Deliverable D 4.9

Concise report on performance prototype

Concise report on performance prototype + Concluding reflection on the governance of retrofitting and the use of the ECODISTR-ICT tool: part A
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<th><strong>PROJECT DATA</strong></th>
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<td><strong>Project Full Title</strong></td>
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<td><strong>Website</strong></td>
<td><a href="http://www.ecodistr-ict.eu">www.ecodistr-ict.eu</a></td>
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This document describes the content of the second prototype of the Integrated Decision Support System (IDSS) developed as part of the ECODISTR-ICT project. It concludes with a discussion on the technical performance, relating the resulting system to the technical requirements defined at the beginning of the project.

This document focuses on the core components of the prototype of the IDSS. It further provides the links to the software, the instructions to future developers, the wiki for end-users, and related documents.
EXECUTIVE SUMMARY

The objective of the ECODISTR-ICT project is to develop an Integrated Decision Support System (IDSS) for sustainable retrofitting of urban districts with a focus on energy efficiency and to test this IDSS in real life case studies.

Version 2.0 of the prototype of this IDSS is Deliverable D4.8 of the ECODISTR-ICT project. Development of the IDSS was a joint effort of the participants involved in WP2 Methods for Data Collection, WP3 Support Modules and WP4 Integrated Decision Support System. The IDSS supports the typical steps in a multi-stakeholder decision process for district renovation (D4.1), which resulted from the preliminary studies in WP1 Stakeholders & Scenarios. The IDSS development has been a continuous process of incremental improvement using a scrum-based approach in which we involved the participants of WP5 Case Studies intensively.

This document is the final deliverable of WP4 Integrated Decision Support System and briefly describes the core components of the prototype of the IDSS, concludes on its performance and provides the links to the software, the instruction to future developers, the wiki for end-users, and related documents.

The system architecture of the IDSS has been developed in the Functional and Technical Design of the IDSS (D4.1 and D4.234). The main components are:

- The Dashboard, for the process facilitator to manage the flow of the decision process;
- The Framework using the IMB Communication Hub, the backbone connecting the components into one system;
- The Data storage and data collection functionality to store and manage the data of the As-Is situation in the district and the Alternatives;
- The Design and Visualisation Module to develop new Alternatives and to present the As-Is situation and the Alternatives on building level;
- The Connectors to Calculation Modules; and
- The Multi-Criteria, Multi-Stakeholder, Multi-Alternative (MCMSMA) Module to present and assess the scores of the designed Alternatives on district level.

All components, except for the MCMSMA Module, are web-based and distributed in the cloud. In the course of the project, prototype versions of these components have been developed and tested in the case studies of WP5 (D5.3) in districts located in Rotterdam (NL), Valencia (ES), Stockholm (S), Antwerp (B) and Warsaw (P). Based on case study outcomes it can be concluded that the IDSS can indeed be a valuable instrument to assist in sustainable district retrofitting processes. The current version is an operational prototype tool which would benefit from further elaboration to increase its usability in real life district processes. Thanks to its modular structure, the IDSS can be expanded with additionally connected Calculation and Supporting Modules. Furthermore, the case studies have underlined the importance of an experienced process facilitator to guide the decision process and manage the data flows.
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<td><strong>Alternative</strong></td>
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<tr>
<td><strong>Ambition</strong></td>
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<tr>
<td><strong>Assessment</strong></td>
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<tr>
<td><strong>BIM</strong></td>
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<tr>
<td><strong>Calculation Module</strong></td>
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<tr>
<td><strong>Component</strong></td>
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<td><strong>DB</strong></td>
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<td><strong>District</strong></td>
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<td><strong>DII</strong></td>
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<tr>
<td><strong>DoW</strong></td>
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<tr>
<td><strong>End-user</strong></td>
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<td><strong>Evaluation</strong></td>
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<td><strong>Framework</strong></td>
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<td><strong>IDSS</strong></td>
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<tr>
<td><strong>IDSS Framework</strong></td>
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<tr>
<td><strong>IDSS Dashboard</strong></td>
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<tr>
<td><strong>IMB</strong></td>
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<tr>
<td><strong>IMB (Communication) Hub</strong></td>
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In the context of computers, three common interface types are: Hardware, Software and User interface. In technical contexts, interface requirements are governed by standard conventions called protocols which could be so complex that the interface itself is considered a separate device or system.

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<thead>
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<th>Interface</th>
<th>Description</th>
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<tbody>
<tr>
<td>JSON</td>
<td>Java Script Object Notation</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator, a measurable indicator for one aspect of the users’ ambition</td>
</tr>
<tr>
<td>KPI Value</td>
<td>Required or predicted score of a KPI</td>
</tr>
<tr>
<td>Measure</td>
<td>A punctual intervention (i.e. window replacement; PV panels installation; building demolition)</td>
</tr>
<tr>
<td>Model</td>
<td>A model performs calculations of KPIs as a simplified view of reality. It makes use of data input and creates data as output.</td>
</tr>
<tr>
<td>Module</td>
<td>An independent functional part of the IDSS. A Module can consist of several coherent components, e.g. the calculation model, IMB connector, local data storage, or visualization.</td>
</tr>
<tr>
<td>Protocol</td>
<td>Set of agreed upon, and openly published and distributed, computer interaction standards that enables different firms to manufacture compatible devices to the same specifications</td>
</tr>
<tr>
<td>Prototype</td>
<td>Pre-production version of a product, engineered for full service test. Changes based on test results are incorporated into the prototype which undergoes the same tests again. On achieving the desired results, the product is approved for volume production.</td>
</tr>
<tr>
<td>Stakeholder</td>
<td>A person, group or organization that has interest or concern in an organization. Stakeholders can affect or be affected by the organization’s actions, objectives and policies.</td>
</tr>
<tr>
<td>Supporting Module</td>
<td>Module of the IDSS that supports the generic functions, such as dashboard, data upload, assessment, design and visualisation</td>
</tr>
<tr>
<td>System architecture</td>
<td>The framework and its components</td>
</tr>
<tr>
<td>Toolbox</td>
<td>It refers to the IDSS that is developed in ECODISTR-ICT seen from the perspective of the end-user</td>
</tr>
<tr>
<td>Variable</td>
<td>An aspect on which a decision can be made</td>
</tr>
<tr>
<td>Vision</td>
<td>A leitbilt or desired end situation</td>
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1 INTRODUCTION

1.1 PURPOSE, INTENDED AUDIENCE AND SCOPE

The purpose of this document is to describe the second version of the prototype of the Integrated Decision Support System (IDSS) in ECODISTR-ICT (IDSS, version 2.0), and conclude upon its technical performance. The software has been demonstrated several times during the project, both internally and externally. The final presentation and demonstration of the software was at the ECODISTR-ICT end-conference in Antwerp, on 27th October, 2016. This final demonstration was open to the general public.

People interested in the results of the ECODISTR-ICT project, such as those involved in multi-stakeholder retrofitting urban district projects, are the primary intended audience. The deliverable is also intended for parties in the close vicinity of the project, such as the stakeholders in the case studies, the EC reviewing committee and possible future users of the system.

