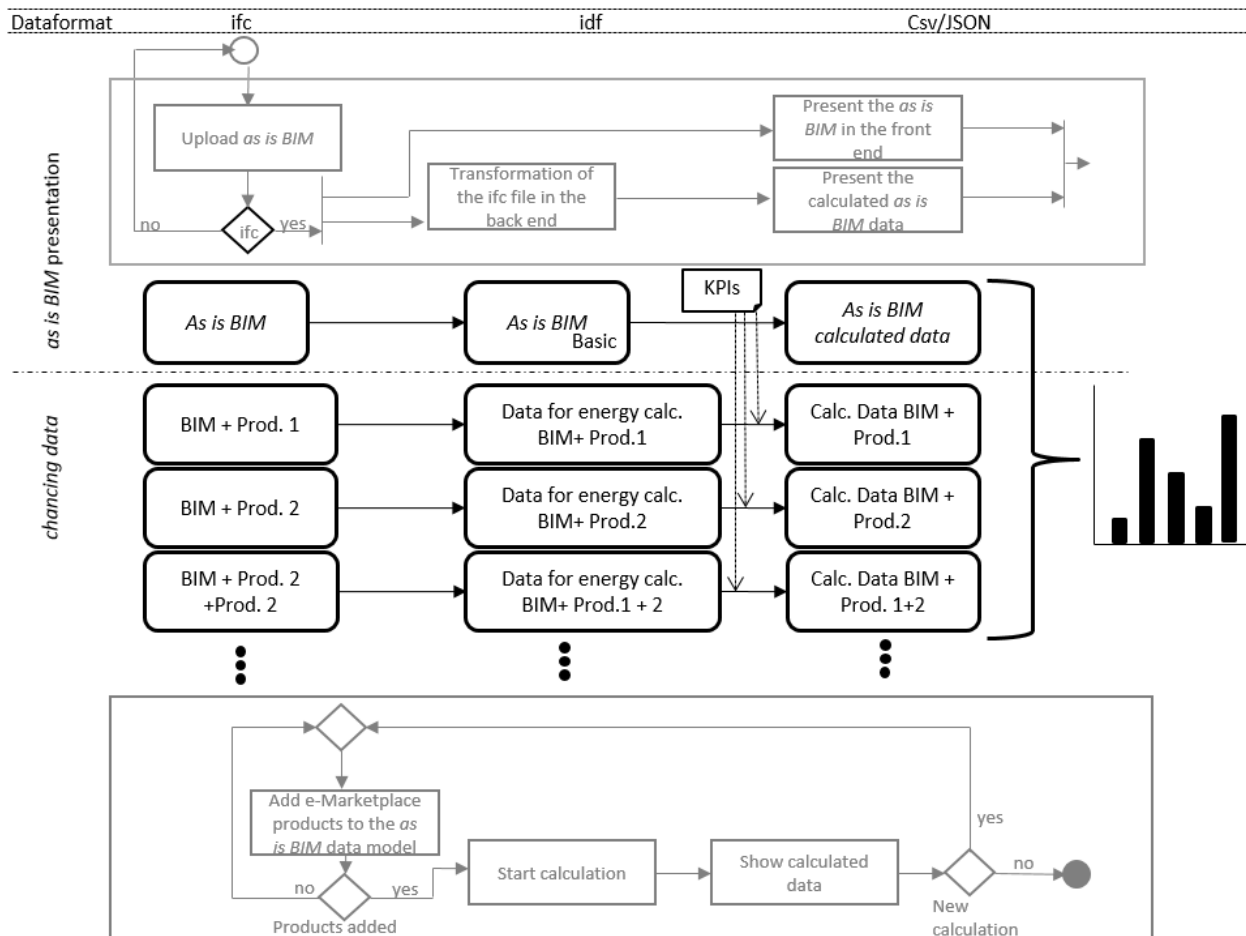


Figure 9: Structure of the data transformation

Figure 10 shows the IDF structure of a window. The window, which is in the *as is BIM* output model, can be seen. In the upper part of the figure, the thermal parameters of the window can be seen from the initial *as is BIM* model. The lower part of the figure describes the new values of the window. After the user has selected windows on the front end of the e-Marketplaces, the changes are transferred to the IDF data. Figure 10 shows the comparison between the old and new window parameters. The calculation is based on the new data. The results of the interim result are stored. This allows an analysis between the old and the new values.

