

SD229074

Getting Started with Generative Design for AEC

Kean Walmsley

Autodesk Research

Learning Objectives

- Understand the core concepts behind generative design across industries
- See examples of how Autodesk Research is using generative design in AEC
- Learn how Dynamo can be used with Refinery to implement generative-design workflows
- Become familiar with Autodesk's plans for generative design in the AEC space

Description

Much of the early work around generative design at Autodesk was focused on manufactured products. Increasingly, though, it is being applied to design problems in architecture, engineering, and construction (AEC). Autodesk Research—mainly through its New York-based architectural studio, The Living—is exploring how one can use generative design to solve a variety of problems in the AEC space. Recent examples include Project Discover, where survey data from Autodesk's Toronto-based employees was used to help choose the layout for our new office in the MaRS Discovery District. Generative design was also used in the design of the Autodesk University 2017 exhibit hall. During this session we'll take a look at the tools available from Autodesk to apply generative design in the AEC industry. And we'll show how to get started with generative design by driving Dynamo with Refinery, Autodesk's new optimization engine.

Speaker

Kean Walmsley is a Platform Architect and Evangelist working for Autodesk Research. Blogs and tweets about developing with Forge, AutoCAD and other Autodesk technology, especially with respect to IoT, VR and AR.

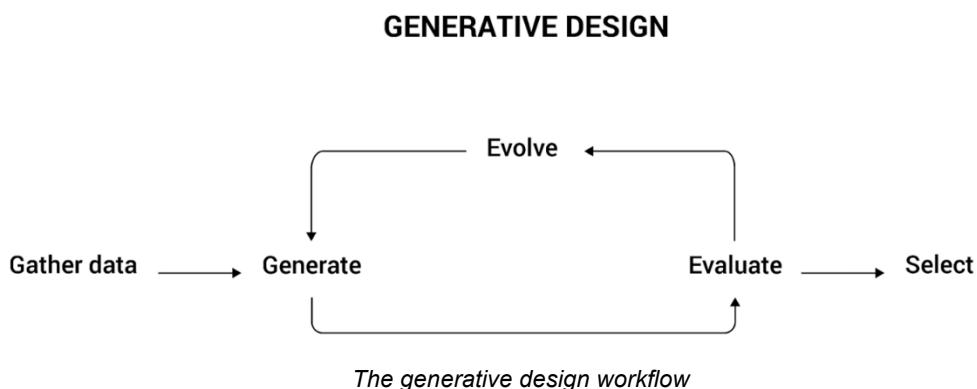
kean.walmsley@autodesk.com

<https://keanw.com>

<https://twitter.com/keanw>

Generative Design

Generative design is a framework for combining digital computation and human creativity to achieve results that would not otherwise be possible. It involves the integration of a rule-based geometric system, a series of measurable goals, and a system for automatically generating, evaluating, and evolving a very large number of design options. This approach offers many benefits for designing buildings and cities – including managing complexity, optimizing for specific criteria, incorporating a large amount of input from past projects and current requests, navigating trade-offs based on real data, structuring discussion among stake-holders about design features and project objectives, offering transparency about project assumptions, and offering a “live model” for post-occupancy adaptation. The framework consists of three main components: 1. **generate** a wide design space of possible solutions through a bespoke geometry system; 2. **evaluate** each solution through measurable goals; 3. **evolve** generations of designs through evolutionary computation.

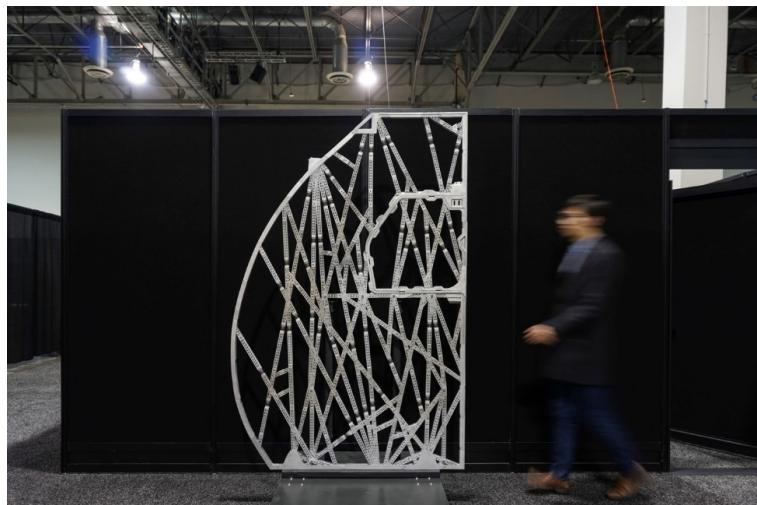


Generative Design is a flexible and scalable framework. It can be applied to a wide range of design problems and scales: from industrial components all the way to buildings and cities.

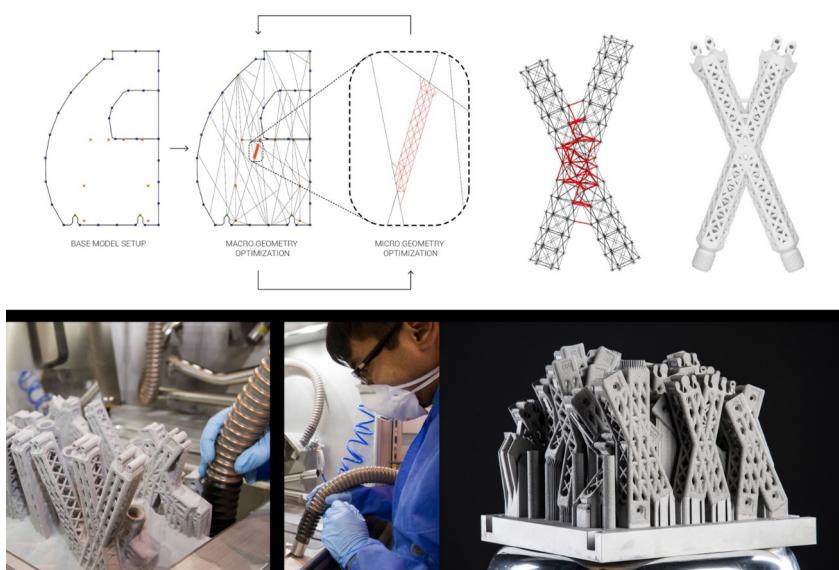
Autodesk Research into Generative Design

The Bionic Partition | Generative Design for Manufacturing

The Bionic Partition is a next generation airplane component designed for Airbus through the application of generative design. It involved creating a custom algorithm using bio-logical rules and two measurable goals: weight and maximum displacement. The result is a metal 3D printed component that is almost 50% lighter and almost 10% stronger than traditional partitions.