The scope of this document is to describe in broad lines the core components of the system. Details, such as the software and the open source code, instructions to future developers, and guidelines to future users, are reported elsewhere and referred to in this document. Experiences with the IDSS in the case studies are reported in D5.3 ‘Final report of the different case studies, a strategy for sustainable renewal of the district’. An evaluation of the performance of the IDSS in the case studies is reported in D5.4 ‘Conclusion report on the governance of retrofitting and the use of the ECODISTR-ICT tool’.

1.2 APPLICABLE DOCUMENTS

- ECODISTR-ICT Description of Work (DoW, d.d. 3rd December 2012)
- ECODISTR-ICT Deliverable D1.1 List of specifications for the decision tool in function of stakeholder input (d.d. 28th February 2014)
- ECODISTR-ICT Deliverable D1.5 Monitoring for progress tracking and updating of scenarios (d.d. 31st August 2016)
- ECODISTR-ICT Deliverable D2.1 Exhaustive list of data required for accurate and reliable energy simulations at district scale, with an acquisition protocol, and identification of data providers (d.d. 31st May 2014)
- ECODISTR-ICT Deliverable D4.1 Functional Design of the IDSS (d.d. 31th March 2014)
- ECODISTR-ICT Deliverable D4.234 Technical Design of the IDSS (d.d. 31st May 2014)
- ECODISTR-ICT Deliverable D2.5 State of the art file formats for data exchange (d.d. 30th September 2014)

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1 The Description of Work (DoW) uses the term Integrated Decision Tool. The term Integrated Decision Support System describes the result of work package 4 (WP4) better. From now on, this term will be used in this Deliverable.
ECODISTR-ICT Deliverable D3.1 A first survey of existing tools and methods supporting evaluation of indicators for urban district retrofitting and renewal (d.d. 31st August 2014)
ECODISTR-ICT Deliverable D5.1 A roadmap for the analysis of the case studies (d.d. 31st May 2014)
ECODISTR-ICT Deliverable D4.56 Data upload functionality and Beta version of the IDSS (d.d. 19th December 2014)
ECODISTR-ICT Deliverable D4.8 Prototype Integrated Decision Tools Version 2 (d.d. 31st October, 2016)
ECODISTR-ICT Deliverable D5.3 Final report of the different case studies, a strategy for sustainable renewal of the district (d.d. 31st October, 2016)
ECODISTR-ICT Deliverable D3.4 Guidelines to users describing the decision support modules (d.d. 30th November, 2016)
ECODISTR-ICT Deliverable D5.4 Conclusion report on the governance of retrofitting and the use of the ECODISTR-ICT tool (d.d. 30th November, 2016)

All documents can be found on esites.vito.be/sites/ECODISTR-ICT/Deliverables/Forms/AllItems.aspx². The public documents can be accessed via ecodistr-ict.eu/.

1.3 CONTEXT ECODISTR-ICT

This document is result of work package 4 (WP4), Integrated Decision Support System of the ECODISTR-ICT project.

Figure 1 Work package structure of ECODISTR-ICT (DoW); this deliverable is part of WP4

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² For access to the ECODISTR-ICT SharePoint site at Vito, please, contact Ighor van de Vyver, ighor.vandevyver@vito.be, for more information.
Figure 1 shows the work package structure of ECODISTR-ICT, in which WP4 integrates the results of WP1 Stakeholders and Scenarios, WP2 Methods for Data Collection and WP3 Support Modules. WP4, Integrated Decision Support System, contains four tasks:

1. Task 4.1 Translation of user requirements into desired functionality of the IDSS
2. Task 4.2 Development of a prototype of Integrated Decision System
3. Task 4.3 Application and implementation in case studies

WP4 has been organised in tasks and steps, as shown in Figure 2. WP4 developed the IDSS Dashboard and the IDSS Framework. The IDSS Dashboard supports the end-users of the IDSS in their decision process. WP2 and WP3 will develop the data collection and support Modules. The IDSS Framework integrates the Dashboard, the data storages and the Modules.

This document is a part of Task 4.2: Develop prototype IDSS.

1.4 READING GUIDE

This document briefly describes the core components of the prototype version 2.0 of the IDSS (D4.8 of the ECODISTR-ICT project, publicly available on GitHub). It further provides the links to the software, the instructions to future developers, the wiki for end-users, and related documents.

Chapter 1 introduces the document. Chapter 2 gives an overview of the IDSS components, the development activities and the version planning, including the functionalities developed. Chapter 3 describes the results of the development activities. Chapter 4 concludes this deliverable with a discussion on the technical performance of the IDSS. In the appendix the links to the software and other relevant documents can be found.
2 IDSS DEVELOPMENT OVERVIEW

Development of the IDSS was a joint effort of many people. It has been a continuous process of incremental improvement using a scrum-based approach and iterative testing in the five case studies. This chapter gives an overview of the main components of the IDSS and summarises the development process, including the development activities, the version planning, the choices made during the process and the coordination.

2.1 IDSS COMPONENTS

As described in the Functional and Technical Design of the IDSS (D4.1 and D4.234), the IDSS basically contains a Dashboard and numerous Modules, linked by a Framework. The IDSS Framework has the aim to connect the Dashboard and the Modules. As described in Deliverable D4.1, Functional Design of the IDSS, Chapter 3, the connection between these parts is provided by a Framework using the Inter-Model Broker (IMB) technology, as schematically drawn in Figure 3. The Dashboard is a common interface for the facilitator of a multi-stakeholder decision process to follow the decision-making process and to control the connected Modules. The Modules will run automatically, controlled by Facilitator of a multi-stakeholder process via the Dashboard, and/or separately controlled by an (expert) User. Data management and storage applications can also be seen as Modules.

![Figure 3](Schematic overview of the IDSS and its main components)

In the course of the development of version 1.0 and version 2.0 of the IDSS the system architecture evolved to the architecture shown in Figure 4.
This document describes the core components of the IDSS, shown in the figure with an orange background. The calculation Modules are described in the ECODISTR-ICT WP3 deliverables.

### 2.2 DEVELOPMENT ACTIVITIES

Based on the core components described above, we identified the following development activities for the IDSS:

1. Dashboard
2. Framework using the IMB Communication Hub
3. Data storage and collection functionality
4. Design and Visualisation Module
5. Connectors to Calculation Modules
6. Multi-Criteria, Multi-Stakeholder, Multi-Alternative Module
7. Coordination
2.3 VERSION PLANNING

Based on coordination with other work packages and in line with the updated DoW, we agreed upon the following version planning:

- **Alpha** Alpha version of Prototype IDSS [month 10]
- **Beta** Beta version of Prototype IDSS [month 12], D4.5 + D4.6
- **IDSS version 1** First version of the Prototype IDSS [D4.7, month 18]
  - Rotterdam Case study 1 [Month 18-20]
  - Valencia Case study 2 [Month 21-23]
  - Stockholm Case study 3 [Month 24-26]
- **IDSS version 2** Second version of the Prototype IDSS [D4.8, month 30]
  - Warsaw Case study 5 [Month 30-36]
  - Antwerp Case study 4 [Month 27-36]
  - Conference Demonstration at end conference [Month 35]
  - Re-iteration of cases in Antwerp, Warsaw, Valencia and Rotterdam for dissemination purposes [Month 35-36]

The Alpha version has been made available to the WP4 partners using a template with a manual for connecting the Dashboard to the Framework. This template has been used by other partners to build on for connecting Modules and Data upload functionality. The Dashboard has been demonstrated internally in WP4 for feedback.