<u>Window data from as is BIM dataset</u>	
windowMaterial:Glazing,	!- Name
LOE CLEAR 6MM,	!- Optical Data Type
SpectralAverage,	!- Window Glass Spectral Data Set Name
,	!- Thickness {m}
0.006,	!- Solar Transmittance at Normal Incidence
0.600,	!- Front Side Solar Reflectance at Normal Incidence
0.170,	!- Back Side solar Reflectance at Normal Incidence
0.220,	!- Visible Transmittance at Normal Incidence
0.840,	!- Infrared Transmittance at Normal Incidence
0.0;	

<u>New window data of a P2Endure e-Marketplace product</u>	
windowMaterial:Glazing,	!- Name
Suncool 50/25,	!- Optical Data Type
SpectralAverage,	!- Window Glass Spectral Data Set Name
,	!- Thickness {m}
0.006,	!- Solar Transmittance at Normal Incidence
0.240,	!- Front Side Solar Reflectance at Normal Incidence
0.180,	!- Back Side solar Reflectance at Normal Incidence
0.330,	!- Visible Transmittance at Normal Incidence
0.500,	!- Infrared Transmittance at Normal Incidence
0.0;	

Figure 10: adding new parameters to the existing model

3.2.4 Display the simulated data with d3.js

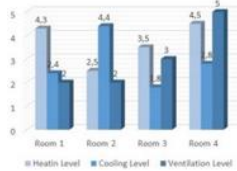
In the first process step, the configurator only showed an assessment of the current energy behaviour of the *as is BIM*. In this process step, these calculation data reflect a comparison between the output values (from the BIM) and the added product data. Therefore, this process step is listed separately.

After the geometrical data and the calculated information have been transferred to the front end, it can be displayed to the user. Figure 11 shows the data representation. Based on these data, the user can obtain information about the thermal (e.g. temperature budget, Co2 balance), energy (e.g. annual energy savings) as well as financial values (e.g. monthly / year cost savings) of his renovation project. By adding or removing the P2Endure e-Marketplace products to the *as is BIM* Model, the user can get an overview of the resulting values and thus assess the influence of the individual products on his project. The values from the output model are always displayed in comparison to the new calculation values with the e-Marketplace products.

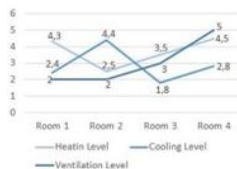
Calculated data out of the as is BIM model

Your Project

Heating and Ventilation



Energy consumption

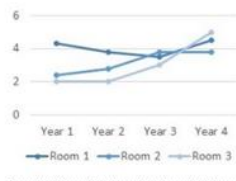


Costs

Renovation Costs



Life cycle Costs



Calculated data (as is BIM and e-Marketplace products)

Your Project

Heating and Ventilation



Energy saving/month



Costs

Renovation Costs



Life cycle Costs

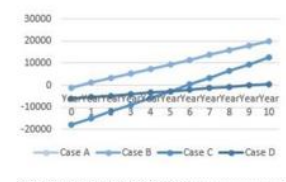


Figure 11: Representation of the simulated data using d3.js

4. Evaluation of the current results

The results so far provide a very good basis for further research work at the TU Berlin in the BIM parametric modeller. It has been shown that a system can be created with the help of a well-thought-out process sequence and incorporating various micro services e-Marketplaces. The parametric modeller can create a data calculation based on parameters, which allows the user a detailed representation of the values of his renovation project. For the system to have the best possible performance and to be scalable, lean data formats are used to transmit the information. The individual micro services (such as the representation of the simulated data using d3.js) are designed in such a way that they are easily expandable. Thus, new parameters in the data transmission can be easily reacted.

The Configurator can directly influence user decision-making. Through the parametric modeller, the users can

- analyse the energy-related comparisons,
- analyse the resulting costs and
- select different products

thus optimally utilizing their budget for the renovation process.

To illustrate the influence, two examples are given. The P2Endure Demo cases from Warsaw and Tilburg are used for this purpose. The energy-thermal calculation of the data should be illustrated once again¹⁰.

Table 3 shows examples of the products added to the demo cases.