Final metal 3D printed partition



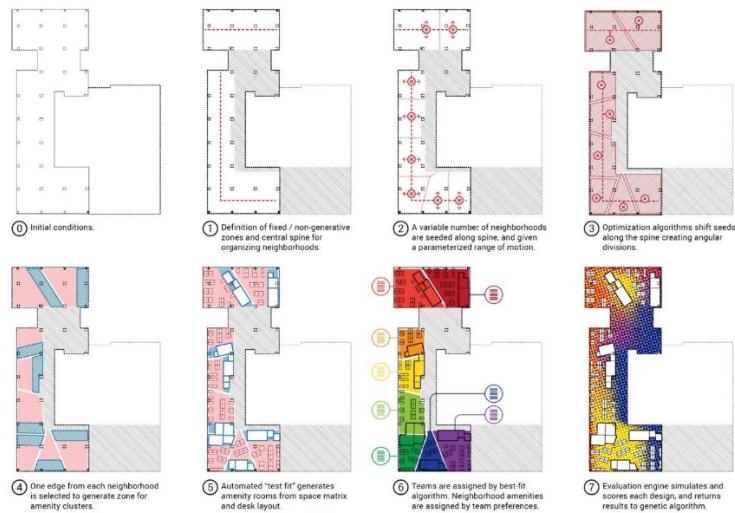
Macro and micro optimization and metal 3D printing process

Autodesk MaRS Office | Generative Design for Architecture

Architecture can often become a more challenging problem than engineering ones. In fact, architecture, unlike engineering projects, involves qualitative aspects of the experience of space that are less tangible and more difficult to measure. In 2017 The Living pushed the boundaries of generative design and applied this framework to architecture for the design of the new Autodesk offices in the MaRS Discovery District in Toronto. The geometric system incorporated several levels of constraints including the size of the space, the number of amenities and meeting rooms and fixed locations for cores and mechanical rooms. The goals combined qualitative aspects of human experience (such as ‘workstyle preferences’ and ‘adjacency preferences’) with quantitative measures (such as ‘daylight’, ‘buzz’ and ‘productivity’). The process allowed the designers to go beyond the one-size-fits-all type of approach to workspace design and offer a space that was diverse and rich in features. Through ongoing monitoring of the space and survey-based data collection, generative design can be used to suggest new design options and the scoring algorithms can be improved.



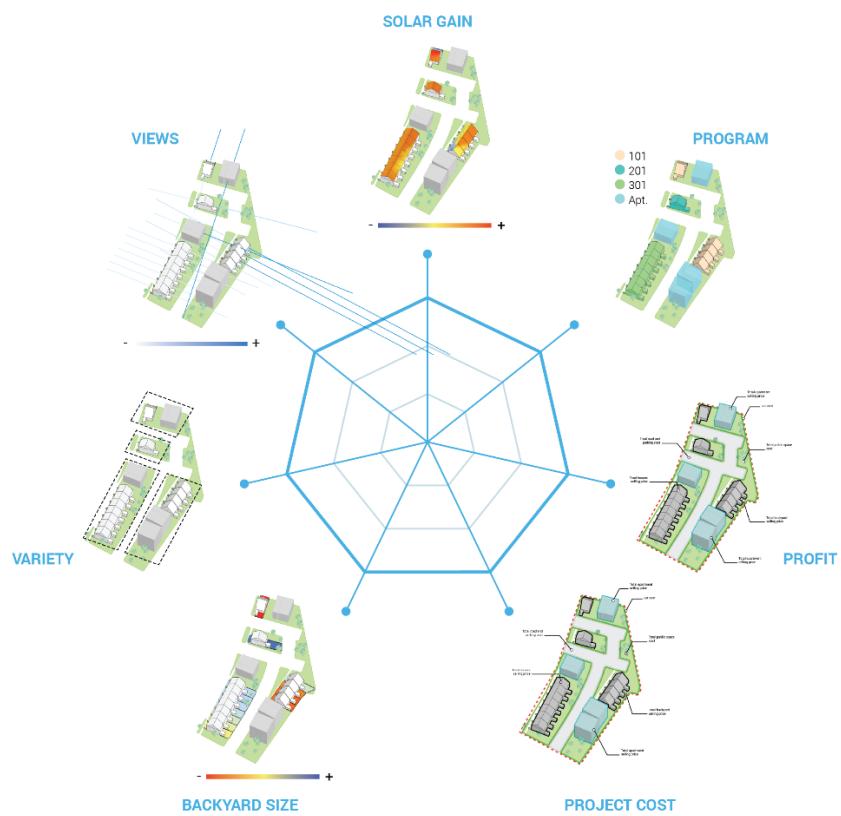
Design goals: adjacency preferences; workstyle preferences; buzz; productivity; daylight; views to outside.



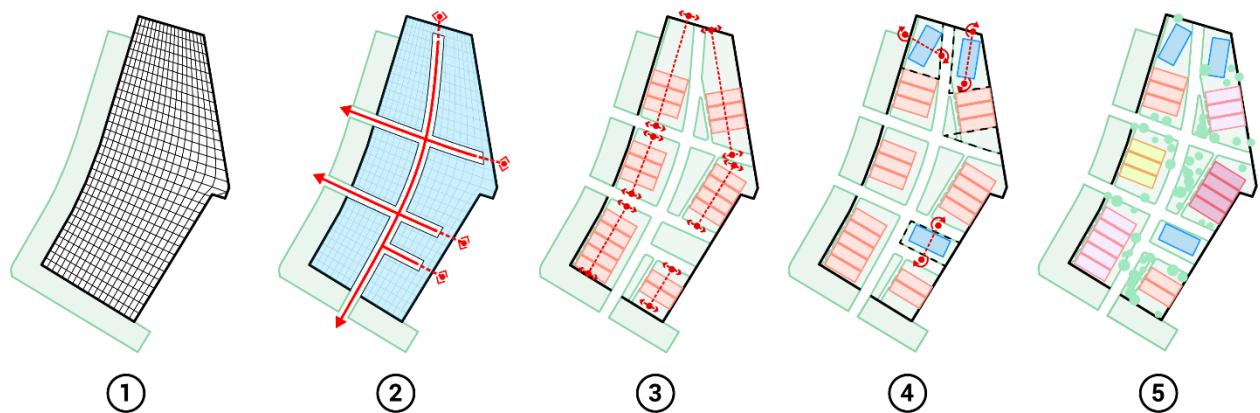
Geometric system: (0) incorporate constraints; (1) define generative and non-generative zones; (2-3) subdivide space into neighborhoods; (4) generate ‘amenity bars’; (5) generate ‘test fit’; (6) assign teams; (7) evaluate solution.