The Beta version has been made available to all ECODISTR-ICT partners. Generally applicable connectors have been made available, with an updated manual on how to use them. As an example some test Modules and Data functionalities have been integrated in the IDSS.

The Alpha and Beta versions, combined with the mock-up of the Dashboard user interface developed earlier [D4.234], have been developed in the second half of the first year of ECODISTR-ICT. These versions have been demonstrated to ECODISTR-ICT partners. Their feedback has been gathered and processed.

Version 1.0 has been developed and tested internally during the third half year of ECODISTR-ICT. It has been developed further, used and demonstrated for the case studies in Rotterdam, Valencia and Stockholm in the second half of the second year and the first half of the third year.

IDSS version 2.0 has been used in the last two case studies in Warsaw and Antwerp, and has been demonstrated to the public at the end conference on 27th October, 2016.

This final version of the IDSS has been made available to the public via a dedicated ECODISTR-ICT repository in GitHub, the open source software community of developers. Under which conditions parties can use the IDSS and its connected Modules, has been discussed within WP6, Exploitation of the IDSS.
2.4 CHOICES MADE IN DEVELOPMENT OF THE ECODISTR-ICT IDSS

The main architecture and the integration principles have been developed by the software developers, as described in the Functional and Technical Specifications (D4.1 and D4.234). Selecting which functionality has to be developed first with the required level of support and which Modules have to be connected, has been a joint process of the users and the developers of the IDSS. Typically, the users (consortium members working in WP1 and WP5), and the project advisory board with external stakeholders defined “What’s needed” and the developers (of WP2, WP3 and WP4) “What’s feasible”, of course, within the scope of the (updated) DoW. We have called this process “the priority list discussion”. We have conducted this priority list discussion in December 2014 - January 2015 for IDSS version 1.0 to be used in Rotterdam and in October 2015 for IDSS version 2.0 to be used in the other case studies.

At brainstormings during the project meetings, desired added or improved functionality items were listed. In a small group with the leaders of WP2, WP3 and WP4 these items were elaborated further with a description of the item and with potential solutions on four Solution levels with regards to integration into the IDSS:

- S1: Outside the IDSS: the IDSS doesn’t provide the functionality; no changes to existing IDSS functionality needed; maybe some changes in documentation / guidelines; the functionality is added by the facilitator using traditional means (e.g. the item ‘giving insight in the accuracy of Modules and data’ is not supported in the IDSS; the facilitator knows the accuracy and communicates it to the stakeholders if deemed necessary during the process);
- S2: Minimum Solution: inside current IDSS; no changes needed; maybe some creative interpretation of existing functionality (e.g. ‘viewing geographical data’ in a separate Module instead of in the Dashboard);
- S3: Intermediate Solution: some adaptations in IDSS needed but limited to 1 or 2 components; not yet full functionality; workable solution (e.g. ‘viewing the KPI set and scores per stakeholder’ is supported; but complete multi-stakeholder analysis with relative gains and losses not);
- S4: Fully integrated Solution: full functionality; might involve changes in several components of the IDSS (e.g. ‘complete connection to the energy consumption Module’, which automatically calculates KPIs related to energy consumption on district and individual household level).

Users from WP1 and WP5 defined “What’s needed” by giving priority (from five = high to one = low) and indicating the minimum Solution level needed for a successful application in their case study. Developers from WP2, WP3 and WP4 defined “What’s feasible” by indicating the effort needed for each Solution level for each item (from 0 to 3, indicating zero, to high effort needed). Of course, both the users and the developers gave feedback on the work of others. This resulted in a joint priority list in which the high priority items for the next case studies were selected for implementation, including the requested Solution level of integration.
2.5 COORDINATION

Each member of the WP4 team has been given the responsibility for one of the development activities, corresponding to their expertise and in line with the role of their organisation in ECODISTR-ICT. We organised the work in so-called scrum sprints of 4 weeks.

In Wikipedia, scrum is described as follows:\(^3\)

Scrum is an agile way of managing software development. In scrum the work is broken down into so called Sprints, iterative time-boxed development cycles. During a sprint a team will develop a working and tested product improvement. Typically the following figure is used to visualise a scrum process\(^3\).

![A typical scrum process](image)

A sprint (or iteration) is the basic unit of development in scrum. The sprint is a time boxed effort; that is, it is restricted to a specific duration. The duration is fixed in advance for each sprint and is normally between one week and one month, with two weeks being the most common.

Each sprint starts with a sprint planning event, the aim of which is to define a sprint backlog, where the work for the sprint is identified and an estimated commitment for the sprint goal is made. Each sprint ends with a sprint review and a sprint retrospective, where the progress is reviewed and shown to stakeholders and improving lessons for the next sprints are identified.

Scrum emphasizes working product at the end of the sprint that is really done; in the case of software, this would likely include that the software has been integrated, fully tested, end-user documented, and is potentially shippable.

Typical roles in a scrum process are Scrum master—who facilitates the process, Product owner and the Development team.

\(^3\)[http://en.wikipedia.org/wiki/Scrum_(software_development)()}
In WP4 the person responsible for the activity played the role of the Scrum Master. He/she was also the main member of the development team. A representative from the case study for which we were developing new functionality played the role of the Product Owner. The priority list functioned as the Product Backlog, containing all the results to be produced in this time period.

Each of the development activities was divided in a number of sprints. Figure 6 shows an example of the overall planning of WP4 in one of the development periods.

<table>
<thead>
<tr>
<th>Main Item</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dashboard</td>
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<td>Internal milestones</td>
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<tr>
<td>Joint Sessions</td>
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<tr>
<td>2x weekly meetings</td>
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</tbody>
</table>

Each sprint started with selecting one or more Product backlog items to be developed. This selection was discussed at the first bi-weekly WP4 meeting. Two weeks later the development plan was presented and discussed. Again two weeks later the results were demonstrated and the items for the next sprint were selected. This was administered using Trello in which each sprint uses one card, as shown in the example of Figure 7.
The so-called user scrums deserve special attention. In these scrums the results of the other scrums were combined to support the main decision processes in the case study at hand: in this example, water retention and energy efficiency.

The overall process was coordinated by TNO. The team held bi-weekly coordination meetings via a tele-conference. The core developers of the team gathered every half-year for a 3-day work session in so-called hackathons. We used the online GitHub repository of the ECODISTR-ICT IDSS to gather and process feedback on the IDSS.

The work was coordinated with the other work packages at the bi-weekly Technical Coordination meeting. The main points of interaction were the discussions on the priority list (see section 2.4) at the start of each development period, and the user scrums at the end of the period. When deemed necessary, content alignment with the other work packages was done by the individual team members, as they are involved in those other work packages too.
3 IDSS VERSION 2.0

We have divided the development work in the following development activities:
1. Dashboard
2. Framework
3. Data storage and collection functionality
4. Design and Visualisation Module
5. Connectors to calculation Modules
6. Multi-Criteria, Multi-Stakeholder, Multi-Alternative Module

This chapter briefly describes the results of these development activities.

