BIM Based Information Management in Renewable Energy Projects

Marin Ljuban*, Marin Curavić**, Luka Budin***, Ivan Duilo***, and Marko Delimar***
* University of Ljubljana, Faculty of Civil and Geodetic Engineering, Ljubljana, Slovenia
** IT Sistemi, Split, Croatia
*** University of Zagreb, Faculty of Electrical Engineering and Computing, Zagreb, Croatia
marin.ljuban@gmail.com, marin.curavic@itsistemi.com, luka.budin@fer.hr, ivan.duilo@fer.hr, marko.delimar@fer.hr

***Abstract* – Proper implementation of Building Information Modelling (BIM) principles leads to better information management, and consecutively higher productivity in construction projects. BIM is an emerging methodology in the world of the built environment. It is a set of processes and standards, supported by digital technologies that aim to enhance information management in every phase of a project. From design and construction, through operations and maintenance, and finally the demolishing phase, BIM has shown advantages over traditional information management processes. Renewable energy is one of the areas which has significant potential, but a low adoption rate of BIM. The objectives of this paper are twofold. Firstly, to introduce the key concepts of BIM methodology to the reader and secondly, to examine them through the lens of renewable energy projects, more specifically, through the framework proposed in the FieldWork 4 RES platform.**

Keywords - BIM; renewable energy; information management; asset management; CDE

I. Introduction

Driven by policies and the market, as well as the negative climate change activities, renewable energy capacity is expected to increase more than twice as much in the next five years as it did in the past five years [1]. The sheer amount of projects that need to be developed on one side and the increasing costs of building materials and workforce on the other make it a necessity to optimize the construction process as much as possible. In that matter, optimized information management makes a key difference [2]. When dealing with optimized information management, as described in ISO 19650, two main fields are recognized: Building Information Modeling (BIM) and Common Data Environment (CDE).

The BIM approach takes its place as a response to the previously stated need for the optimization of the project's processes. As stated in [3], BIM represents a digital information management approach, using 3-D modelling with attached data that can be distributed between all project members, at all project stages from planning and design through maintenance and demolition. The main result of using the BIM approach is the more efficient use of resources, as well as more effective communication which enables greater flexibility between partners and improved long-term planning of the project itself. In short, Building Information Modeling provides a methodology that enables structuring the information so that technology can process it.

Design stage researchers are exploring the potentials of BIM, generative design, and machine learning for early-stage optimization, both for structural design [4] as well as occupant comfort [5]. Additionally, notable efforts are being done in the field of digital building permitting [6]. In the construction phase, a combination of BIM data and lean principles can ensure better project management [7]. The operations and maintenance phase has also seen an uptake in research in the last years [8], with research being done in the integration of BIM, BMS, and IoT for Facility Management [9], among many others. This research is being done both for new buildings, as well as existing buildings, with the special attention being on maintaining buildings of special cultural value, called Historic or Heritage BIM (HBIM) [10]. From the computer science point of view, the new trend in research is to explore the move from traditional, object-oriented data models towards more interoperable semantic web-based data models [11]. In addition to academic research, a strong link with the industry in the EU is fueled by public funding such as the Horizon Europe program, with many projects regarding digital building permitting, construction safety, energy consumption optimization, etc. currently being developed [12].

CDE, as stated in [13], presents a combination of technical solutions and process workflows represented by software (or another form of a tool) that allows all project participants to share important information about the project (including BIM models). The CDE workflow defines the processes used for collecting, managing, and disseminating structured and unstructured information, while the CDE solution is the technology that enables these processes. The introduction of CDE is a significant part of the realization of the ISO 19650 standard. The ISO 19650 standard, as shown in Figure 1, presents a subset of the complete ISO 55000 standard for asset management.