Alkmaar Residential Neighborhood | Generative Urban Design

Van Wijnen is an innovative Dutch development and construction company that seeks to change the way buildings are designed and made. In 2017 they partnered with The Living to apply generative design at the scale of the city. The project involved the design of a geometric model that could meet the local building code constraints (such as number and location of access streets, setbacks, parking rules etc.), and satisfy the developer's requirements (such as amount of two-story residential units and apartment buildings). Urban design problems generally present many stakeholders, often representing conflicting requirements and interests, thus intensifying the complexity of the design. Generative design is able to aid the management and structuring of such complexity through the definition of the goals. In this case the project involved seven distinct goals, including financial ones (revenue and construction cost), environmental ones (such as solar gain and views), as well as more architectural ones (such as variety).



For urban design problems, the generative design framework can aid the management and structuring of complexity through the definition of goals that can represent the interest of different stakeholders.



Geometric system: (1) create mesh from boundary; (2) generate streets; (3) subdivide into lots; (4) place housing units; (5) place apartment buildings.



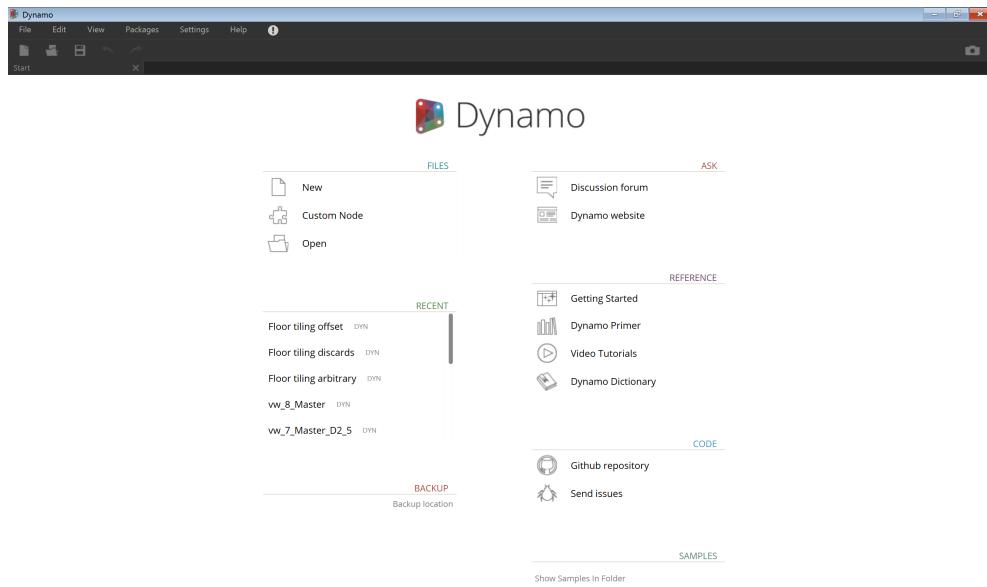
Evolutionary process.

Implementing Generative Workflows using Dynamo and Refinery

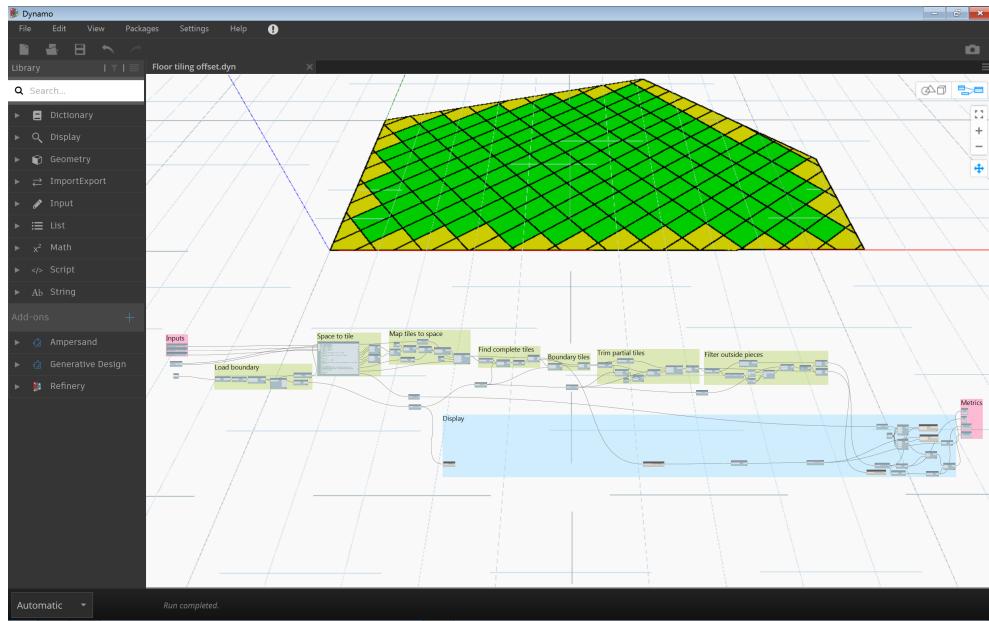
Autodesk Research has engaged in some interesting projects related to Generative Design in the AEC space, but what technologies are available outside of research to do something similar?

The good news is that Autodesk customers can start working on these workflows today with a combination of two tools: Dynamo for Revit and Refinery. The latter one is currently still in Beta, but the link to join the Beta has been provided during the class.

Most people will already be familiar with Dynamo: it's the node-based, visual programming tool that's commonly used for computational design.

