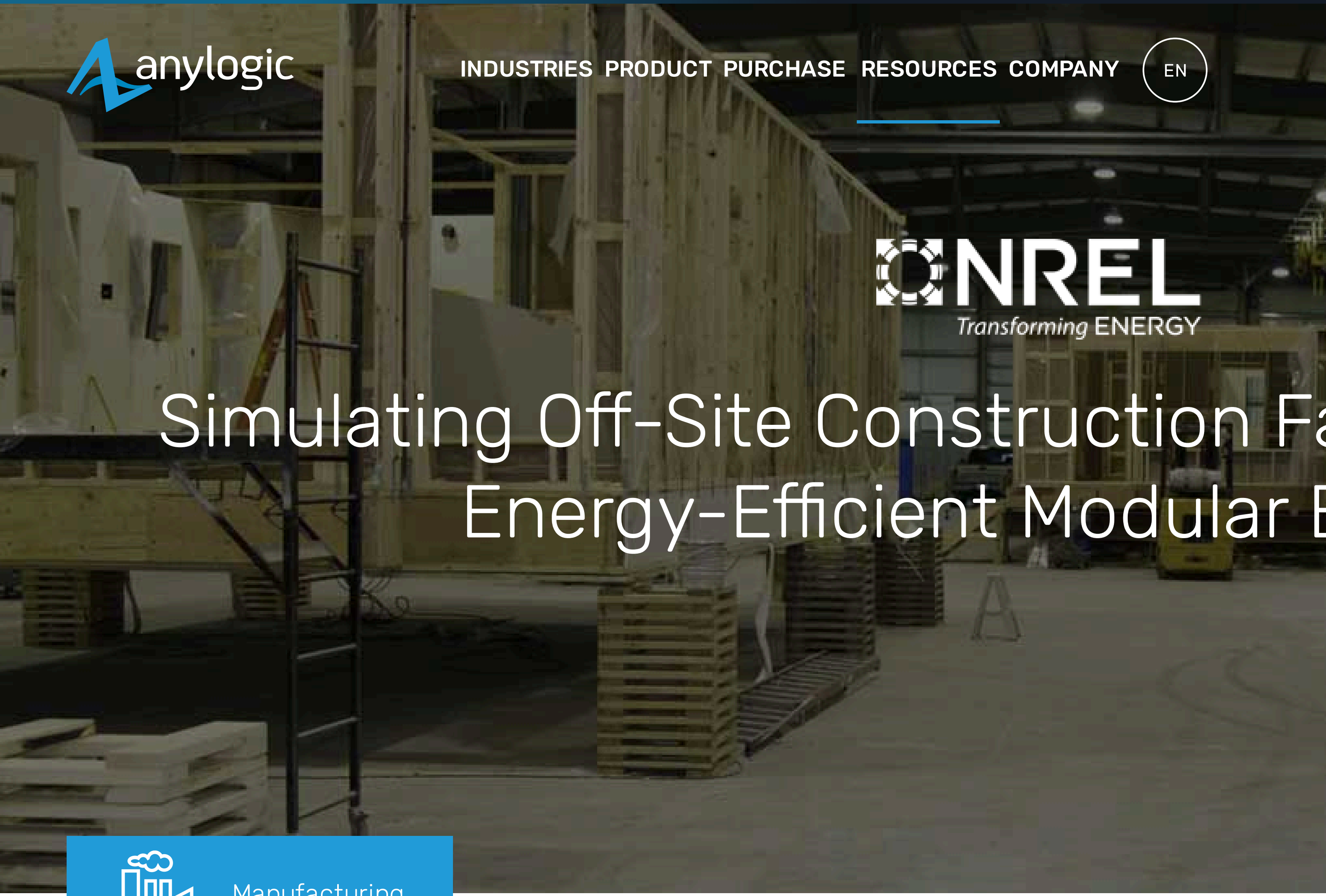



# Simulating Off-Site Construction Fa
# Energy-Efficient Modular E

Manufacturing

In the United States there is a significant divergence between manufacturing productivity and construction productivity. From 1994 until 2011, productivity in manufacturing almost doubled, but in construction it remained flat. In addition, buildings are one of the most carbon-intensive and energy-consuming industries or sectors in the US.

