How Sustainability and Fusion 360 Can Help You Save Money and the Planet

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### Learning Objectives

- Learn about key sustainability trends, material and energy efficiency, circular economy, and governmental regulations.
- Learn how to apply generative design for lightweighting, part consolidation, and sustainable material selection.
- Learn how to implement nesting and AM support structure optimization for waste minimization.
- Discover CAM workflows for machine energy efficiency.

### Description

With increasing pressure from consumers and regulations, manufacturers need to figure out how to produce more-efficient products with a reduced negative impact on the environment. Beyond reducing their pollution levels, organizations embracing sustainability save costs and are more competitive and innovative. In this class, we'll discuss the impact and opportunities of the major trends in sustainability for designers and manufacturers. Find out how you can use Fusion 360 software to drive efficiencies and innovation in your processes that will benefit your bottom line and the planet.

### Speaker(s)

**Chas Sullivan** - Sustainability Customer Engagement Manager

Sustainability Customer Engagement Manager at Autodesk, where he helps our Product Design and Manufacturing customers leverage technology to realize their sustainability and impact goals. Before joining Autodesk, Chas worked at Stratasys for eight years in various engineering roles and most recently managed a team of application engineers who supported customers across automotive, aerospace, consumer products, industrial manufacturing, and entertainment industries. He has a background in Mechanical Engineering, specializing in additive manufacturing, manufacturing engineering, CAD tools, and sustainability. He’s a passionate gearhead and outdoor enthusiast, anything from restoring vintage sports cars/motorcycles to skiing the Alps.

**Tyson Fogel** - Workshop Supervisor, Autodesk's Toronto Technology Centre.

Inspired by circularity and biomimicry, Tyson is an avid maker and sustainability advocate. He works directly with residents, innovation communities, and researchers to provide technical expertise and fabrication consultation through the Autodesk Outsight Network. A designer and cabinet maker by trade, Tyson’s past work includes everything from additive, subtractive manufacturing, woodworking to CAD/CAM, Generative Design, construction, and more recently - robotics.

Before Autodesk, Tyson worked at the University of Toronto as a Technician in their woodshop and at Ryerson University developing programs to support social entrepreneurs.
Future Forecasting, Industry Trends, and How to Create More Sustainable Products

Autodesk’s Approach to Sustainability
Autodesk’s at the top of a lot of sustainability rankings, and that’s not by accident – it’s through a lot of hard work with our partners. The 10th annual Autodesk FY2020 Sustainability Report was released in July 2019 – and we’re proud to share our learnings.

Some of the highlights:
• Corporate Knights ranked as #5 most sustainable company and #1 most sustainable Software company. The majority of the list are customer’s we’re working with too!
• Over the past ten years, we’ve managed a 41% reduction in greenhouse gas emissions – that’s even as the company grew.
• 100% of our facility and data center energy is now sourced from renewable energy.
• And our colleagues have volunteered over 800-thousand hours of your time and given over 6-million dollars in contributions.

The Sustainability report could more accurately be called an Impact report because, as you can see from the recognition we’ve received, we are leading in social impact and environmental impact. That includes our work on Diversity & Inclusion, AEX (Education), Training, Philanthropy, and more.

Key Achievements

![Image](image_url)

Future Targets and Commitments
Our philosophy is to lead by example so that we can teach others. Our climate commitments help us better understand the needs of our customers.

We were one of the first companies to set a scientific target for reducing our greenhouse gas emissions – back in 2008, we developed a target, and this year we just reached that target. Now we will go past our target and – as our CEO Andrew announced globally at Autodesk University last year – go to net-zero emissions.

The way we’ll do that is by putting a price on carbon. We’re one of the first companies to commit to putting a price on carbon. That means for every ton of emissions you emit, it’s going to cost your cost center ~$10. This goes into a pool to invest in efficiency, renewables, and offsets.

Autodesk also joins thousands of companies, 195 countries, and countless city and local governments in our commitment to the Paris Agreement’s principles and spirit.

Key Sustainability Trends

Today we’ve emitted already more carbon. We can feel this impact with global warming, rising sea levels, extreme weather events (heat waves & draughts), etc. We know this – for a long time, we had something called Carbon budgeting. You can reverse engineer from the climate outcome you want and how much carbon you have left to spend. We’ve already used up a lot.

The Paris climate agreement gives us this climate outcome of 1.5°C by 2050. And basically, they said that we have ten years to achieve a 55% reduction, and that’s only to give us a 50% chance to reach the under 1.5°C. For your reference, this is the equivalent of the emissions of China, the US, and India combined!
But that’s not even the full story.