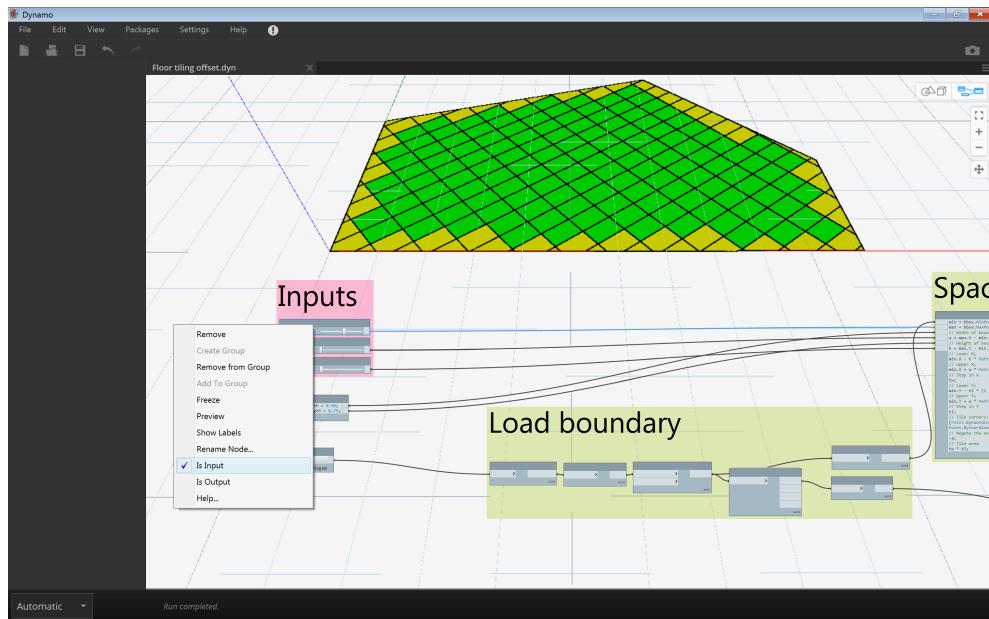


In this session we're going to use a relatively simple Dynamo graph with Refinery. This graph takes a floorplan – that's exported from AutoCAD – and attempts to fit tiles into it in an optimal fashion. The inputs are the angle of the tile and the offsets in X and Y. The outputs we will measure are the number of complete tiles, partial tiles, and the area of tile that will be discarded.

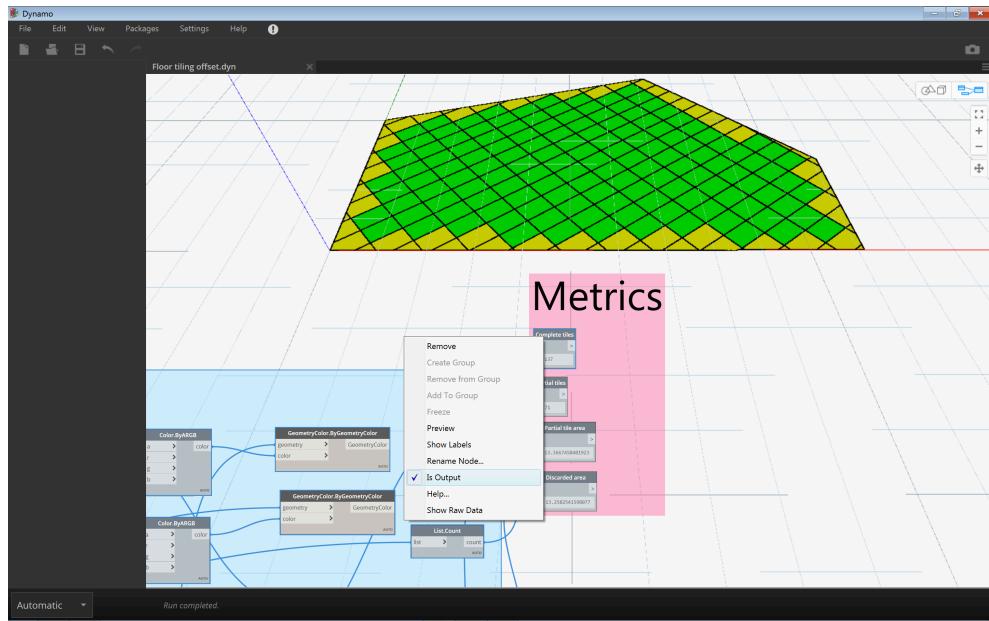


Refinery installs as an extension to Dynamo and adds various capabilities to execute many different instances of your Dynamo graph, essentially enabling generative workflows in Dynamo.

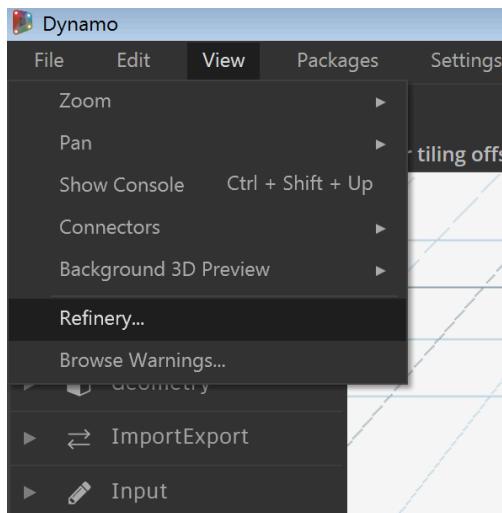
To prepare your graph for use with Refinery, you need to make sure the inputs you want Refinery to control are numeric slider nodes with their “*Is Input*” flag set to true.



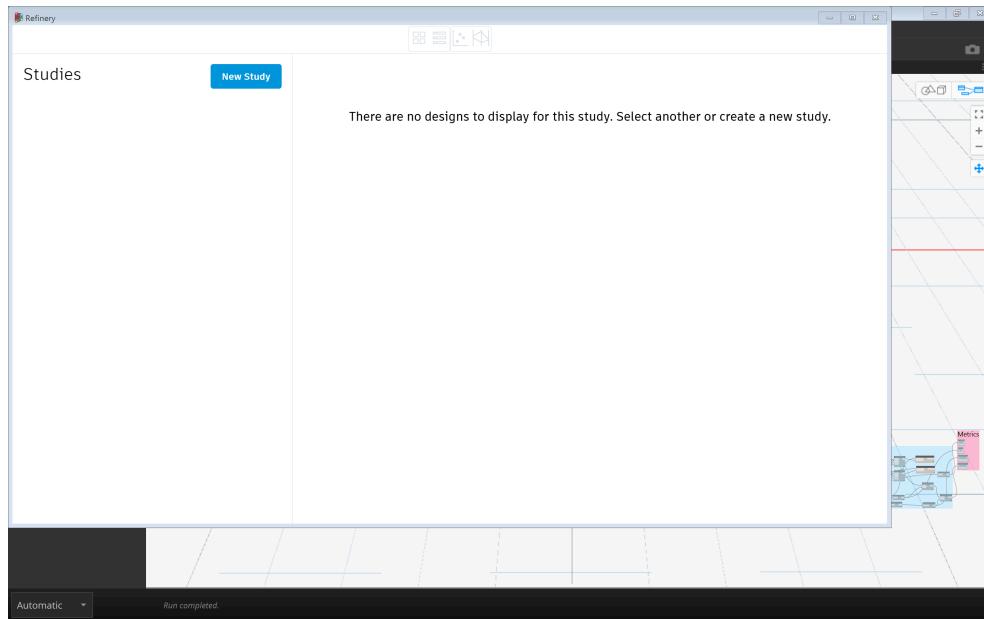
The outputs need to be Watch nodes that have been given a nickname and have their “*Is Output*” flag set to true.