Furthermore, the surveys, carried out in [14], show that most of the surveyed companies are aware of the benefits of asset management, but lack the time, resources, and knowledge to properly implement the processes and tools required. Qualitative asset data is vital to risk management, but most companies still cope with it, often opting for the traditional paper-based workflows in more than 50% of cases. Also, 50% of companies don't use an IT system to handle their assets. It is stated that digitization of information management according to ISO 19650 could bring benefits to the renewable energy industry, both itself, as well as an intermediate step towards overall standardization of asset management per ISO 55000.

This paper is based on research developed through the project "Integrated solution for asset management and support of investment processes of design, planning, and implementation of renewable energy sources construction" supported by the European Union within the European Regional Development Fund (KK.01.2.1.02.0146).

FieldWork 4 RES (FW4RES) is a platform specialized in supporting Renewable Energy Sources (RES) projects in all project phases, from planning and preparation, throughout the construction of the RES projects, as well as the maintenance of the RES assets, including a full range of functionalities to satisfy the requirements of all end users – investors, planners, contractors, and managers. The FW4RES unites all the previously mentioned barriers and uses CDE and BIM for optimized information management. The FW4RES also includes a various number of functionalities for RES projects, which are listed and described in [15].

The objective of this paper is to present the implementation of key principles of information management using BIM methodology, as introduced in ISO 19650, on RES projects. This approach could utilize the data produced in the design stage to optimize the construction process, making it quicker and more efficient. At the end of the construction process, data would be verified and passed over to the asset managers, who could use it as input in their information management systems, extending it with new information about project maintenance as it is created.

This paper is presented in the following order; firstly, an overview of key concepts, terminology, and standardization in information management in construction is presented to introduce the theoretical framework of the application in RES projects; then, the BIM terminology is presented. Both areas are followed by application in the specific FW4RES use case.

II. Standardization of Information Management

The productivity of the construction industry grew by only 1% over the last two decades, in comparison with an average growth of 2.8%. The key way of actually improving productivity is adopting a collaborative approach across the industry [16]. To support collaboration efforts concerning new technology development, a standard was developed in the United Kingdom (BS 1192), which formed the base of the later published international standard ISO 19650 – „Organization and digitization of information about buildings and civil engineering works, including building information modelling“. The standard defines collaborative production and management of information across the lifecycle of a built asset. It is aimed at all people and organizations involved in the whole life cycle of an asset. In the context of asset management, it is also important that ISO 19650 can be interpreted as a subset of the international standards that define organizational and asset management.

A. Concepts and principles of ISO 19650

The key objects for decision-making throughout the life cycle of an asset are information models. Depending on the phase, they are named project information models (PIM), or asset information models (AIM). These information models can include structured information containers, such as video clips or unstructured information containers such as BIM models, or databases [18].

These information models are of key importance to all the participants involved in the project. To enable the successful delivery of these information models, ISO 19650 introduces many different terms regarding actor roles (e.g. appointing party, appointed party), teams (e.g. delivery team, task team), and document types (e.g. organizational information requirements, exchange information requirements), as well as the workflows that describe interactions between these actors, teams, and documents. All the aforementioned is described in detail in the standard itself and, for the sake of length, will not be discussed in this paper. However, one term, named common data environment (CDE) is of particular importance and will be examined more thoroughly.

Figure 1. Project and asset information management lifecycle [17]

B. Common Data Environment (CDE) workflow

Common Data Environment is an “agreed source of information for any given project or asset for collection, managing, and dissemination of each information container through a managed process”, where the information container is a “named persistent set of information retrievable from a file, system or application hierarchy” [17]. The CDE is a centralized repository for the management of data in the entire life cycle of a built asset. The ISO 19650 standard makes a clear distinction between the CDE workflow and a CDE solution, where a CDE workflow defines the processes to be used, while a certain CDE solution provides the technology that makes the implementation of these processes easier [17]. Several key concepts that make up a standardized CDE workflow are explained in the rest of this chapter.

Classification system - classification is a method of organizing entities logically, so they can be differentiated one from another. Many classification systems were derived from the core ISO 12006 standard, and the one commonly used in Europe is called Uniclass 2015. Uniclass is a faceted system that allows the classification of all building elements according to several tables (e.g. Products, Entities, Systems). Besides building elements, Uniclass has several additional tables that allow the classification of other important entities in the project, such as actors, and the activities they need to carry out.