There is a concept of committed emissions – these are the emissions we already committed by having fossil fuel and machinery in action. Suppose we don’t build a single new combustion engine, a single new powerplant that burns fossil fuel. In that case, if every furnace is electric tomorrow, we still commit more than enough carbon dioxide to take us above the 1.5 limits, probably more. That means we have zero years, and there is no time left.

Above is the carbon reduction target we need to achieve if we want to reach the Paris agreement’s 1.5C degree target. That means picking carbon emission this year and decreasing dramatically to get carbon neutral by 2050.

So that means we need to start designing the machines that we’ll use in 2, 3, 5 10 years, and they need to today carbon neutral.

United Nations Sustainable Development Goals

![UNSDG's image]

We found the UNSDG’s are the best way to relate across all design and manufacturing fields to unit towards common goals. UN Sustainable Development Goals - are the blueprint for achieving a better and more sustainable future for all. They address the global challenges we face, including poverty, inequality, climate change, environmental degradation, peace, and justice. Learn more and take action.

Autodesk can best support you with Goal 7 (Affordable and Clean Energy), Goal 8 (Decent Work and Economic Growth), Goal 9 (Industry, Innovation, Basic Infrastructure), Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Consumption and Production), and Goal 13 (Climate Action). We organized a series of Industry Coalitions to meet and discuss how we might solve these problems upstream, leveraging big data to interconnect.

Circular Economy
One promising model that I’m particularly fond of is the circular economy model. Today we live in a linear system where we take, make, and waste. The circular economy is trying to avoid wasting by cycling back product, component, and material as much as possible. The circular economy is excellent, but we still need to do more and do it faster, and that’s where AI is such a great tool.

Below are our favorite resources:
- [Leveraging Design for Circular Momentum](#) – Webcast video at Circularity 2020 hosted by Greenbiz
- [Don't Recycle, Upcycle: Why Future Sustainability Requires a Circular Economy](#) – YouTube Video on Circular Economy
- [All the ways recycling is broken and how to fix them](#) – Fast company article

Solutions for Material & Energy Productivity

Doing more with less is what we call productivity. Manufacturers can improve their bottom lines by leveraging technology to increase Energy Productivity and Materials Productivity to meet many's needs while using less resources.

Although the word “sustainability” might not come up in regular conversations, it certainly is paramount to solving topics around cost, compliance, and brand reputation. Cost – reducing waste, meeting deadlines, avoiding costly part failures, delayed shipments, reducing operation costs, and improving your bottom line.
Compliance – ensuring products meet environmental regulations and standards across markets, avoiding costly fines, and recalls. Brand – increasing demands in both B2B & B2C, also offering a Unique Selling Point (USP). These can all be achieved by making more sustainable products.

Let’s look at the intersection of three key trends.
• Lean – systematic method for waste minimization without sacrificing productivity. Value stream map.
• Smart manufacturing – a broad category of manufacturing with the goal of optimizing concept generation, production, and product transaction.
• Similarly, Sustainability techniques use LCA (life cycle assessment), the Scientific process used to assess the environmental impacts of products and materials across their entire life.
They are quite similar in goals and practices, and when coupled, they can significantly minimize the negative environmental impacts of a product.

The Autodesk Sustainability team has found the majority of current and future design and manufacturing demands fit within three key trends. Material productivity & circularity. They are encompassed by the three R’s Reduce (light-weighting products), Reuse (design to be disassembled, circular economy), Recycle (prevents waste from being sent to landfill). Energy productivity & smart manufacturing, consider deploying IoT and smart technologies which will enable manufacturers to understand and improve performance, predict and schedule maintenance, reduce breakdowns, and reduce machine downtime. Responsible Supply Chain Management With 80% of global trade flowing through multinational corporations, one in five jobs is tied to global supply chains, and over 80% of GHG emission in most consumer-goods industries stemming from their
supply chains, supply chains play an outsized role in many of the most pressing social and environmental challenges

Autodesk has a continually evolving set of workflows and tools. Outlined above are key trends we’ve identified, how to solve them, and what tools solutions you can leverage!