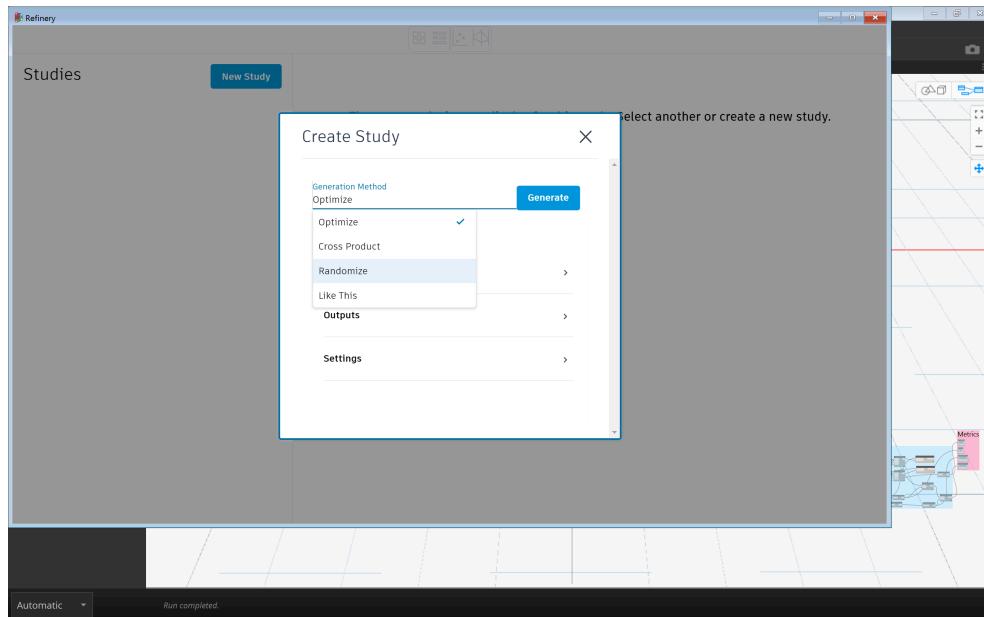
Once you've installed Refinery you can get access to it from Dynamo's view menu (in this case I'm using Dynamo Sandbox independently from Revit):



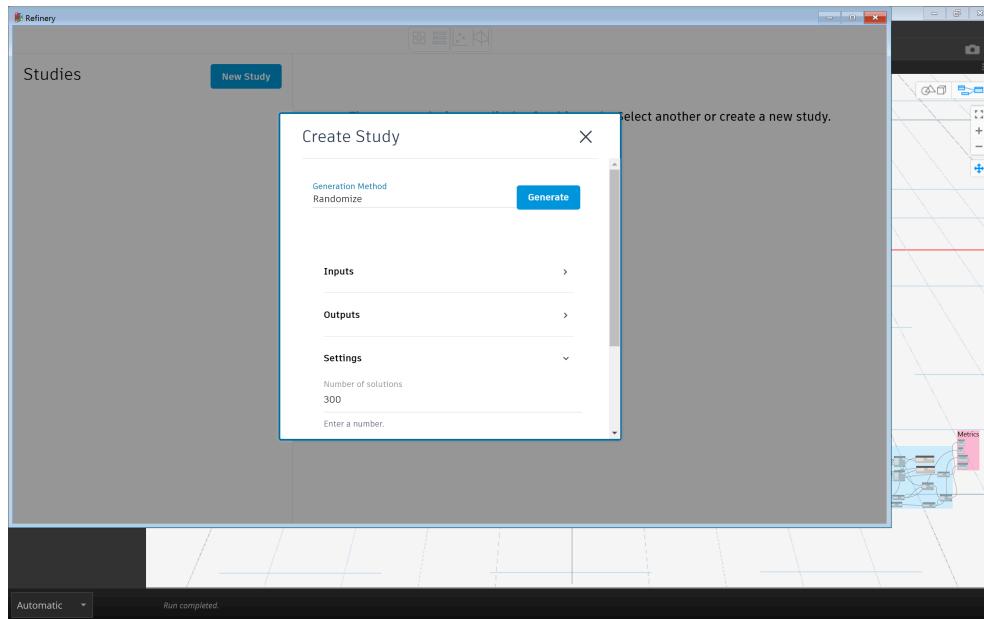
On launching Refinery for the first time, you should see an empty browser window.



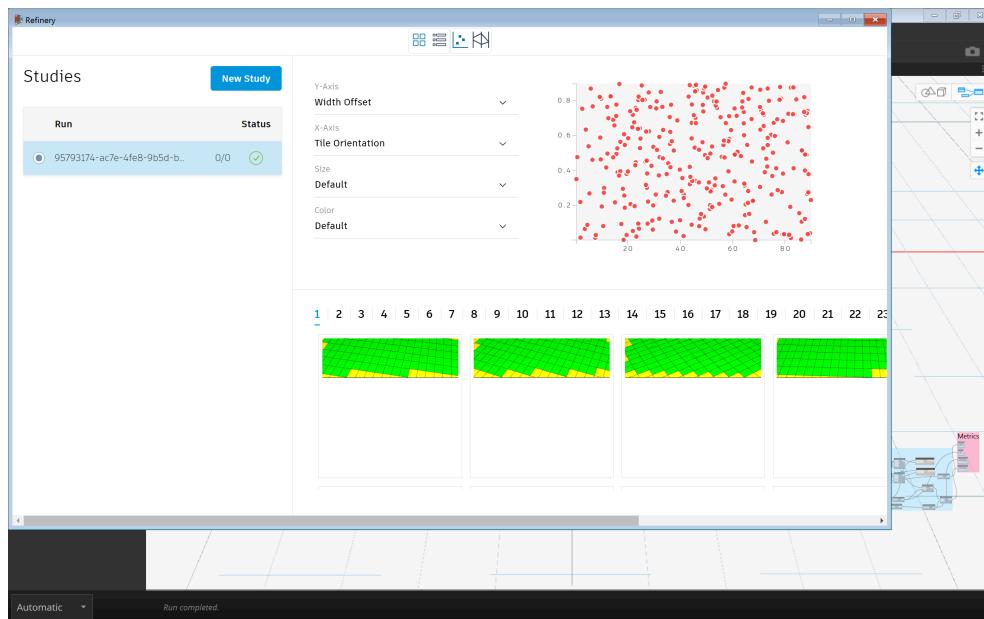
Clicking on **New Study** will allow you to explore designs created in various ways. The first one you should try is a random study. This will create solutions throughout the design space, allowing you to explore the trade-offs between the various input parameters.