Naming standard - information is, as mentioned, kept in the CDE in form of a structured or unstructured information container. To ease the navigation of the CDE user between all the different containers, a naming convention should be adopted following conventions set in the ISO 19650 national annex.

The information states – each of these containers can exist in various states. There are four states, shown in Figure 2. with their important characteristics. The presence of information states ensures that proper information is shared with exactly those actors that should receive the information, thus reducing the risk of information overload.

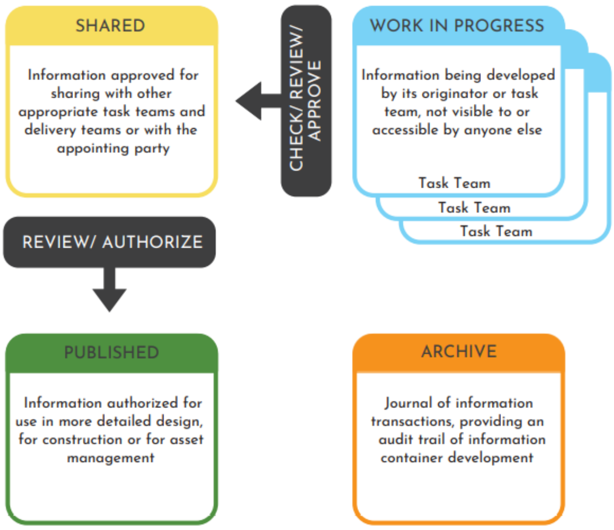

Figure 2. Common Data Environment information states [17]

Roles – similarly, all the project actors should be organized according to their roles and project teams (e.g., surveying company, civil engineering company, electrical engineering company) in the project to ensure that only the information needed is communicated to them.

- Classification code

Approval workflows – to put all the mentioned terms in a useful system, approval workflows are developed. These approval workflows take an information container as input, process it by sending it to different actors higher up the decision chain depending on the workflow, and after gaining approval, automatically change the information state of the specific container, making it visible to other actors.

C. Common Data Environment (CDE) solution

It is important to differentiate the workflow from a technological solution. While not practical, even a non–digital solution such as postal service can be classified as a CDE solution while CDE workflows are respected [15]. On the other hand, a cloud file repository (e.g. Dropbox, Google Drive) is not a CDE by itself because it does not have some of the features of the CDE workflow. The most common solution is the integration of CDE workflows in electronic document management systems (EDMS), which is also the situation in the FW4RES platform. Due to the complexity of the construction industry, CDEs are still primarily file-based opposed to most business process management solutions. It is useful for FW4RES to utilize both the database and file-based management of information.

FW4RES supports both horizontal and vertical hierarchical organizational arrangement at multiple levels, which adapts to any actual organizational structure of the business environment it serves as a CDE solution. Organizational units and corresponding project teams can be internal and external. Internal organizational units are departments or project teams within the business entity of the owner of the application that is specialized in performing a particular type of work. External organizational units or project teams are all organizational units that do not appertain to the business entity of the owner of the CDE solution. External organizational units are typically contractors or subcontractors as executors of the work.