Table 3: Example: Selection of products for three demo cases (selection is for illustrative purposes only)

	EASEE Panel	Smart Window	Rooftop retrofitting	PnP HVAC	3D printing
Warsaw	X	X			X
Tilburg		X	X	X	

In these projects, the products marked with an X from the P2Endure e-Marketplace are to be added as an example.

¹⁰ The P2Endure demo case from Gydnia has already been used in chapter 3.1 to illustrate the operation of the parametric modeling



Figure 12: Demo Case Warsaw

Figure 12 shows the P2Endure project from Warsaw. The products "EASEE Panel", "Smart Window" and "3D Printing" were added to the as is BIM model.

Calculated data out of the as is BIM model



Calculated data (as is BIM and e-Marketplace products)



Figure 13: Simulated data (demo case Warsaw)

Figure 13 shows the simulated performance. On the left side, the figure shows the output data of the as is BIM model from Warsaw. After the products are added, a re-calculation is performed. Figure 13 shows the newly simulated performance data on the right side.

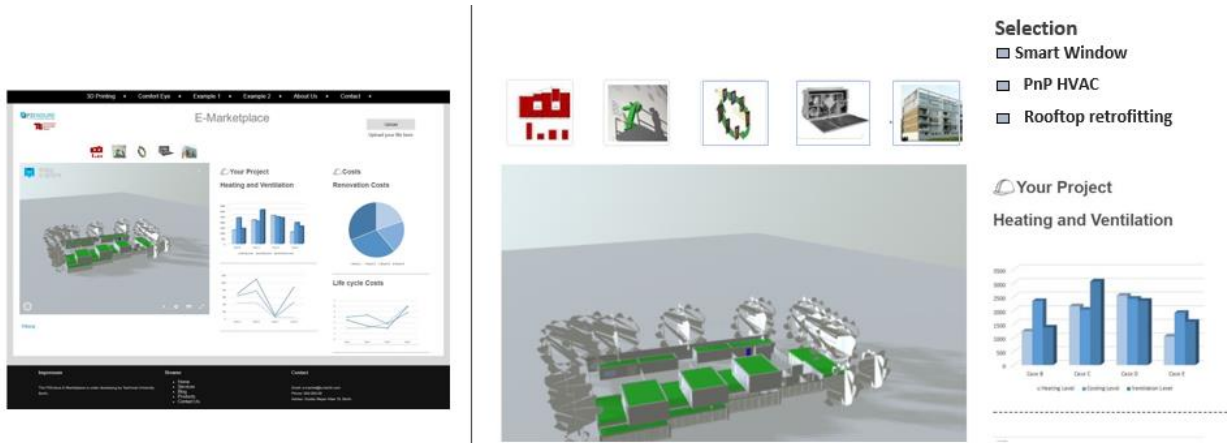


Figure 14: Demo case Tilburg

Figure 14 shows the example of the P2Endure project from Tilburg. The products "PnP HVAC", "Smart Window" and "Rooftop retrofitting" were added to the *as is* BIM model.

Calculated data out of the *as is* BIM model



Calculated data (as is BIM and e-Marketplace products)

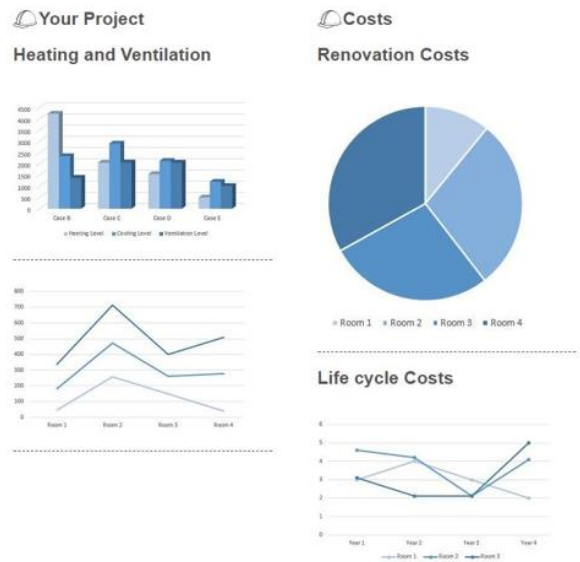


Figure 15: Simulated data (demo case Tilburg)

The left side of Figure 15 shows the initial data of the *as is* BIM model from Tilburg. After the product data has been added, the data are resimulated. This is shown on the right side of the figure.