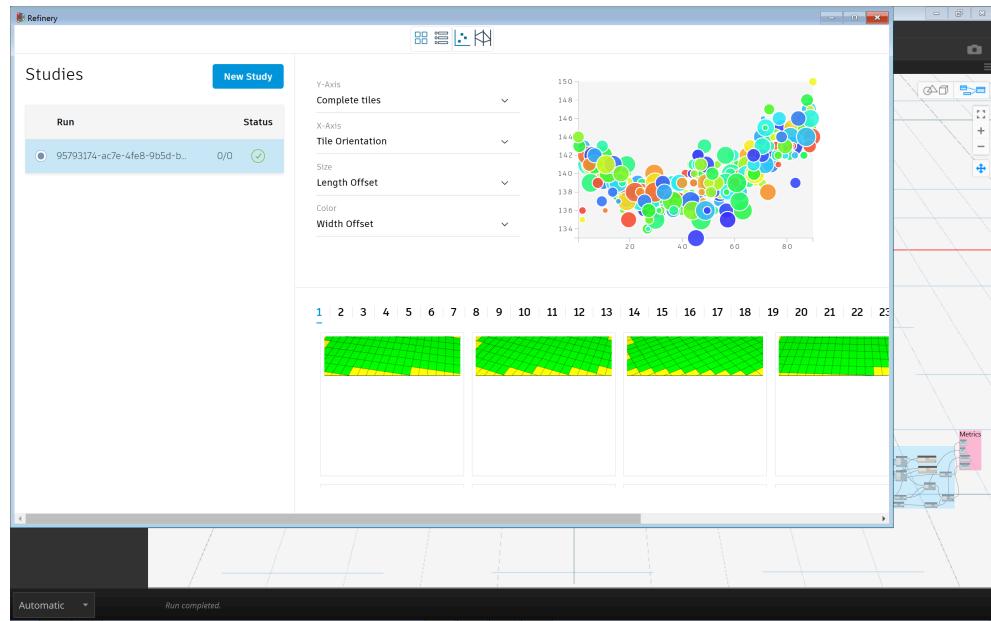
When using the **Randomize** option, you can choose the number of designs to generate along with a seed for the randomization. (The random numbers aren't truly random: if you use the same seed it should generate the same results for the same sized run.)



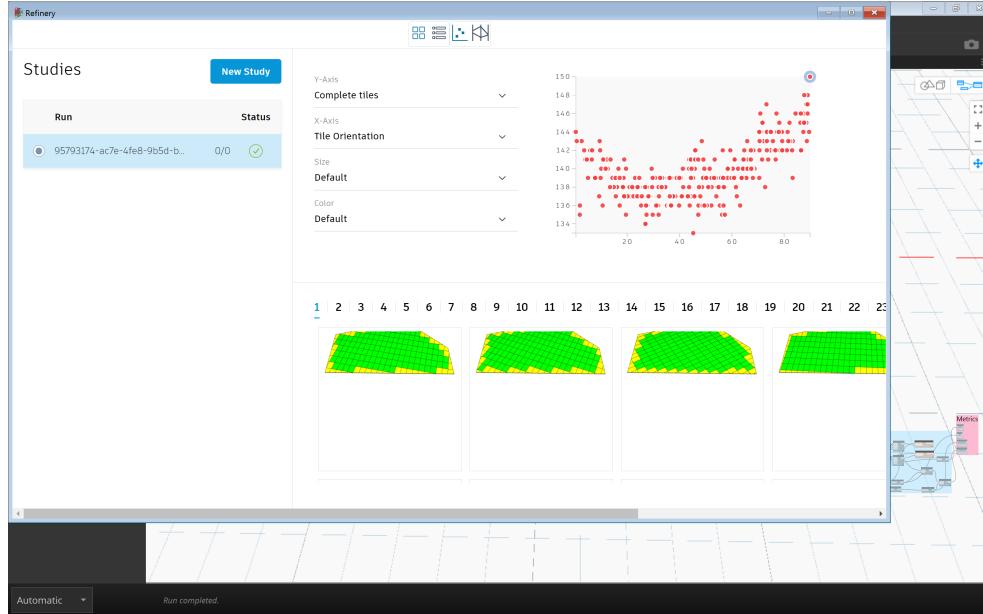
The results of this method are, as you might expect, randomly distributed through the design space.



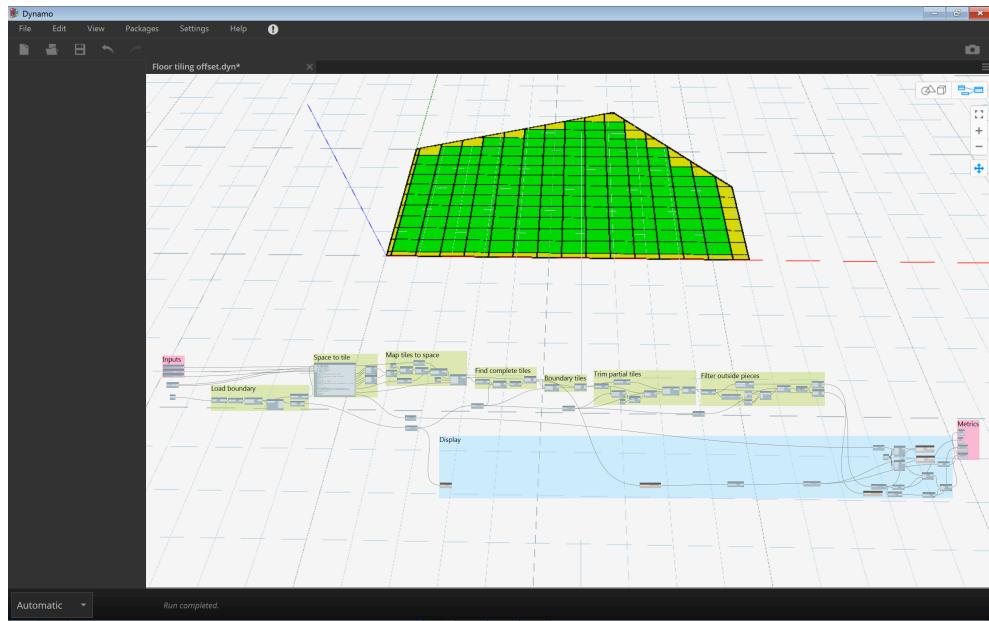
Changing the axes and color/size allow you to fine other ways to make sense of the results:



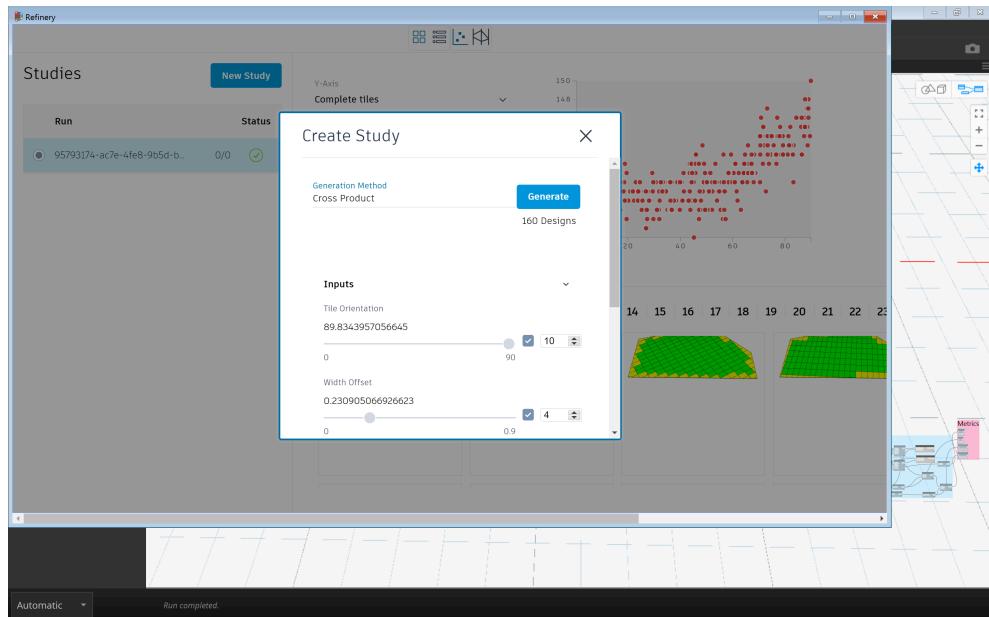
When you find a view that works for you, clicking the individual solutions will transfer the settings to Dynamo. Here we're selecting the top-right view that shows the largest number of complete tiles:



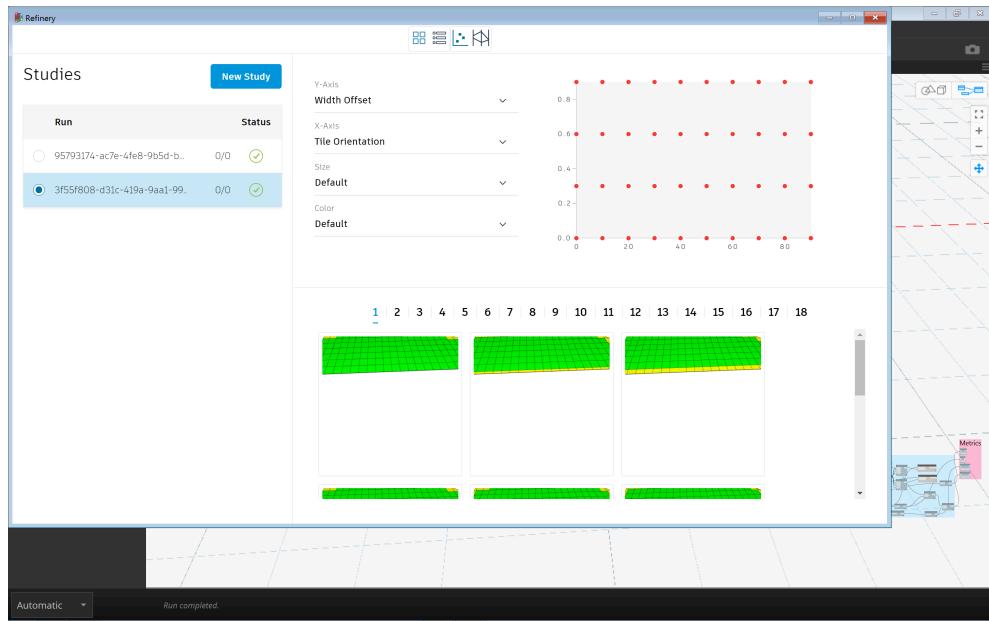
Here's that design inside Dynamo:



If you're more interested in "optioneering" – much as was made possible with Project Fractal – then you'll want to try the **Cross Product** generation method. This will take the specified number of items (spaced evenly inside the parameter space) for the various parameters and combine them to perform a more systematic exploration of the design space.



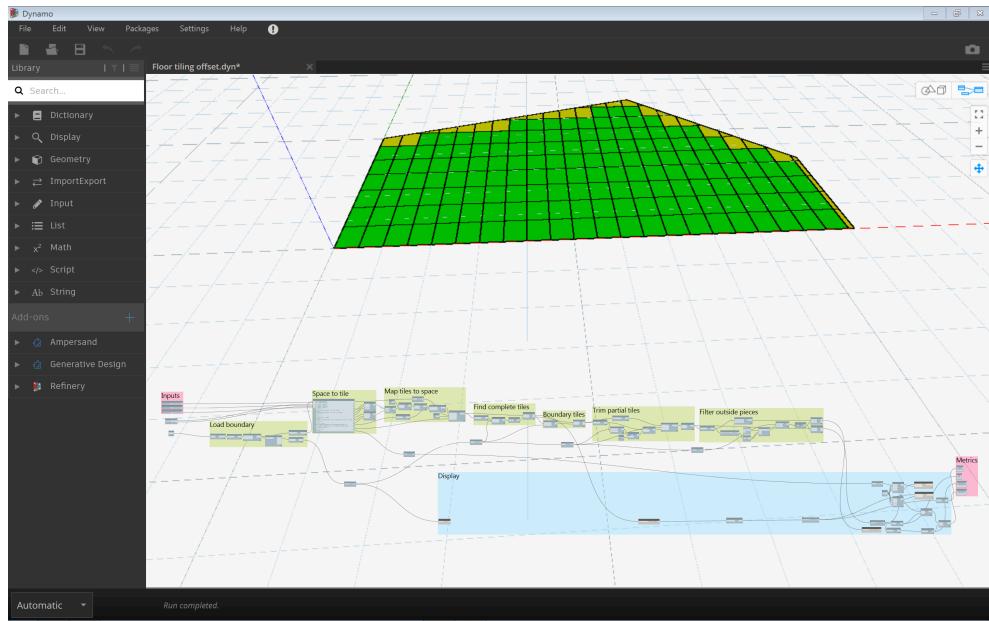
As you might expect, the standard display of the results is very evenly spaced!



As you tweak the axes you start to see things a bit differently, of course.