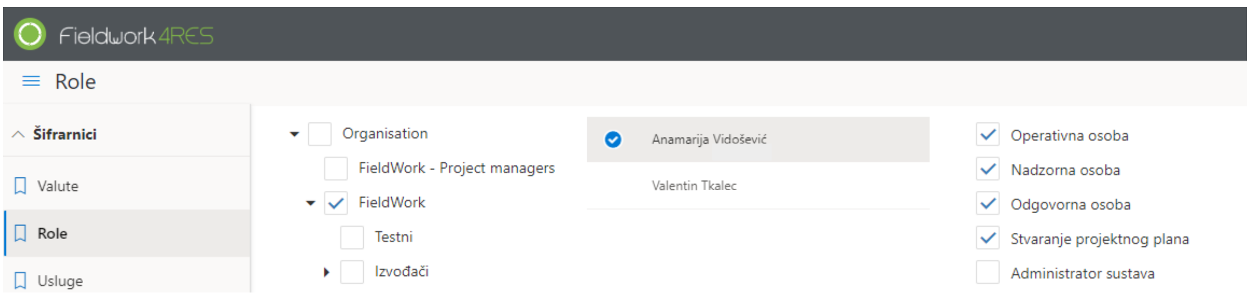

Figure 3. Screenshot from FW4RES – role management within an organizational unit

Metadata – metadata is formally defined as a set of data that describes information about other data. Container metadata is the information that describes this particular container more thoroughly. The ISO 19650 recommends that the following metadata is included in each information container:

- A revision code
- Status code

Also, FW4RES users can be assigned one or more roles within an organizational unit to work with documents, as shown in Figure 3. Through roles, the user is assigned a process role (action) on documents. Usually, three levels (operational, supervisor, and responsible) are considered quite sufficient and an optimum between administrative effort and the potential benefit. If necessary, however, the anticipated Uniclass system defines more than two hundred roles that could be used to describe actors in finer detail. For description purposes, Uniclass roles can be used as additional metadata for system users with the assigned solution role. The Uniclass roles table is also extendable and customizable according to specific business demands so it allows the additional definition of an arbitrary number of roles. The naming convention recommended for information containers is the one from the ISO 19650 UK Annex but can be customized as needed.

Considering project execution, the operational person as a first level should have the possibility of entering bills of quantities, distributing works, accepting the project plan, changing contractors, entering calculations, creating receipts, and manually opening production orders. The supervisory person as a second level of document approval supervises the operational person and accepts or rejects the report on the works carried out through the return for supplementation (correction). The responsible person as a third level of approval supervises the operational person and accepts or rejects the report on the works carried out through the return for supplementation (correction). Performs financial control and approves settlements. All these changes can go through predefined approval workflows and result in changing the database or moving the information container to another state in the CDE structure (e.g., from shared to published folder).

FW4RES's core function as a CDE solution is the planning and execution of construction or operation and maintenance projects. Hence, the project plan is the first document in the development process and as such is a prerequisite for the creation of all other documents because all types of later-created documents in the process are linked to the approved project plan and derived subprojects. Through the project plan (creation of the new project is shown in Figure 4.), the primary division of the work in the planning phase is done. This work-in-progress information state has multiple substates (new project plan, approved supervisor, approved responsible, accepted). Approved and accepted project plan is translated into shared or in realization state creating a detailed design plan with detailed subprojects and situations whose structure is identical to the structure of the project plan – subprojects. With the creation of a detailed design plan with detailed sub-projects and situations, the planning phase is completed, and the implementation phase begins with the project being published. After it stops being useful, each information container changes its state to the archive information state to keep its content and audit trail available.