| Material efficiency and circularity | • Improve materials efficiency, create lighter products, and reduce waste with generative design and composites  
| | • Make greener materials choices  
| | • Conduct simulations to test and design more durable products  
| | • Nest pieces to optimize flat sheet cutting and reduce waste  
| | • Pack products and use support material efficiently to reduce waste in additive manufacturing  
| | • Improve print accuracy and success rate to decrease waste in additive manufacturing  
| | • Minimize waste by repairing parts with hybrid manufacturing |

| Energy efficiency and smart manufacturing | • Design and create energy-efficient electronics and machines  
| | • Reduce energy use and waste in production by optimizing machine use and cooling cycles  
| | • Analyze and optimize factory building energy consumption |

| Responsible supply chain | • Audit suppliers to ensure product quality and compliance  
| | • Increase quality through failure analysis and reports  
| | • Comply with regulations with material and supplier declaration |
Sustainability Through Generative Design (GD)

Autodesk Generative Design (GD) is a workspace and design exploration technology native to Fusion 360. GD uses an artificial-based algorithm that creates multiple design solutions and permutations for one design challenge. This allows you to simultaneously generate various CAD-ready solutions based on real-world manufacturing constraints and product performance requirements. The software becomes your design partner, allowing you to curate and explore design variations.

Image: Venn diagram illustrating Generative Design’s ability to contribute to a circular economy by acting as the connective tissue between sustainability and manufacturing

GD vs. Topology Optimization

GD and topology optimization are both systems algorithms and methods of determining an optimal material layout in a design space, but their approach is dramatically different.

Topology optimization typically uses a finite element engine to define (generate) each voxel as it pertains to a specific load. Topology optimization will consistently obtain one solution given a set of design conditions through material removal only.

GD, on the other hand, uses a finite element analysis as an evaluative tool rather than a generator. This is done by defining the minimum distortion parameter through repetitive calculation and moving this newly defined boundary surface on the part to account for these calculations. The resulting volumetric shape both adds and removes material from the ground up for each instance of constraints and design parameters, meaning multiple designs ready solutions are produced.

GD in the Product Development Process
As you may know, the typical product development cycle is an iterative process that involves a series of stages. Some of these include ideation, evaluation, prototyping, validation, and production. Historically, this process is loose, non-linear, and success is predicated by time or monetary constraints. The early stages of this cycle are massively sensitive to downstream manufacturing implications and end of life decisions. Specifically, the conceptualization phase, as roughly 80% of a product’s embodied carbon is locked in at this point. While all roles involved in the process are crucial in minimizing a product’s carbon footprint, the industrial, product, and mechanical engineers should be heavily targeted as they set the tone.

GD flips this traditional model on its head by bringing accurate data to the forefront of your development process. This means downstream insights on manufacturability, costs, and quality can be discovered prior to breaking the digital thread. It’s easy to see the direct benefits that can be incurred from the ability to gauge the validity of dozens of designs in the early stages of product development. With GD, the entire process becomes streamlined and helps offset the pitfalls of a perpetual design iteration cycle.

**Time Allocation – Expectations vs. Reality**

Despite being an integral tool to add to your product development toolbox, some misconceptions about the work are required to produce an end-use part using GD. The software does not single-handedly carry the design through to the final phase of development. Like any CAD feature, it requires user input and a thoughtful approach to generate the best outcomes. Following a GD study, anticipate a degree of simulation and post-production to ensure the utmost quality and confidence in the part moving forward.
The Sustainable Benefits of GD

A generative design approach's benefits are many – part consolidation, lightweighting, ease of manufacturing, enhanced part quality, performance, and production, etc.

- **Consolidation & Assembly** – Generative Design has the innate capability of making very organic and undulating connections to critical features. Effectively reduce overly complex and multi-part assemblies into a single geometry that's better suited for disassembly.
- **Lightweighting** – Optimize the material needed throughout a part to meet your product's structural and functional requirements and then explore what this means across material selections. Lightweighting is a direct byproduct of any Generative Design study.
- **Enhanced Performance and Quality** – Following a study, GD allows you to filter through massive amounts of performance data to understand better how your part performs and meets different criteria, expediting time to market. Including, but not limited to: cost, mass, volume, the factor of safety, stress, and displacement.
- **Ease of Manufacturing** - Generative Design considers how a part will be fabricated and creates design solutions specific to certain manufacturing processes. Since GD only adds material where necessary, it cuts through the noise to produce better results than even those of highly experienced design and manufacturing engineers (E.g., Optimization for 2.5 axis milling).

Drawing a direct correlation to sustainability, these benefit translate into a reduction of embodied carbon and material required to produce a part. Further, less energy is consumed and used throughout your product's entire life cycle, e.g., manufacturing, shipping, consumer usage, end of use. It's easy to see how drastic or fractional improvements in any of these areas can directly influence the bottom line.