The software, source code, instruction for developers, issue lists, for some tools the wiki for end-users are all to be found on https://github.com/ECODISTR-ICT. Each component has its own repository. The guidelines for the end-users are gathered in a Wiki, to be found on http://ecodistr-ict.eu/wiki-section/. The GitHub and end-user wiki also contain the results of WP2 Methods for data collection and WP3 Support Modules. They will stay active after the ECODISTR-ICT project has finished and thereby remain publically accessible and usable.

3.1 DASHBOARD

3.1.1 Introduction

The Dashboard is a web application for the user to manage the flow of the decision process. As reported earlier the different steps of the workflow have been added and evolved, such as creating a case, defining KPIs and work with the As-Is situation, To be situation and the different Alternatives. In the later phase of the project several Supporting Modules, such as the Data Module, Design Module and the Data Upload Module have been connected to the dashboard together with Calculation Modules to enrich the functionality of the system as a whole.

3.1.2 The main usage and roles of the dashboard

Two types of accounts have been created to access the Dashboard. The primary role is the Facilitator, who has access to all functionality in the decision process, called a Case. From the Dashboard the Facilitator can manage cases, KPIs and access and interact with the different IDSS Modules. The facilitator can also add stakeholder accounts to give people affected by the case the possibility to access the dashboard and define their ambition. As further discussed in D5.4, the role of the facilitator requires both stakeholder management and technical skills. The combination of these two very different competences can be quite challenging, especially during the testing phase of the IDSS. Therefore, in the ECODISTR-ICT case studies, these tasks were appointed to two distinct persons sharing the facilitator account in the IDSS: a “process” facilitator and a “technical” facilitator.
The secondary role is the Stakeholder. Each stakeholder is identified in the dashboard in the first step of the process. A stakeholder can view all information in the IDSS. A stakeholder can identify his/her priorities and ambitions. At the end of the process the results can be assessed from the perspective of each stakeholder.

3.1.3 The workflow and functionality of the dashboard

Seven steps are defined as basis of the decision process and these steps are used to navigate and work in the dashboard.

1. **Analyse the problem.** Setup the case, connect stakeholders and setup the KPIs
2. **Collect data.** Use the link to the Data Upload Module to upload data into the Data Module. The input status of data can then be validated per Module through the dashboard.
3. **As-Is situation.** This step calculates the current situation by executing the Modules and shows the KPI values, both the mean value for the district as a whole, and the individual values for district elements such as buildings and spaces using the Design and Visualisation Module.
4. **To-be situation.** The facilitator can set the priority and ambition for each KPI for the stakeholders. It is also possible for the stakeholders to log in by using their credentials and set their priorities and ambitions themselves.
5. **Develop Alternatives.** In this step, Alternatives for the district can be created, in which retrofit measures are implemented. For each Alternative the facilitator applies the Design Module to configure the new district in detail by selecting the measure he/she wants to apply. This affects the input that is sent to the Calculation Modules in the next step. The ‘develop Alternatives’ step can be used to generate several distinct development scenarios for a district, but can equally be used to explore a single development plan in which the Alternatives represent different stages over time (e.g. the expected status in 5, 10, 15 and 15 years).
6. **Assess Alternatives.** In this step new calculations can be done for the newly created or updated Alternatives. This is similar to how it works in the As-Is situation; every Alternative has a list of KPIs that can be calculated and the KPI values are shown, both the mean value for the district as a whole, and the individual values for district elements.
7. **Compare Alternatives.** The final step of the dashboard is to look at all the collected results at the same time. The raw data can be examined in the dashboard by using filters on the page for this step. Complementary to the raw data in the Compare Alternatives page in the dashboard, the MCMSMA Module provides a more visually appealing way to communicate the results to stakeholders, and perform advanced filtering and grouping. The MCMSMA Module is a desktop application which retrieves its data and can be accessed through the Compare Alternatives page.

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4 Secondary in the sense of active use of the system; certainly not secondary in importance in the process!
In reality, decision making processes are often not as linear and straightforward as these 7 steps might suggest. For example, based on intermediate results, additional KPIs or Alternatives could be requested by the stakeholders. Therefore, special effort has been made to assure that users can use the IDSS dashboard in an iterative way, going back and forth between the 7 steps.

3.1.4 Module connections

Many connections are made between the dashboard and the other components. The IDSS has been developed as a cloud based system, in which the components can actually be running from distinct servers. The main data traffic is done through the connector to the IMB Hub. The following list gives examples on the message procedure:

- When the dashboard starts up it will send a message to ask which Modules are available.
- When a new case is created, a message is send to prepare the Data Module for storing new input and output of the Modules. The same procedure runs when an Alternative is created.
- On the collect data page, a message is sent to the Modules to validate the current state of the input
- In order to calculate a KPI, a message is sent to trigger a calculation. Any progress messages during the calculation can be shown directly in the dashboard user interface.
- In order to view the data in the MCMSMA Module a message is sent which includes the data necessary to update the interface of that Module. This enables quick iterations.

The dashboard messaging also enables requests from other Modules to get case data. The case details, e.g. KPIs used and Alternatives that exist, can be returned from the dashboard to other Modules on request. Another type of connection uses an HTML link which sends a session ID with the command to open a new tab in the web browser. In that way the separate web application will pick up the user details, case and Alternative that should be used for the work session.

3.1.5 Setup

The source code of the dashboard is publically available on GitHub with instructions of how to install and run the software. The guidelines for users can be found on the wiki.

3.1.6 Summary

The dashboard has been developed to fully embrace the decision process as it has been defined in the project. Also the navigation and workflow has been refined step by step, for example a separate KPI page has been created to view all the details about the KPI, which Modules are connected and the current value in the active case. The connection to the IMB Hub has proven to be a flexible solution since adding new kinds of messages has been done painlessly through the development process. Also connecting other application and Modules with normal HTML links has made the system very flexible when it comes to the decoupled architecture which separates the concerns of the developers. With this future proof setup of the dashboard new developments can easily be made, e.g. coupling additional Calculation Modules which respond to specific local requirements.
3.2 FRAMEWORK, USING THE IMB COMMUNICATION HUB

As described in previous deliverables, the IDSS components communicate both with each other and with the Dashboard through a Framework using the IMB Communication Hub.

3.2.1 IMB Communication Hub in general

The abbreviation IMB stands for “Inter-Model Broker”: a so-called message broker. It serves as an intermediary with a client and a server side, enabling communication between two or more applications without the need to run on the same physical machine. It parses messages from A to B and back. All the applications communicating through the IMB Hub should apply the same protocol.

IMB makes use of a so-called Publish-Subscribe mechanism. This resembles radio communication (the kind that needs a transceiver device, which both transmits and receives), where the listener can only receive radio messages when tuned in on a specific frequency or channel on which someone is broadcasting, all applications that need to talk to each other through IMB should use the same channel as well. Only in this case, the “channel” is called a federation.

This federation is managed on a server, where a service is running that handles all the messages: the IMB Communication Hub. This hub can handle multiple federations at the same time. A component (e.g. a Calculation Module) that publishes to a certain federation, is basically sending messages to the Hub. Any other application, maybe on another physical machine, can now subscribe to the same federation and will thus be able to receive the messages the other application sent, through the IMB Hub.