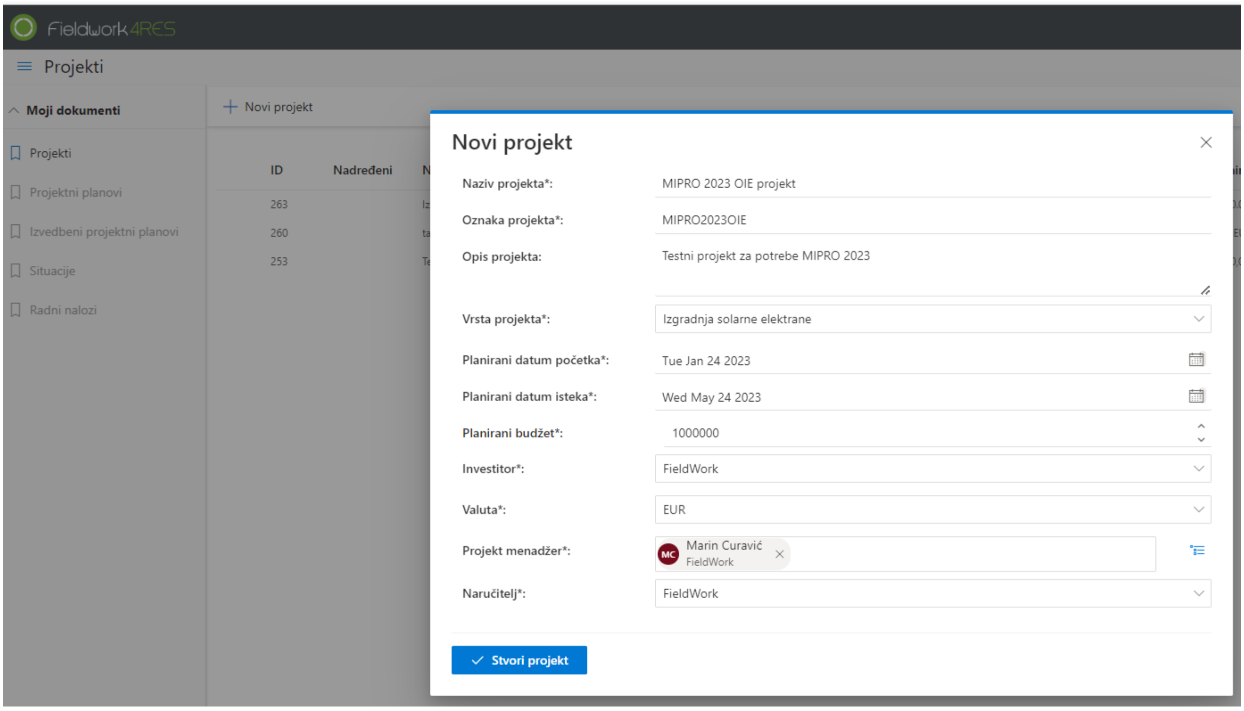

Figure 4. Screenshot from FW4RES – creation of the new project using input data

III. Building Information Modelling

A building information model should be the main container in the information management process aligned to ISO 19650, and all the other information containers should refer to it [18]. A building information model is the consequence of the realization of BIM methodology in a project. Due to its key role in information management, it is of key significance to understand what BIM represents.

BIM is most easily explained as a set of standardized digital construction processes. These processes are supported by technology and result in an accurate virtual model of the project being designed. The model is built by placing instances of BIM objects in the model, and each of these objects contains alphanumeric metadata that describes it. By building the project digitally before it is built, BIM brings several important benefits to the involved actors. This model is used as the key part of information exchange in all the project stages. Benefits of BIM consist of, however, are not limited to [19]:

- Design:
  - earlier and improved collaboration of different disciplines,
  - earlier and more accurate visualizations,

- increased consistency of data and design drawings,
  - improved cost estimation
- Construction:
  - synchronization of design and construction planning,
  - better implementation of lean construction techniques,
  - synchronization of procurement with design and construction
- Operations and maintenance:
  - improved commissioning and handover,
  - improved visualization of operations,
  - easier communication with field workers.

Furthermore, it is essential to highlight that although a 3D model (like the one shown in Figure 5.a) is the most prominent deliverable of the process, 3D models that do not contain metadata cannot be categorized as BIM models. BIM models are data-rich and parametric, and very often alphanumeric data contained within elements proves to be more useful than the geometry itself, especially in the O&M stage. In the example, each element of the geometrical model (Figure 5.a) can be accessed individually and contains information about the manufacturer, installation date, and warranty, among others (Figure 5.b). BIM can also be used for better information management of already existing projects using the scan-to-BIM method, as shown in figure 6.