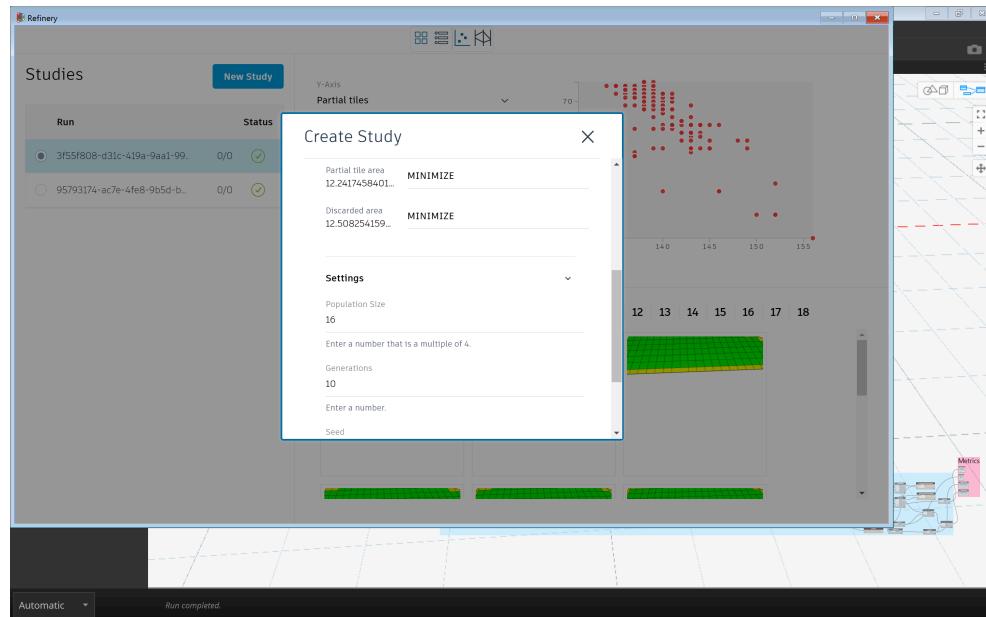
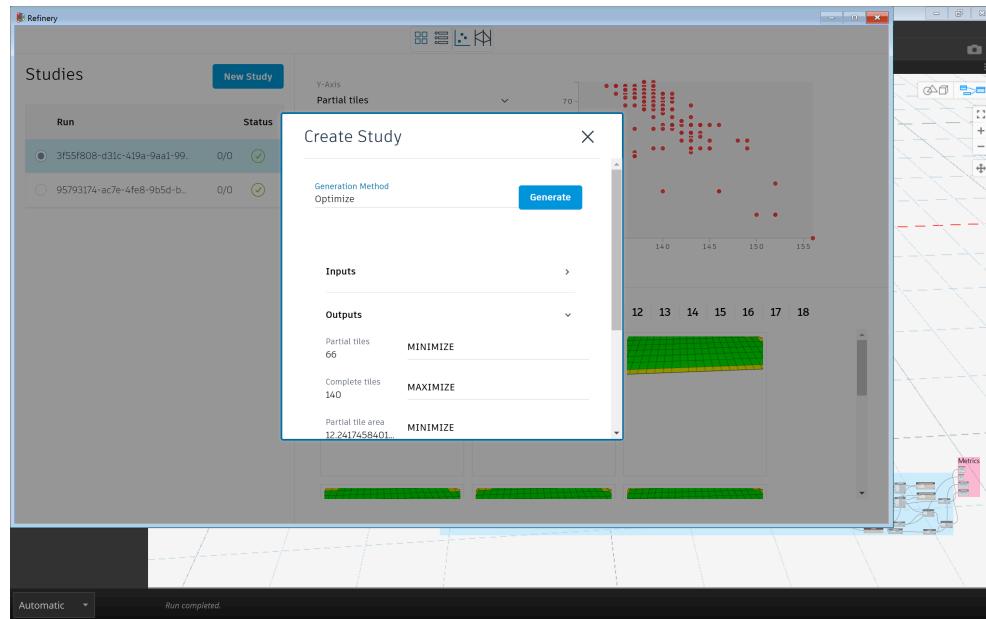
Taking a look at the option with the fewest partial tiles and most complete tiles, we get a slightly different (but also very similar) solution to the one we had previously.



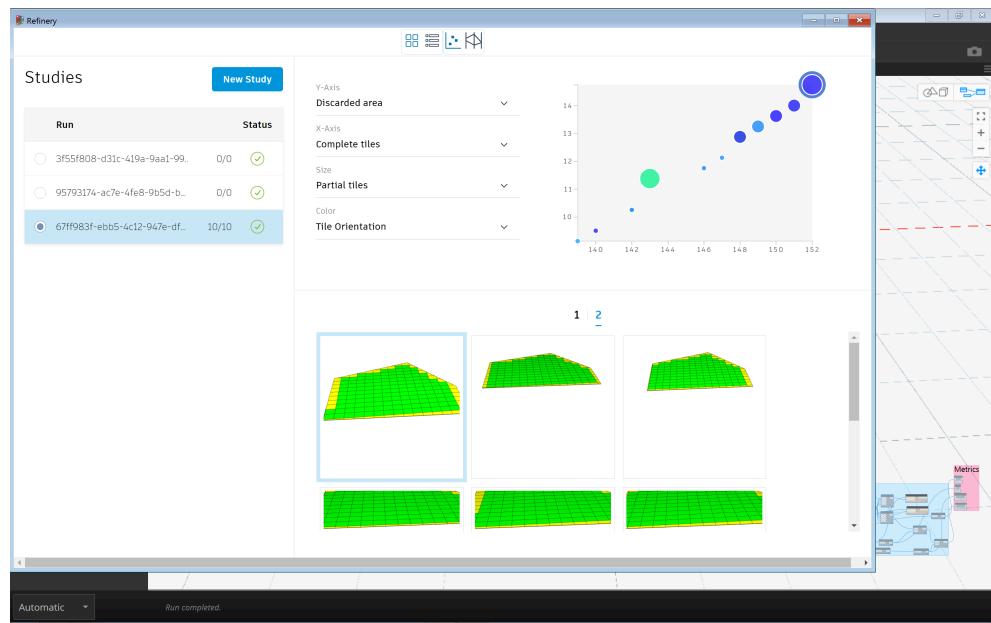
The generation method that really allows you to make use of generative design in its broadest sense is **Optimize**. This will tell Refinery to employ a genetic algorithm to find interesting solutions.

How does Refinery work? It uses NSGA-II optimization, which is a meta-heuristic algorithm for multi-objective optimization. Genetic algorithms are commonly used to generate high-quality solutions to optimization and search problems by relying on bio-inspired operators such as mutation, crossover and selection. A genetic algorithm is a population-based optimization, in that maintains and improves multiple candidate solutions, often using population characteristics to guide the search. Each round of the optimization processed in the genetic algorithm is called a generation. So, when you set the generation value to 40, the process of selection, crossover, and mutation happens 40 times for each population of (say) 40 designs.

While when optioneering we focused on the *inputs*, deciding how to vary them during the generation process, in this case we're going to focus on the *outputs*, saying which ones we want to optimize for and whether the system should maximize or minimize them.



When we look at the results, we see that there are far fewer results, as the optimization process has selected a subset with characteristics that interest us.



Refinery really comes into its own when dealing with more complex scenarios with goals that aren't so closely interconnected, but this should hopefully give at least some sense of its power.