Once again, just like in radio communication, the IMB Hub broadcasts its messages whether someone is listening or not. The Hub also doesn’t care how many subscribers are listening to the messages. Moreover, communication through IMB is bidirectional as well: subscribed applications can also publish at the same time.

The main advantage of such a system is its scalability and flexibility. The system can equally run a simple simulation with only two Modules or a full-blown simulation with fifty Modules. And if the Hub really becomes too slow, it’s even possible to set-up more Hubs, that are able to communicate with each other as well. Another advantage is that a Module developer does not need to be informed upfront how the messages from his/her Module are received by another Module. A Module only needs to interpret the specific messages it requires and it will have to send out messages that other Modules might require, but not necessarily need to pick up if they are not running.

5 Publish-Subscribe pattern: http://en.wikipedia.org/wiki/Publish%20%26%20Subscribe_pattern
In general the implementation of IMB enables the following possibilities:

- Interactivity between users on different locations
- Interactivity between a user and one or more Modules (responding to a user action)
- Interactivity between Modules (responding to another Module)
- Real-time input of sensor data
- Data exchange in standardized formats between Modules, allowing more Modules to be hooked up to the framework relatively easy
- Data exchange between Modules and data stores in standardized formats, disabling the need for Modules to write and read to a data store themselves, making the Modules more manageable for developers
- Flexibility in terms of where Modules, user interfaces and data stores can reside within the framework (e.g. on a local machine or on different locations)
- Long term expansibility: framework capacity can be enlarged

3.2.2 IMB changes regarding ECODISTR-ICT

The IMB Communication Hub was already under development at TNO before the ECODISTR-ICT project. During the project it has been developed further and released as open source. The following changes were made concerning the IMB Hub specifically for ECODISTR-ICT.

- Installation of the IMB Hub on an external server. The IMB Hub is now up and running on an external server hosted by CloudVPS. This makes the connection to IMB easier and accessible from anywhere.
- IMB has been upgraded to 4.0. IMB 3.0 had no security imbedded into it, which made it vulnerable and only employable in-house. With the upgrade to IMB 4.0 the security was added by implementing the use of certificates. This means there is now encryption, authentication and authorization between the different IMB clients used by the ECODISTR-ICT Modules and the IMB Hub.

By upgrading IMB and the IMB Hub also the IMB Hub clients needed to be updated and re-implemented in the ECODISTR-ICT Modules. Also client certificates needed to be provided to the Modules to be able to make secure connections. This has been done for all ECODISTR-ICT Modules.

3.2.3 Messaging protocol

The Dashboard and other Modules communicate using JSON-serialized messages. JSON (JavaScript Object Notation) is a lightweight data-interchange format. The messaging protocol is documented for future developers in the GitHub wiki, and a JSON schema for messages has been created to simplify validation of messages. This JSON schema can be used, for example, in the Dashboard code to validate that all incoming messages are correct. The JSON schema for messages is available at GitHub.
3.2.4 .NET messaging library

Since nearly all Modules communicate with the Dashboard, via the protocol discussed in 3.2.3, there was a need for a common structure in order to remove the need for every developer to create their own structure for creating and interpreting received JSON-messages. This has been done for the C# programing language in .Net 4.5, resulting in a well-documented dll. The use of this dll will reduce Module development time and will make the process of attaching new Modules simpler. At this point there are two Modules running utilizing this dll (SP LCA, MSR LCC). The .Net messaging protocol can be found on GitHub. The dll is documented as an msdn-styled class library, containing descriptions of the structure, classes as well as code examples and examples of the appearances of the resulting JSON-messages. The documentation has been built with the sandcastle software and can be opened by the Microsoft compiled html help file viewer. The documentation can be found at GitHub.

3.3 DATA

3.3.1 Introduction

In order to assess the as-is situation as well as the performance of the Alternatives, data on the district and its composing elements are essential. These data must be read, processed and altered by a multitude of calculation Modules and support Modules, which requires a common data storage and a shared understanding of the data format and its attributes. In order to ease the process for a facilitator not acquainted with cloud based databases, a data upload functionality has been developed. Before proceeding to the upload, there is a prerequisite to prepare these data and combine in a structured manner the various types of information needed by the other technical Modules.

In order to explicitly define the information required as well as its structure, different templates have been defined. Additionally the information carried by the instantiation of these templates needs to be combined (or joined) with geographic information (location, building footprint, orientation, etc.). Most of the time in such project acting at the district scale, there are existing GIS files containing (at least) the geographic information mentioned above. Nevertheless, a quick guide has been established also to provide solutions for the elaboration of such GIS file, which can be found in the wiki.

Facilitators will consequently enrich this geographic basic information with extra information according to the fields which are predefined in the templates and upload the resulting file to the database.

This combination / enrichment of geographic information and additional data is the heart of any GIS system. An initial technical choice to store this combined information has been made at the early stages of development of the IDSS and its Modules. This choice was relying on the CityGML format to convey in an open standardised way the information exchanged at the IDSS level among
the various Modules. A first attempt has been developed towards this objective but it appeared that it was too ambitious for different reasons.

The CityGML underlying data model is rather complex and even if XML is well suited to support such complexity, the translation of this model into a database structure of linked tables leads to a complex management of the resulting database both in terms of upload of new information and query for retrieving existing data. The specific focus of the project on green aspects / energy / district heating is not natively supported by the core CityGML data model. These domains are partially supported by so-called “ADE” (Application Domain Extension) of the CityGML data model. Currently, the two main relevant ADE covering the Energy topic and the Network utility topic are still under development and as a consequence the development of software solution supporting these new proposals is not stable. Thus it has been decided to shift to a more flat structure based on the WKT format to convey geographic information and CSV for the extra data.

The conversion of any GIS files into this WKT format can be easily done by using current GIS editor software. (For instance QGIS – an open source GIS desktop application). The export as a CSV file (encapsulating the WKT information) is also a current feature of a GIS editor. This simplified choice lead to a far less complex structure in the database, and thereby simplified data handling in the latter case studies by making use of a flatter data model.

3.3.2 Data preparation

The preparation of the information relies on the use of 3 kinds of spreadsheet templates corresponding to the different situations we faced for the project pilots:

- District template aims at covering the needs at the district level
- Space Template aims at covering the needs at the “Space” level (the notion of “Space” is corresponding to a subset of the notion of District. For instance, it is well suited for the description of Green areas in a district)
- Building Template aims at covering the needs at the building level

These templates are containing several columns starting with headers. All of these headers are corresponding to district/zone/building information that need to be entered into the system before making use of dedicated Modules to perform some calculation over these data. A specific document describing these templates and detailing the meaning of each of the selected variables has also been developed in parallel. This document is available on the wiki.

For users not having this initial GIS file, there is a need to start creating it. This can be done easily following for instance the process described below.

- Create manually a GIS file using a GIS editor. This can be done for a small project (containing a few set of buildings) or a project that is working on new buildings to be erected.
- Rely on existing GIS database (OpenStreetMap or national geographic institute) to retrieve GIS base maps for the considered area. Retrieving this information from OpenStreetMap will result in having a LOD 1 file. It means the file will describe the various footprints of the district elements (buildings, streets, parks, etc.).
- Generate a CSV file. The above mentioned file needs to be open via a GIS editor (e.g. QGIS), in order to be exported as a CSV file.