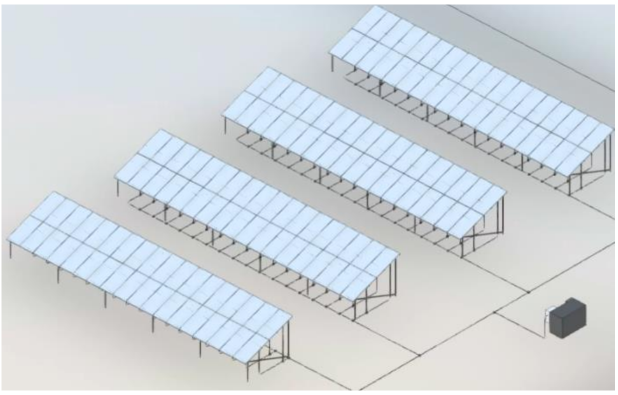

Figure 5.a Solar power plant IFC model – SE VIS Solis

TagNumber	IfcGUID	Accessibili	AssetT	ClassificationCategory	Colour	Description	DurationUnit	Ex	Manufacturer	ModelNumber
01_01_01	3Di2VImD99f8MjR0Bn8ral	NoIssues	Fixed	Pr_60_70_65_63	Aluminium	Solar Panel	Years	25	Longi	450
01_01_02	3Di2VImD99f8MjR0Bn8rbY	NoIssues	Fixed	Pr_60_70_65_63	Aluminium	Solar Panel	Years	25	Longi	450
01_01_03	3Di2VImD99f8MjR0Bn8rbo	NoIssues	Fixed	Pr_60_70_65_63	Aluminium	Solar Panel	Years	25	Longi	450
01_01_04	3Di2VImD99f8MjR0Bn8rb2	NoIssues	Fixed	Pr_60_70_65_63	Aluminium	Solar Panel	Years	25	Longi	450
01_01_05	3Di2VImD99f8MjR0Bn8rbl	NoIssues	Fixed	Pr_60_70_65_63	Aluminium	Solar Panel	Years	25	Longi	450
01_01_06	3Di2VImD99f8MjR0Bn8rwY	NoIssues	Fixed	Pr_60_70_65_63	Aluminium	Solar Panel	Years	25	Longi	450
01_01_07	3Di2VImD99f8MjR0Bn8rwo	NoIssues	Fixed	Pr_60_70_65_63	Aluminium	Solar Panel	Years	25	Longi	450
01_01_08	3Di2VImD99f8MjR0Bn8rw2	NoIssues	Fixed	Pr_60_70_65_63	Aluminium	Solar Panel	Years	25	Longi	450

Figure 5.b Part of the non – graphical data for the solar power plant IFC model

A. Terminology

Since BIM aims to manage information of a project in all of its stages, as well as the information of all the disciplines (e.g., architecture, mechanical, and electrical engineering), it has to solve many interoperability issues to be able to communicate effectively. To do so, many standardization efforts have been undertaken, most of them led by an international non-profit organization buildingSMART. After spending some time in the development, the most

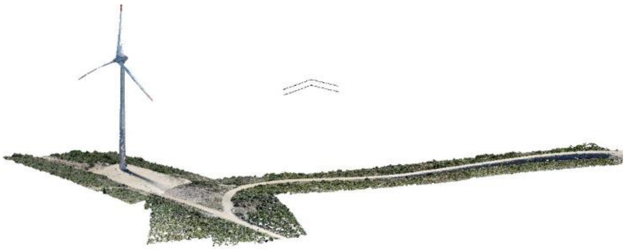

Figure 6. Photogrammetry model used as a starting point for scan-to-BIM method for creating wind power plant model – VE Danilo

successful efforts were formalized in the form of ISO standards. Others are not formalized in the ISO standard form, but their wide use makes them the *de facto* standard. The ones that are key to understanding the workflow are explained below.

IFC – to standardize information exchange on the software implementation level, a common language needed to be created. This language is called Industry Foundation Classes, often abbreviated as IFC. The IFC is an open, non-proprietary, and standardized digital representation of built assets. It is an EXPRESS-based, object-oriented data model that describes the identity, characteristics, and relationships of objects. Objects can be built objects, such as columns, slabs, or energy conversion devices, but also processes (installation, maintenance), people (owners), and abstract concepts (performance, costs). A such data model is encoded in different file formats (XML, JSON, STEP), and used to exchange information between actors [20]. As the core interoperability concept in construction, IFC is currently undergoing a transformation that will enable it to move from a file-based sharing to being used in a transactional environment [21], making it possible to integrate it completely with the business process management solution in FW4RES.