Key Considerations in GD

Incurring these widespread benefits through GD starts with having a profound understanding of the design challenge you hope to resolve. In many ways, you will have to think differently about how you approach your product's design.

**Choosing a Part**

There are some nuances in selecting the right part for GD. Despite the capability of running everything through technology, some components are better suited for optimization. Conducting an audit on your manufacturing and assembly processes can help narrow the scope and identify the potential GD candidates. Start by exploring a combination of the following pain points:

- Periods in the assembly process that are the most time-intensive
- Overly complex assemblies that have the most parts
- Heavy, bulky, and overly robust components that could benefit from weight reduction
- Components that are time and resource-intensive to manufacture
- Components that could benefit from additional rigidity without adding weight
- Parts that could benefit from improved performance and analytics

**Setting up a GD study**

![Image: Generative Design user interface (Fusion 360)]

Developing a Generative Study will require the following parameters and points of consideration
- **Geometry Requirements** - There are three different types of geometries available to inform a GD study, only one of which is critical to a solve: Preserve (Required - Any regions within a design space that we want GD to keep intact), Obstacle (Optional – Select areas we want the algorithm to avoid), Starting (Optional – Geometry that acts as an usher for how a GD outcome will form).

- **Design Criteria** - Two distinct design objectives can be achieved. Those are: Minimize Mass and Maximizing Stiffness, giving the user direct control over the expected factor of safety and weight.

- **Design Conditions** - Define the problem in which GD will try to solve; this is where the load conditions or acting forces are inputted. There are two unique points of consideration:

- **Material Selection** - Determine which materials will focus on the study and see how they will react under the given load conditions.

- **Manufacturing Constraints** - Another level of constraints to contribute to the overall effectiveness and quality of your study. Constraints range in manufacturing type and characteristic parameters within that type, meaning things like minimum feature thickness, radius size, overhang angles, and tool length are accounted for to produce more fabrication friendly results for that design instance. Current types of manufacturing constraints include: Unrestricted (no limitations), Additive, Milling (2.5, 3, and 5 axes), Die Casting, and 2 axis cutting. Lastly, the manufacturing constraints include a production volume parameter, providing insight into the fully burdened and cost per piece.

Filtering GD results for sustainability and cost

Exploring results

Understanding how to navigate and filter through the different GD outcomes for the best possible solution for the intended applications is equally important as setting up the study. This is done through the ‘Explore’ feature. Within the explore workspace, there are several options in how you visualize, consume, and evaluate the resulting data.

![Image: Generative Design explore interface (Fusion 360)]
Viewing & Filter Types

The left-hand column has several self-explanatory checkbox and range filters. Filtered results and their properties can be visualized through a scatter plot graph, list (ascending/descending filters), and thumbnails images. The use of these individual viewing spaces is depended on the type of properties you would like to compare, contrast, and rank.

Additional filters beyond those that were chosen during the initial study setup include: Cost per piece, mass, the factor of safety, Max Von Mises stress, displacement, volume, etc.

Individual instances can be clicked to open up a new dialog, allowing the user to get up close to the design. The up-close viewing provides for rotation, panning, stress views, and the ability to scroll back to prior iterations before the study converged or completed. It is in this workspace that individual designs can be exported. Select up to four design outcomes to view up-close simultaneously. This allows for a more in-depth comparison across the most promising designs.
The Importance of Simulation

There are various simulation types; some specific to design quality are native to Fusion 360 within the Simulation workspace. These are simulations of how a product will react under certain conditions. Some of these simulation types include: Static stress, displacement, modal frequency, thermal, thermal stress, non-linear static stress, event simulation, buckling, and electronics cooling. Running your designs through a simulation tool before fabrication can help pinpoint areas of need and help identify opportunistic regions within a design. These could be areas that require further consolidation, lightweighting through ribbing, latticing, or bolstering. Essentially, simulation is a diagnostics tool to help a designer better understand a component's integrity, performance, and structure in different environments and under varying conditions.

During the actual fabrication of a part, additional simulations can occur and are specific to in-process fabrication (like that of metal additive or subtractive manufacturing). The importance of this should not be understated. In the same way that we want to ensure our product lives up to specific standards once on the market, we want to ensure the product is made with the same diligence, and we are extending this level of care to the machines doing the work.
Sustainable Benefits to Simulation

The road to sustainable best practice is paved by workflow pain points, pitfalls, and outliers in the labor/cost breakdown. A high majority of manufacturing complications stem from a lack of operator/designer foresight. The inability to project downstream stream pitfalls can cause an error to compound incrementally to the point of failure.