5. Discussion and further research work

The P2Endure parametric Modeller offers the user the possibility to plan his/her renovation project by adding product solutions before the actual start with regard to the energetic, thermal and financial parameters. The products, which can be added by the user to their respective *as is* BIM model, are described by parameters and stored centrally in a product catalog. To describe the products, the respective providers must provide the minimum requirements for product information. These requirements were designed by the TU Berlin in the form of a UML diagram and serve as a guideline. In the course of the project, however, these guidelines will be repeatedly questioned, checked for consistency and, if necessary, supplemented or removed. With the help of the P2Endure partners iteratively an optimal amount of information to the respective product groups is found.

The results obtained so far from the P2Endure parametric modeller form the basis for further research activities. With the results so far, the TU Berlin has created a stable, scalable and high-performance framework. The further research work will include:

- Dynamic import and analysis of data
 - In the representation of the simulated data by d3.js.,
 - in the data transformation of IFC to IDF as well as,
 - in the transformation of IDF into CSV or JSON.
- In addition, the implementation of the P2Endure e-Marketplace is to be expanded in such a way that the integration of different products by providers becomes possible. For this purpose extensive test data are created, which can be used for simulation and testing.

Likewise, the front end is examined for errors in usability and, if necessary, improved. The back-end system is subjected to a performance test and checked for good scalability. All components used are subject to a good maintainability or good support.

The announcement in deliverables 2.2 (a prototypical configurator, which allows the configuration of the data of all test cases using Autodesk software) requires two changes to be added.

In contrast to the suggestions in the initial proposal text, we decided against the implementation of the Autodesk Dynamo software. This is mainly because the P2Endure consortium decided to use Open BIM standards and software throughout the project. The Autodesk software is only usable under license and therefore not open source. Thus, the broad and simple integration and provision of the parametric modeling cannot be guaranteed. The TU Berlin has therefore decided to develop the parametric modeller from a combination of web-based applications and the software EnergiePlus.

The advantage of this choice is the development of a stable, scalable open source application. This allows the development and adaptation of the individual software elements without restriction. The future integration and application of the software solution is also possible for the users without restrictions.

Unfortunately, at time of writing this report we were not able to show the functioning of the existing prototypical configurator on all P2Endure Demo cases. The reason for this is the lack of energetic building data. However, these data form the basis for the representation of a calculation. Therefore, test data are currently being used to control the operation of the parametric modelling. However, these test data already give an impression of the functioning of the existing prototype.

6. Conclusions

The P2 Endure parametric modeller offers the user the opportunity to create energetic, thermal and financial calculations. The respective micro-services form a consistent, scalable and well-maintainable system.

The starting point of the calculation is the *as is BIM* model, which is provided by the user. The user can add products, which are on the P2Endure e-Marketplace, to this model. By comparing the "old" *as is BIM* model parameters and the new added product parameters, a calculation can be generated in the back end. This calculation takes the thermal and energetic values as the starting point and thus generates information, which provides the user in the front end as diagrams about the expected values. Based on the thermal and energetic data, financial expectations are also provided to the user.

With the development of the P2Endure parametric modeller, TU Berlin has laid a foundation for further research. The system and its components and the interfaces between the components have already been defined. The basic operation of the individual components has already been worked out.

The individual micro services of the system are further refined for future research activities.

Research requirements include the conversion of IFC to IDF as well as the dynamic transfer of the product data into existing IDF model data.

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Appendix 1 - Calculation

A simulation scenario is presented in Tables 3 and 4. The following elements with the respective parameters are considered:

- Window:
 - Single pane and double pane
- Building façade
 - Thermal resistance: 2.29 and 3.29 m² k/W
- Rooftop
 - Thermal resistance: 5.45 and 6.45 m² k/W

Eight different scenarios are included in the calculation. Table 3 shows these simulation cases. These scenarios simulate the possibilities that the user has when selecting their products on the P2Endure e-Marketplace. Depending on the choice he makes, other parameters are used in the simulation of energetic, thermal and financial analysis. Table 4 describes the results of the calculation. These results consider the parameters of the respective cases and generate a monthly analysis of the energy consumption. The individual cases are combined in the diagram. The diagram shows the monthly energy consumption using the various product parameters the user has added to the *as is BIM*.