BCF – while IFC enables interoperability between software tools, it does not solve the issue of communication between actors that work in different software. For this purpose, the BIM Collaboration Format (BCF) was created. It can be described as an additional layer on top of the IFC. After selecting an IFC object, the user can create issues and assign them metadata such as description, responsibility, and deadline. These issues can then be delivered to other actors via the cloud (through BCF-API) or encoded in a file format (BCF-XML).

B. BIM in FieldWork 4 RES (FW4RES)

Generally, the utilization of BIM models in tools downstream from the authoring tools depends on the BIM uses that model is designed for. Since the model is always a simplified representation of reality, it is important to establish these model uses before a specific project, according to one of the established models, such as the Penn State or BIMe Initiative model framework.

FW4RES aims to utilize the BIM model throughout the complete lifecycle of the built asset, from the design and planning phase until the decommission, but like any other tool, is not powerful enough to have all the functionalities needed in a project. The most prominent uses it is aimed for can be grouped into two model use series per BIMe Initiative [22]. The first series is capturing and representing, and the second one is operating and maintaining.

Depending on specific project workflows, the IFC model can be designed in an authoring tool (e.g. Revit), and later enriched with data regarding quantity takeoff, cost estimation, or project planning in another tool (e.g. Bexel Manager). Such a model can be imported to the FW4RES platform at any stage. The platform has an integrated IFC parser that can obtain all the information about the model such as a spatial tree, non-graphical properties, and metadata, among others, and display it to the user. It can also render the IFC model, showing it in 3D view, where all the elements and their properties can be accessed individually. There are also possibilities to extend the platform with specific tools, that would parse the data from the model and then show it in specific views, such as cost breakdowns and Gantt charts, among others. This is an important benefit that is aimed at supervising and responsible roles in the project. They can access the latest model at any stage of the project, and without knowledge of specific software and access to often expensive licenses, they can examine and report possible issues back to the operating personnel.

The second important aspect is operation and maintenance. After the project close-out and handover of the verified as-built model, the need for specific tools does not exist anymore, and the FW4RES platform can be utilized as the only source of information for all the actors in the project. The supervising and responsible actors can access the web platform and input the data about the planned maintenance through the BCF format. Depending on the specifics of each project and other tools used (e.g., ERP), integrations via BCF-API can be made to ensure relevant data streams. After doing the planned maintenance activities, the operating actors can report the successful completion of these activities, as well as possible issues, again via BCF.

IV. Conclusion

Most stakeholders involved in renewable energy projects are conscious of the significance of proper asset management, but most still do not do it in a standardized way. Information management is an important subset of asset management, and the digitalization of information management is an important intermediate step towards efficient asset management throughout the life cycle of a renewable energy project. This paper investigates the possibilities of implementation of standardized information management principles from construction projects, as stated in ISO 19650.

Starting as an attempt to organize the novel methods of project delivery revolving around BIM methodology, ISO 19650 introduced several important concepts in information management, the most notable of which is the notion of a Common Data Environment. The CDE is a central repository for the collection, management, and dissemination of information in the project, where ISO 19650 separates the CDE workflow from a CDE solution. The paper presents universal concepts of CDE workflow and also presents how these should be implemented in the CDE solution of the FW4RES platform. An additional facilitator of information management is the introduction of the most important principles of BIM and their implementation in the FW4RES platform.

The future work will be focused on the complete implementation of the concepts presented in a functional FW4RES solution. Besides the implementation, future work will also keep track of the latest developments in the interoperability domain (IFC 5, openCDE API) to make the FW4RES interoperable with further solutions, both more granular (e.g., contractor CDEs), as well as more consolidated (e.g., municipality digital twin platform).