The challenge for the construction industry, and especially the building sector, is to improve productivity

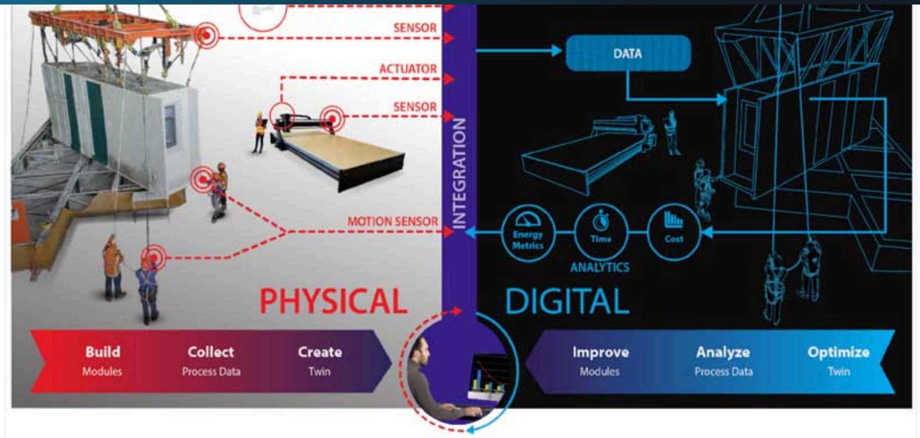
The US DOE is pushing an initiative called Advanced Building Construction (ABC) to deliver affordable, appealing, energy-efficient, and low-carbon new buildings. In addition, they are looking at methods to integrate more energy efficiency in the highly productive construction sector of the US. The US DOE is investing in new technologies, while at the same time engaging with stakeholders from both the public and private sectors.

The NREL, together with the US DOE, have two specific approaches to achieve the set targets. The first is permanent modular construction, which is when buildings are constructed off-site before they are transported and assembled at the final site. The second is simulation environments and a digital twin, where a model is combined with the current state of a live system. Existing tools such as AnyLogic can be used to achieve this.

In an off-site construction factory in the US, there is a manual workforce and a large material handling system. The final product is shipped to the required destination, where it is assembled with minimal work. It is 40% faster to build in this way, however, it is unclear if the process is more energy-efficient and leads to more energy-efficient and low-carbon buildings. This is where a digital twin and simulation environments can be used to understand the processes involved, make better decisions, and deliver these buildings.

## Solution

The NREL uses a data collection strategy for the off-site factory, which in this case is the physical

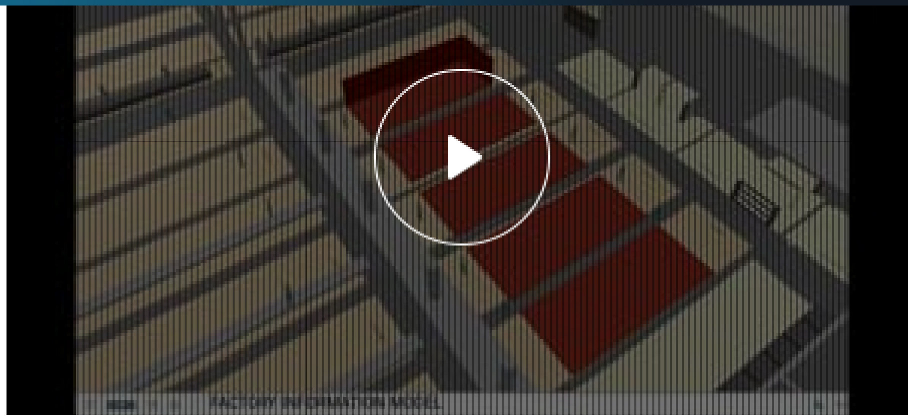



Near-real time simulation of off-site construction factories with every process and discrete activity involved

Off-site factories still require a lot of manual labor, and so it is difficult to understand the implications of labor productivity, cycle time or even downtime. This led to using AnyLogic multimethod simulation modeling.

An agent-based approach can simulate actions and interactions of autonomous agents, which in this case are the construction workers. Discrete-event simulation modeling works better with simple assembly lines and conveyors. In system dynamics, layers of the material handling system and material flow can be added. To really understand the labor productivity, a multimethod simulation model can be created, but with a strong focus on the agent-based approach.