A list of required inputs and produced outputs has been made for each of the selected Modules. It is available on the wiki.

A specific way to gather data is using the ‘crowdsourcing’ tool (see D1.5). A dashboard enables the facilitator to create a questionnaire and gather data from local inhabitants or other stakeholders. The data is geo-referenced: the user can click on a building or other component in the district, and connect the questionnaire results to such an object. The data can be exported to a csv, and after quality checking by the facilitator it can be added to the district database using the Data Upload Module. See the ECODISTR-ICT wiki for the end-user guidelines and GitHub for the source code and the developers’ instructions.

3.3.3 The overall process of the data upload

The rationale behind current developments is that the ECODISTR-ICT project will rely on databases (cloud based) that will be fed with data coming from various sources: web services, open data, stakeholders, crowd sourcing, etc. These data will be formatted according to the templates defined among the ECODISTR-ICT partners and the specific geometric information is written in WKT format and encapsulated in a dedicated cell in the building template.

Thus, a “Geo-database” is instantiated for each case study, aggregating the data collected. With more than 400 different variables we consider that the templates are expressive enough to support various pilot cases and scenarios. In order to enable the proper use of the different Modules it is mandatory that the input information uploaded on the DB is well formed. The three different templates have been developed to support different usage of the platform. In the wiki, there is an explicit description of the dependencies between the input data (and which template to use) and the Calculation Modules.
Once the As-Is situation is stored, the Modules can connect to the case study DB and gather their inputs. Once done, the calculation is run, and the resulting KPIs are produced and rendered in the Dashboard and stored in the dashboard database. Figure 9 illustrates the link between Modules, the databases containing the As-Is situation and the Alternatives (or renewal solutions).

3.3.4 Technical choices and installation instructions

The Upload Module consists of a simple web service capable to convert CSV data (defined by templates as described above) and to store them into the remote ECODISTR-ICT database.

The database chosen is a spatial database (posgres/posgis) which is used to store and retrieve attribute/geometry data. The standard geometry format used is the WKT (LOD 0 only). The various attributes that can be used to describe the characteristics of the considered District / Space / Building are defined into the different upload templates of the project.

Each Alternative has its own data stored in a separate district database. This implies that for each case there are multiple district databases: one for the As-Is situation, and one for each Alternative. When a new Alternative is created, it always starts with a copy of the As-Is district database.
The Data Upload Module is a Python script deployed as a Tornado Web Service. It can open a webpage that displays and authorizes a file selection, a button to launch the upload and a text result status. It is also able to check and to upload a well-defined / filled csv file and store it into the right database fields.

3.3.5 Data Module and district database

The Data Module was originally built by CSTB and written in Python. Later this Module was integrated into the Design Module by TNO, which already had a tight integration with the database.

The Data Module binds the database to the other Modules over the IMB Hub. It also handles the case/variant management in the database, controlled by the dashboard. The second function is data retrieval/updating. For that a dynamic set of queries are executed per request to form a JSON reply with the requested data. More specifics can be found in the wiki of the Design Module.

The Data Module is now built for 2 database structures. The original structure was based on city GML. This is now extended with a flat Data Module where objects with their properties are stored in tables. For this model each row represents an object, contains a GIS object for visualization and has a unique id. Properties are of type integer, float, Boolean or string.

The database is a PostgreSQL database server.

For both data models each case and Alternative is stored in a separate database schema. The Alternative schema is the same as the corresponding case schema extended with a unique id. The IDs for the schemas are generated by the dashboard. A new case is created by copying the public schema which contains all base tables, views and scripts.

The Data Module depends on scripts in the public schema for managing the schemas:

- clone_schema
- drop_schemas

Tables that should exist in the public schema:

- Design Module
  - public.di_measures
  - public.di_measureshistory
  - public.di_objectproperties
  - public.di_queries

- rest api (used for Crowd Sourcing Module)
  - public.di_restapi

- Data Module
  - public.dm_queries

For more details on these tables see the wiki of the Design Module.
3.4 **Design and Visualization Module**

3.4.1 **Introduction**

The goal of the Design Module is to visualize map based data of the district and its Alternatives and manipulate the data by applying measures on objects within the district.

Data are visualized by coloured objects like buildings based on properties of those buildings. Colouring is done through the use of a legend defined per visualized property or based on the definition of KPIs. KPIs are defined within the dashboard, not in the Design Module. All defined and processed KPIs are automatically available as a “Detail” item in the Design Module.

![Figure 10 Example of visualisation of As-Is data in the Design Module](image)

In the Design Module objects, like buildings or spaces, can be selected. Per project, measures are defined that can be applied on specific objects or on the district as a whole as part of a specific Alternative. When applied on a set of selected objects, these measures change values of properties of the selected objects.⁶ Calculation Modules can read these changed values and calculate KPIs based on those values. The KPIs that are related to objects can in turn be visualized by the Design Module. This chain of Modules is controlled by the ECODISTR-ICT dashboard.

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⁶ A second option to change object properties is by means of a dialogue where properties can be manipulated directly. This feature has not been applied during the EODISTR-ICT case studies.
The source code, documentation, the developer instructions and end-user guidelines for the Design Module are in the ECODISTR-ICT repository on GitHub and are open source. All source code is available except for some third party tools.

Figure 12 shows the main parts of the Design Module.

3.4.2 Web Client

The Web Client is the user interface of the Design Module, with its functionality as described above. The user can filter the information displayed by switching domains on or off to make the selection of layers and graphs easier.
From the IDSS dashboard, the user opens the menu item "As-Is" or "Develop Alternatives". In those screens there is a button "open Design Module". This starts the Design Module Web Client for the selected case and Alternative. There is a user manual for the Web Client in the ECODISTR-ICT wiki.

3.4.3 Web server

The web server can be any standard web server that can serve web pages. Because we also use web sockets (C# web service) and a Tiler (ISAPI web service) it is recommended to use IIS server on Windows server 2012 or higher so all services for the frontend can run on the same server and share the same TCP port.

3.4.4 WS2IMB

The WS2IMB service converts a web socket that is created by the Web Client bi-directionally to the IMB Hub so the communication to and from the Web Client can be redirected easily to a different server or service. Basic session management is included in this service so every Web Client connection is signaled to other services (add/remove), unique session IDs are defined for each and every session has its own channel on the IMB Hub. The service is written in C# and uses WCF to create a web socket service. Because of this Windows server 2012 or higher is required.

3.4.5 Tiler

The tiler service is an ISAPI based web service that runs on IIS. This service generates tiles: png images of 256*256 pixels. The Web Client is not guaranteed to have enough performance to display all geo related information in the form of objects on a map. The base map already consist of tiles. The geo date is processed into tiles by tiler service that offloads this task from the Web Client. The bulk of the geo data is already on the server side and ‘near’ the tiler service so only the resulting tiles (small png images) have to be transferred to the Web Client on request.

3.4.6 Publishing Module

The Publishing Module is the main server side implementation of the Design Module. It handles all specific ECODISTR-ICT functions for the Web Client: connect to the database. Listen on the IMB Hub for data changes and sending that data to the tiler but also informing the Web Client of new tiles when they change. Translate commands like selecting objects, applying measures and link available data to URLs that point to the tiler web service etc.