Table 4: Simulation cases

Simulation cases	Window	Building Facade	Rooftop
Case A	Single Pane	2,29	5,45
Case B	Double Pane	2,29	5,45
Case C	Single Pane	3,29	5,45
Case D	Single Pane	2,29	6,45
Case E	Single Pane	3,29	6,45
Case F	Double Pane	2,29	6,45
Case G	Double Pane	3,29	5,45
Case H	Double Pane	3,29	6,45



Table 5: Simulated performance data of the different cases

	Case A	Case B	Case C	Case D	Case E	Case F	Case G	Case H
Jan	3647,563407	3231,189501	3150,843597	3541,414525	3042,458325	3122,645403	2709,494121	2598,458001
Feb	3538,959233	3343,12008	3023,984751	3428,489287	2911,235578	3230,818614	2806,210875	2691,341381
Mar	2428,100185	2373,432537	2058,202471	2350,062224	1978,431203	2294,466217	1989,498334	1908,511883
Apr	1245,39811	1457,814298	1013,891208	1198,570585	967,0190641	1411,77978	1219,79861	1172,994201
Ma y	513,9509294	620,1515808	406,167331	490,0621625	385,8065143	599,2140086	510,6081729	489,710898
Jun	137,2898918	238,5926423	95,65689663	129,1139671	89,79334857	231,2261456	189,8550733	182,6001937
Jul	68,84333946	130,3497021	43,17650989	64,28297612	38,0810521	126,1587684	102,5972548	98,31179551
Aug	68,43405991	130,1378063	42,47960685	62,02758801	37,67815417	123,5374537	97,24083528	90,93743723
Sep	410,9965432	626,0752555	309,9115145	386,4351605	285,2522039	601,5665155	521,4048813	496,5326743
Oct	1422,304634	1524,773344	1185,873855	1367,780533	1130,678771	1470,233507	1283,916437	1228,023251
Nov	2826,387099	2690,045667	2412,95671	2734,707117	2319,285212	2596,78013	2259,634641	2164,170719
Dec	3589,913554	3159,13961	3104,788895	3486,483553	2999,141742	3053,364813	2649,414109	2541,169322

Based on these different values, for example, the energy consumption of the respective scenarios can be presented. Figure 12 shows this.

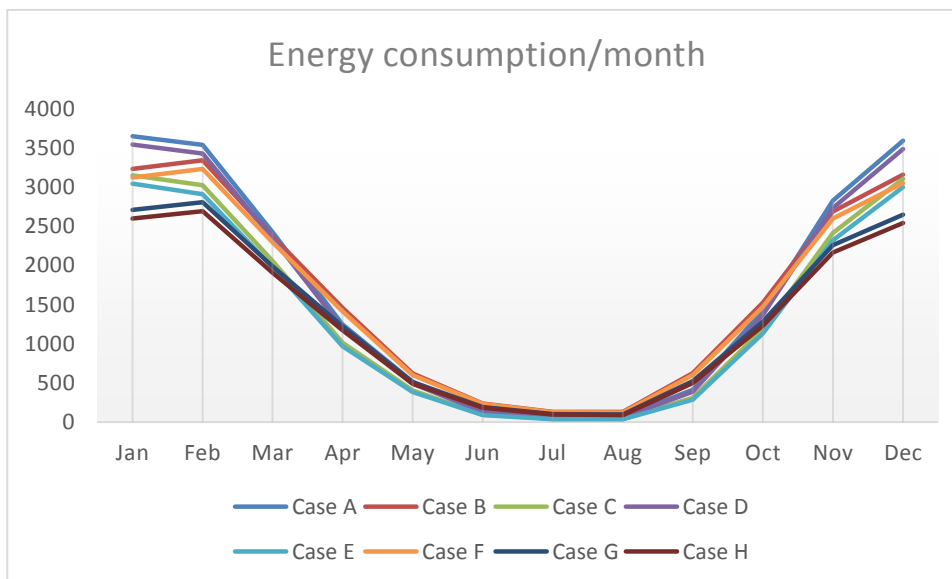


Figure 16: Energy consumption of the different cases

