up to date, for example if the characteristics of a component a provided in two different formats.

In fact, the fixed hierarchical ontology of formats like the IFC is not needed anymore because most people use the search instead of clicking through the hierarchy. Semantic BIM "structures itself" and makes it easier to find what you need. With this, it solves the problem of having too few or too many entities.

On the one hand side, innovations which go beyond current hierarchies can easily be described with sematic web technologies, by pointing to the entities of a data dictionary. On the other side, there is no complex hierarchy which makes semantic BIM simple for new users.

Semantic Product Database

Lawrence Berkeley National Laboratory (LBNL) plans cooperate with Fraunhofer Institute for Solar Energy Systems (ISE) to create a cloud-based international product data base for architectural glazing, daylighting, solar-shading and active-solar components. It will be based on improved measurement and data-processing methods and use semantic technologies so that practitioners can easily find and include the most suitable available products in their planning.

To date, laboratories can provide an extensive amount of measurement data for components. If a planner receives this data, they can often use only a part of this data. In the future, companies should need to measure their components only once and planners should have access to the detailed measurement data of a large number of components. Furthermore, it should become simple to extract the relevant information and use it directly for a building project.

CONCLUSION

This paper proposes four ways to use digitalization to reduce the costs and increase the reliability of building performance simulation. First, functions in machine-code can be used to reduce the cost of creating simulation models, to facilitate the exchange of capabilities and to reduce errors in this exchange.

Second, simulations models are proposed which adapt their accuracy and can therefore be used from very early up to late stages of the planning process. This enables a higher accuracy and reduces the cost of switching to more accurate models.

Third, BIM based on semantic technologies is proposed to provide more flexibility and make it easier to find the right components.

Finally, a semantic international product data base is planned by LBNL and Fraunhofer ISE to make it easier for practitioners to identify most suitable product.

ACKNOWLEDGMENTS

This work was funded by the German Federal Ministry for Economic Affairs and Energy (BMWi), based on a decision by the German Bundestag.

REFERENCES

Beausoleil-Morrison, Ian, Michaël Kummert, Francesca Macdonald, Romain Jost, Timothy McDowell, and Alex Ferguson. 2012. "Demonstration of the new ESP-r and TRNSYS co-simulator for modelling solar buildings." Energy Procedia, 30: 505–14. DOI:10.1016/j.egypro.2012.11.060.

Beetz, Jakob, Jos van Leeuwen, and Bauke de Vries. 2009. "IfcOWL: A case of transforming EXPRESS schemas into ontologies." Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 23 01: 89. DOI:10.1017/S0890060409000122.

Crawley, D. B., J. W. Hand, M. Kummert, and B. T. Griffith. 2008. "Contrasting the capabilities of building energy performance simulation programs." Building and Environment, 43: 661–73. DOI:10.1016/j.buildenv.2006.10.027.

Djunaedy, E. External coupling between building energy simulation and computational fluid dynamics. Technische Universiteit Eindhoven.

Gao, Ge, Yu-Shen Liu, Pengpeng Lin, Meng Wang, Ming Gu, and Jun-Hai Yong. 2017. "BIMTag: Concept-based automatic semantic annotation of online BIM product resources." Advanced Engineering Informatics, 31: 48–61. DOI:10.1016/j.aei.2015.10.003.

Horvat, Miljana, and Maria Wall. 2012. "Report T.41.B3: Solar Design of Buildings for Architects: Review of Solar Design Tools: IEA SHC Task 41 Solar Energy and Architecture." Accessed July 15.

Janak, M. 1997. "Coupling building energy and lighting simulation." Paper presented at the Building Simulation Conference 1997, Prague, September 8-10.

Maurer, C., T. Baumann, M. Hermann, P. Di Lauro, S. Pavan, L. Michel, and T. E. Kuhn. 2013. "Heating and cooling in high-rise buildings using facade-integrated transparent solar thermal collector systems." Journal of Building Performance Simulation: 1–9. DOI:10.1080/19401493.2013.766263.

Maurer, Christoph, and Tilmann E. Kuhn. 2017. "Modelling of active building envelopes for cost-

effective evaluation." Journal of Facade Design and Engineering, 5 2: 75–82. DOI:10.7480/jfde.2017.2.1740.

Maurer, Christoph, Wendelin Sprenger, Steffen Franz, Marouane Boudhaim, Jan Lodewijks, Uwe Rüppel, and Tilmann E. Kuhn. 2017. "Machine-code functions in BIM for cost-effective high-quality buildings." Energy and Buildings, 155: 467–74. DOI:10.1016/j.enbuild.2017.09.029.

Mitterhofer, Matthias, Georg F. Schneider, Sebastian Stratbücker, and Klaus Sedlbauer. 2017. "An FMI-enabled methodology for modular building performance simulation based on Semantic Web Technologies." Building and Environment, 125: 49–59. DOI:10.1016/j.buildenv.2017.08.021.

Pauwels, Pieter, and Walter Terkaj. 2016. "EXPRESS to OWL for construction industry: Towards a recommendable and usable ifcOWL ontology." Automation in Construction, 63: 100–133. DOI:10.1016/j.autcon.2015.12.003.

Sahlin, Per, and Edward F. Sowell. 1989. "A Neutral Format for Building Simulation Models." Paper presented at the Building Simulation Conference 1989, Vancouver, Canada, June 23-24.

Trčka, Marija, Jan L. Hensen, and Michael Wetter. 2009. "Co-simulation of innovative integrated HVAC systems in buildings." Journal of Building Performance Simulation, 2 3: 209–30. DOI:10.1080/19401490903051959.

Wetter, Michael. 2011. "Co-simulation of building energy and control systems with the Building Controls Virtual Test Bed." Journal of Building Performance Simulation, 4 3: 185–203. DOI:10.1080/19401493.2010.518631.