There is a specific implementation of the publishing server for ECODISTR-ICT. The ECODISTR-ICT version is written in Delphi, can handle all Web Client commands needed in the ECODISTR-ICT project and also includes the ECODISTR-ICT Data Module for reasons of code efficiency. The integrated database client can connect to the Postgres database used in ECODISTR-ICT.
3.5 CONNECTORS TO MODULES

Based on the choices made during the project, a number of Calculation Modules has been connected to the IDSS. Basically, these connections can be made on three levels:

1. Full connection: the Module is fully integrated in the IDSS architecture. The Module is connected to the dashboard and the data functionality via the IMB Hub. As a result, it is fully connected to the dashboard, it can be used to calculate a KPI score on district level, it can be started from within the dashboard, it uses the central database as input and stores the results of its calculation (e.g. on building level) again in the database. To enable such a connection a Connector has to be developed for each Calculation Module, depicted in Figure 4 as a light blue square.

2. Intermediate connection: the results of the calculations are integrated in the database using data collection tools. The Module is run separately from the IDSS architecture. The expert running the Module ensures that the same input data is used. Via the data collection tools, the results of the calculation on building level are fed into the district database and the results on the district level into the dashboard database, so they can be visualised and assessed as part of the decision process. An example is the connection to Dimosim, as used for energy calculations in the Warsaw case study.

3. Manual connection: the results of the calculations are fed into the dashboard manually. The Module is run separately from the IDSS architecture. The expert running the Module ensures that the same input data is used. Via the functionality for qualitative KPIs, the result of the calculation on district level is fed manually into the dashboard database by the facilitator of the decision process, so the KPI score can be assessed as part of the decision process. An example is the connection to the heat stress Module, as used in the Valencia case study.

The Calculation Modules are described in the WP3 deliverables. This section focuses on the fully connected Calculation Modules.

3.5.1 Generic Excel Module

In order to make the process of attaching new Modules simpler a generic Excel Module has been developed. With generic means that it contains the fundamental structure needed to be connected to the IMB Hub, respond to the Dashboard/Module messaging protocol (using the .Net messaging dll discussed above) as well as set and get values from an Excel Module. This generic Excel Module has been used with the following Excel Modules: LCC Module, Affordability Module, Green Berlin Module, Green Stockholm Module, Renobuild Module (LCA) and the Mobility Module. The code and the developer instructions for these Modules can be found on GitHub. The end-user guidelines can be found on the ECODISTR-ICT wiki.

This generic Excel Module is not connected to a specific Excel calculation, but it contains generic connecting functionality which can be inherited by a Connector for a specific Module. The specific Module class describes what data a Module need and how that data should be used with an excel calculation Module. In order to do this, the developer needs to override methods from the generic
Excel Module, more precisely the methods \textit{CalculateKpi}. The data needed for the Module is added to the database using the data upload functionality, described in section 3.3.. Queries in the database define what data are to be downloaded to the Module for each calculation case. The \textit{CalculateKpi} utilizes the data on the Excel document and extracts the result(s). The generic Excel Module together with its documentation can be found on the GitHub.

The Excel Module consists of a dll (dynamic link library) file developed in C# .Net 4.5. The Excel Module is developed using Excel 2013, Microsoft.Office.Interop.Excel version 15.0.0.0. It is possible to connect Excel documents developed in version 8 (1997) and forward. It could be used with both the old (BIFF8) .xls format and the new XML-based file format .xlsx. An overview of the structure of the dll can be seen in the class diagram in Figure 13.

![Class Diagram](image)

Figure 13  Classes used in Excel Module sample application

### 3.5.2 BIM Energy Map Module

The BIM Energy Map Module is a fully integrated Calculation Module. This means that a link is provided in the KPI page of the dashboard to access the Module user interface. In the Module user interface a more detailed explanation of the calculation is possible since the input and output is more comprehensive than what is possible in the IDSS. The Module is a proof of concept and works as an example for other developers to connect new Modules to the system in a flexible way.
The connection to the system is done via the connector to the IMB Hub written in Node.js. This is the same connector that is used for the dashboard and also shows, just like the Excel connector, that the connectors are reusable and prepare way for adding more Modules in this platform.

To link to the Module from the dashboard the BIM Energy Map Module sends its own web URL when the dashboard requests its metadata. This means the link is dynamic and up to the Module creator to define. The link can be pointed to a documentation page, a commercial page or as in this case the calculation page in the Module. The dashboard also sends along the session ID as described in section 3.1. In this way the Module can load all the data needed from the dashboard and the other Modules in the system.

The connection to BIM Energy Map Module also shows the concept of connecting a commercial Module to the IDSS. When starting the Module the user needs to log in to their BIM Energy account, which means that an account needs to be created if not already done.

Functionality to map the data from the IDSS Data Module format to proprietary data format in the Calculation Module, as well as save back data to the IDSS is required. This could make the Calculation Module to overlap the functionality in the Design Module in some aspects if allowing the Module to change the input in a way that it also affects properties in the IDSS data format. Also the results of the Calculation Module could affect the input of another Calculation Module. The BIM Energy Map was in this case saving back data from its output to the IDSS Data Module used as input for the LCC Module.
3.6 **MULTI-CRITERIA, MULTI-STAKEHOLDER, MULTI-ALTERNATIVE MODULE**

The development of the Multi-Criteria, Multi-Stakeholder Multi-Alternative (MCMSMA) Module is based upon already existing Vabi Dashboard software for multi criteria KPI visualisation. In the beginning of March 2015, a meeting was set up to define the exact functionality of the Multi Stakeholder functionality. The main decisions resulting from this meeting are:

- To use the already existing Vabi Dashboard software for the multi-criteria and multi-stakeholder visualisation.
- To add a multi-alternative aspect to the visualisation Dashboard, resulting in a MCMSMA Module (Multi-Criteria, Multi-Stakeholder, Multi-Alternative)

A screenshot of the first version of this Module used in the Rotterdam Rubroek case is given in the Figure below.

![Figure 15](image)

Figure 15  Example of visualising one Stakeholder multi-criteria score (divided in thematic categories)

The basic visualisation functionalities of the ECODISTR-ICT Dashboard are:

- Visualise an overall score aggregated from the individual KPIs. In the Figure, for AS-IS, TO-BE and each Alternative, the individual KPIs are shown in the columns under the aggregated score. In the IDSS Dashboard, each Stakeholder can give each KPI an individual
weighting factor. The aggregated score is the weighted average score of all KPIs for each Stakeholder. This is the multi-criteria aspect. Different Stakeholders can choose different KPIs and/or adhere other weighting factors to the KPIs.

- Each column shows the scores for a single Alternative from the viewpoint of a single Stakeholder. This is the multi-alternative aspect.
- There is also the possibility to "freeze" an Alternative and show the scores for each of the Stakeholders in a separate row (shown in Figure 18). This is the multi-stakeholder aspect.

The Dashboard sends the data to the MCMSMA Module. The objects to be exchanged are determined. The communication between the Dashboard and the MCMSMA Module is done over the IMB Hub via JSON, as shown in the Figures below.