The inputs in the model are the worker movements and activities that are taken from real world off-site factories. These inputs can then be placed in the AnyLogic environment. The video below shows the modeled factory floor. Here, human resources are



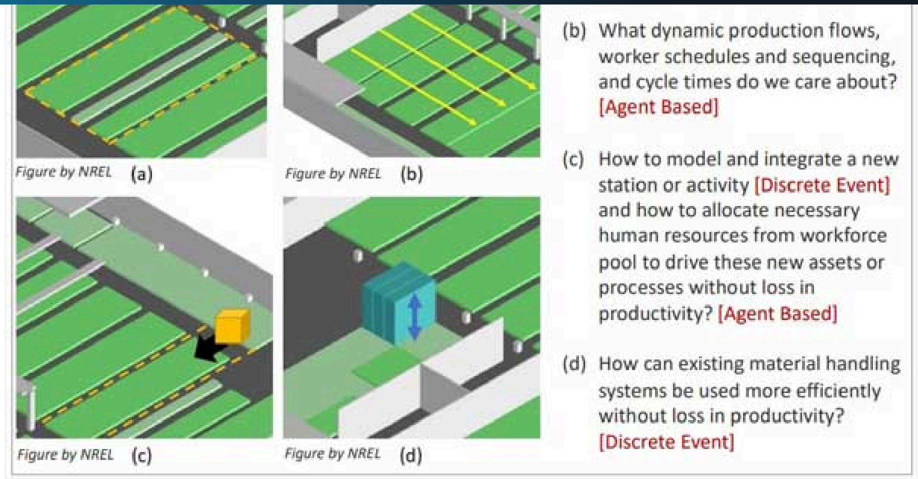
Video of the factory simulation model

In the model there are different stations, and in each station there are workers allocated. As the modular unit moves across these stations, those particular stations' resources are activated and the exact schedule of the workers from the real-world situation is added as an input in the factory model. Therefore, a baseline for the existing condition of the factory can be created.

The entire factory can be simulated in great detail and in the model it is possible to zoom in to really understand the different stations. The modeler can really understand the effects of the material handling system.

Looking closer at four different areas of the created model (see diagram below), numerous research questions can be identified using the simulation environment. These questions can then be mapped to different methods within AnyLogic. Answering these questions allows for a better and low-carbon efficient product to be delivered.

Model builders, using what-if scenarios, look at the



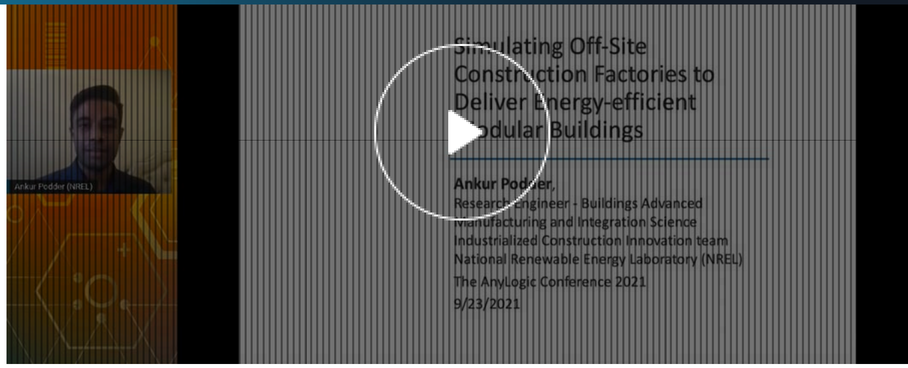

What-if scenario modeling in AnyLogic (click to enlarge)

## Next Steps

This model is a work in progress and as near-real time data is continuously received from deployed cameras and sensors in participating factories across the US, it continues to be improved. The current model shows how to represent an existing factory, but in the future, once there is an established baseline, what-if scenarios can be created and AnyLogic capabilities will allow this to be done. The future work will involve what-if scenarios for trade-off analysis and productivity vs new resources and activities.

The case study was presented by Ankur Podder, of the National Renewable Energy Laboratory (NREL), at the AnyLogic Conference 2021.

The slides are available as a PDF.

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