References

[1] International Energy Agency, “Renewables2022 - Analysis and forecast to 2027,” 2022. [Online]. Available: link

[2] P. Adekunle, C. Aigbavboa, O. Akinradewo, A. Oke, and D. Aghimien, “Construction Information Management: Benefits to the Construction Industry,” *Sustainability (Switzerland)*, vol. 14, no. 18, Sep. 2022

[3] “BIM and ISO 19650 from a project management perspective.” [Online]. Available: link

[4] L. Gradišar, R. Klinc, Ž. Turk, and M. Dolenc, “Generative Design Methodology and Framework Exploiting Designer-Algorithm Synergies,” Buildings, vol. 12, no. 12, Dec. 2022

[5] H. H. Hosamo, M. S. Tingstveit, H. K. Nielsen, P. R. Svennevig, and K. Svidt, “Multiobjective optimization of building energy consumption and thermal comfort based on integrated BIM framework with machine learning-NSGA II,” Energy Build, vol. 277, Dec. 2022

[6] F. Noardo et al., “Unveiling the actual progress of Digital Building Permit: Getting awareness through a critical state of the art review,” Building and Environment, vol. 213. Elsevier Ltd, Apr. 01, 2022.

[7] K. el Mounla, D. Beladjine, K. Beddiar, and B. Mazari, “Lean-BIM Approach for Improving the Performance of a Construction Project in the Design Phase,” Buildings, vol. 13, no. 3, p. 654, Feb. 2023

[8] O. Adetayo, D. Onatayo, “A Scientometric Review of BIM in Facility Management Research,” 2023, [Online]. Available: link

[9] L. Chamari, E. Petrova, and P. Pauwels, “A web-based approach to BMS, BIM and IoT integration: a case study Holistic BIM-Based Sustainable Building Design and Performance Assessment View project Flemish Cities in Transition-A Framework for a Web-based Built Heritage Platform Using BIM, GIS and Linked Data View project A web-based approach to BMS, BIM and IoT integration: a case study”

[10] M. Bonduel, “A Framework for a Linked Data-based Heritage BIM”, 2021, [Online]. Available: link

[11] K. Jeon and G. Lee, “The Status Quo of Graph Databases in Construction Research”, 2022, [Online]. Available: link

[12] SmartBuilt EU, “Smart Buildings EU-funded Innovations – January 2023” 2023.

[13] J. Ford and G. Try, “Facilitating the common data environment (workflow and technical solutions).” [Online]. Available: link

[14] Deloitte, “Asset Management: A Risk-Based ApproachEnergy & Resources Benchmark Survey”. [Online]. Available: link

[15] M. Curavić, Z. Mavretić, I. Duilo, L. Budin and M. Delimar, "Blockchain Application in Digital Platform FieldWork 4 RES used for Planning and Realization of Renewable Energy Sources Projects," 2022 45th Jubilee International Convention on Information, Communication and Electronic Technology (MIPRO), Opatija, Croatia, 2022, pp. 65-70

[16] McKinsey Global Institute, “Reinventing Construction: A Route to Higher Productivity”. [Online]. Available: link
[17] International Organization for Standardization, *ISO 19650-1:2018(en) Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles.* [Online]. Available: link
[18] Sphere, “How to move digital twin environments to the AECOO sector.” [Online]. Available: link
[19] C. Eastman, P. Teicholz, R. Sacks, and K. Liston, “BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors.” Wiley, 2018.
[20] T. Pazlar and Ž. Turk, “Interoperability in practice: Geometric data exchange using the IFC standard,” *Electronic Journal of Information Technology in Construction*, vol. 13, pp. 362–380, Jan. 2008.
[21] L. van Berlo, T. Krijnen, H. Tauscher, A. van Kranenburg, P. Paasiala, and solibricom Solibri, “Future of the Industry Foundation Classes: towards IFC 5.” [Online]. Available: link
[22] B. Succar, N. Saleeb, W. Sher, “Model uses: foundations for a modular requirements clarification language” Australasian Universities Building Education (AUBEA2016), Cairns, Australia, July 6-8, 2016