Figure 16  Example of ECODISTR-ICT Dashboard with connection to the MCMSMA Module
The connection to the Dashboard has been upgraded from IMB 3.0 to IMB 4.0.

Please, note that in this example the former term “variant” is still used. Later, it was replaced by “alternative”. 

Figure 17 Example JSON-data. 

```json
{
   "stakeholders": [
   {
      "user": {
         "id": "553f618b6459201f15a9ab9d0",
         "name": "Vincent"
      },
      "variants": [
      {
         "variantId": "553f61cf6459201f15a9abdb",
         "description": "The TO BE state defines the KPI ambitions for a connected user",
         "name": "To be",
         "type": "to-be",
         "kpiList": [
            { "kpiValue": 1, "kpiId": "quality-of-life---rubroek" },
            { "kpiValue": 1, "kpiId": "quality-of-life---residents" },
            { "kpiValue": 2, "kpiId": "water-drainage" },
            { "kpiValue": 1, "kpiId": "water-storage" },
            { "kpiValue": 50, "kpiId": "water-damage" },
            { "kpiValue": 15, "kpiId": "real-estate-value" },
            { "kpiValue": 1, "kpiId": "payback-period" },
            { "kpiValue": 1, "kpiId": "return-on-investment" },
            { "kpiValue": 8, "kpiId": "communications", "disabled": false }
         ]
      },
      {
         "variantId": "553f61cf6459201f15a9abdc",
         "description": "The "Slinger" is sold to a private investor. The "Slinger" is renewed. The "Slinger" is rented to new residents. The private investor invests in green roofs, slowed-down drainage and water-proofing the ground floor",
         "name": "Slinger renewal",
         "type": "variant",
         "kpiList": [
            { "kpiValue": 1, "kpiId": "quality-of-life---rubroek" },
            { "kpiValue": 1, "kpiId": "quality-of-life---attractiveness" },
            { "kpiValue": 2, "kpiId": "water-drainage" },
            { "kpiValue": 1, "kpiId": "water-storage" },
            { "kpiValue": 50, "kpiId": "water-damage" },
            { "kpiValue": 15, "kpiId": "real-estate-value" },
            { "kpiValue": 1, "kpiId": "payback-period" },
            { "kpiValue": 1, "kpiId": "return-on-investment" },
            { "kpiValue": 8, "kpiId": "communications", "disabled": false }
         ]
      }
   ]
}
```
For the demonstration and evaluation sessions, the MCMSMA Module has 3 basic modes:

1. The Alternative mode, showing all individual scores for all Stakeholders for **ONE Alternative** (see Figure 18).
2. The Stakeholder mode, showing all individual scores for all Alternatives for **ONE Stakeholder**.
3. The Overall mode showing the **weighted overall score** for all Stakeholders for each Alternative (see Figure 19)

![Alternative mode MCMSMA Module](image)
For toggling between modes and cycling to the Alternatives/Stakeholders shortcut keys were used. This functionality was used and evaluated in Rotterdam and Valencia. Evaluation from these cases showed that an overall view with both the Stakeholders and Alternatives was missing. For this overall view a third mode was added, for all Alternatives showing an aggregated score based on the aggregated scores from the Stakeholders (evenly weighted).

Based on the experiences of the Stockholm and previous cases the following functionalities were added/removed:

- Mouse over for long Alternative / Stakeholder / KPI names
- Pull down menu for selecting the modes (Alternative / Stakeholder / overall)
- Pull down menu for selecting Alternatives / Stakeholder
- Pull down menu for comparison with the as-is or to-be.
- Filter for Alternatives, Stakeholders and KPI’s (see Figure 20)
- Shortcut keys for Toggling were removed
- Module for communication with the IMB Hub integrated as DLL.
- Screen capturing functionality was added to clipboard or file.
- Legend for colour of the scores was added.
• Configuration file for location of temporary files / selection of Port (443 or 4443) for communication with the IMB Hub.
• Filter for CaseID incorporated in corporation for preventing interference between different cases.
• Message when data is received from another case

Figure 20  Filter for Alternatives, Stakeholders and KPIs

The MCMSMA software is distributed as open access. It can be found on GitHub. Guidelines for the users can be found on the wiki.
4 CONCLUSIONS

This chapter focuses on the conclusions on the IDSS from a technical or implementation perspective. The conclusions on the applicability of the current version of the IDSS in decision processes of urban retrofitting projects are dealt with in Deliverable D5.4. From the technical perspective the following conclusions can be drawn from the IDSS Version 2.0 and its development process, reflecting back on the functional design (D4.1) and the technical design (D4.234) for the IDSS formulated at the beginning of the development process:

The Dashboard has been successfully implemented with a client–server approach, as the technical demands as formulated in the technical design, are all met:

a) Web-based: the architecture of the dashboard is fully web-based;
b) Technical demands with respect to interaction with users, the framework and data handling are all met;
c) Integration with the Framework using an IMB connector has been successfully implemented;
d) The dashboard is released completely open source under a BSD license and available for future use and further development.

The Framework has been successfully implemented with the IMB 4.0 Communication Hub, as the technical demands as formulated in the technical design, are all met:

a) Interactivity between users on different locations across Europe: all components of the IDSS are accessible via the internet; the system ran with hosts in Ireland, Sweden, the Netherlands, Belgium and France;
b) Interactivity between a user and one or more Modules (responding to a user action): users were able to invoke the available Calculation Modules in their decision process;
c) Interactivity between Modules (responding to another Module): the Modules shared the data functionality, the output from one Module could be used as input or the next;
d) Data exchange in standardized formats between Modules, allowing more Modules to be hooked up to the Framework relatively easy: data are stored in one shared database;
e) Data exchange between Modules and data stores in standardized formats, disabling the need for Modules to write and read to a data store themselves, making the Modules more manageable for developers: data are stored in one shared database;
f) Flexibility in terms of where Modules, user interfaces and data stores can reside within the Framework (e.g. on a local machine or on different locations): Modules used in the case studies ran both “in the cloud” and on local machines;
g) Long term expansibility: the modular set-up and external hosting allows the capacity for data storage, speed of data exchange and duration of use of the IDSS to be adapted flexibly.

The IDSS is ready for use in practice. The partners in ECODISTR-ICT encourage everybody to apply the system in their retrofitting projects and provide feedback on their experiences.
APPENDIX A REFERENCES TO OTHER ELEMENTS OF THE DELIVERABLE

The final deliverables of WP4 are the software (D4.8), the GitHub website, manuals for developers, a wiki for the end-users and this report. These can be found using the following links:

- GitHub site ECODISTR-ICT for the software code, executables and manuals for developers of its components: https://github.com/ECODISTR-ICT
- Wiki with end-users guidelines for the end-user ECODISTR-ICT components: http://ecodistr-ict.eu/wiki-section/
- Publically available deliverables of the ECODISTR-ICT project: http://ecodistr-ict.eu/public-resources/
- Previous Deliverables of the ECODISTR-ICT project which version 2.0 of the IDSS builds on: https://esites.vito.be/sites/ECODISTR-ICT/Deliverables/Forms/AllItems.aspx

8 For access to the ECODISTR-ICT SharePoint site at Vito, please, contact Ighor van de Vyver, ighor.vandevyver@vito.be, for more information.