Simulation (both in-process and usage) can give you this insight and the ability to adapt to improve or address any inefficiencies.

GD + AM + Simulation

The power of these digital tools lies in their ability to work in collaboration with each other. Generative Design, Simulation, and Computer-Aided Manufacturing don’t exist in silos. The ability to move seamlessly across workspaces makes for beneficial and fast design iteration digitally while saving money in production, manufacturing, and reducing any related (negative) environmental impact.
Naturally, these workspaces (plus others in Fusion) are useful in creating products/parts and incredibly dynamic in their ability to assist in the fabrication of a part across different manufacturing technologies. Take for example, our Generative Design use case:

- Created a Generative Design swing arm for a motorcycle. The study was set up, reflecting the constraints and load conditions a motorcycle bracket that’s connecting the wheel and frame might experience.
- Chose a complex design outcome that we would like to metal 3D print.
- Required a degree of post-operational milling on the swing arm after it was printed to clean up certain features and surfaces. We needed a workholding solution to ensure rigidity of this complex geometry within a 5-axis CNC machine.
- Ran a second Generative Design study, using our initial outcome as obstacle geometry to create a clamping enclosure for our original design to lock into a vice.
- Simulated final results to validate the Generative Design load conditions we had used and see if our part/material will hold up to the wear and tear of reality.

This is just a snapshot of Fusion’s flexibility and ability to leverage a suite of digital tools to suit unique customer needs.

### Additive Manufacturing & Sustainability

#### What is Additive Manufacturing (AM)?

Additive manufacturing (AM), also known as 3D printing, is the process of joining materials to make objects from 3D model data, usually layer-upon-layer, instead of subtractive manufacturing methodologies. The processes in AM are all essentially based on the same core concept of the technology. The process begins with a CAD model of the part, which is sliced horizontally into layers of specified thickness using the software. The model is then read by the AM system, converted to tool-paths, and printed in a layer-upon-layer build plan. The feedstock material can be plastic, metal, composite, wax, or paper.

Over the past three decades, the technology of AM has improved to account for seven different technologies. These include vat photopolymerization, material extrusion, material jetting, binder jetting, powder bed fusion, direct energy deposition, and sheet lamination.

#### Sustainable Benefits of Additive

If saving money is the driving factor for adopting sustainable practices, then additive manufacturing can help us get there. We must be pragmatic in our approach. Ultimately, it’s less about changing ‘what’ you do and more about changing ‘how’ you do it. Sustainability means recalibrating your AM workflow to be more pragmatic and thoughtful.

Additive manufacturing makes a strong argument for being perhaps one of the most sustainable prototyping technologies. The brilliance lies in its capability of using the lowest amount of raw material to produce a functional part. Any additional material usage is required to support certain features, calibrate the machine, or ensure layer adhesion. Despite the limited material usage, additive manufacturing can be quite energy-intensive.

Thus begging the question, how do we optimize the parameters we can control? Through our experience, we’ve noticed there are effectively four things that contribute to an additive process’s ability to be sustainable: **Material Consumption, Energy Consumption, Runtime, and Preparation.**
AM Pitfalls

A high majority of additive manufacturing complications stem from a lack of operator/designer foresight. The inability to project downstream stream pitfalls can cause error to compound incrementally to the point of failure. Below are some of the additive pitfalls noticed at the Technology Center’s:

1. **An excess of print failures** – There is a limit to the amount of acceptable print failures, especially true when we start thinking about more complex additive processes that cost thousands of dollars in materials, energy and labour to produce.

2. **Failure to section/slice or scale throughout the prototype process** – Referring to the lack of scaling the part in its entirety or the action of sectioning the amount being printed, e.g., focus a prototype on specific fit, form, function, or critical features).

3. **Ridiculous print times** – Orientation aside, many factors contribute to a build’s run time. The ability to analyze the fit, form, and function of a part to determine where compromises in parameters like the infill, layer thickness, speed, and support structure can occur is crucial in minimizing run times without sacrificing the components integrity.

4. **Overly complex geometries and assemblies** – The reverse of this would be an excessively complex assembly. An argument can be made that additive manufacturing can provide detail at no extra cost; however, the trade-off can sometimes increase print time and the need for the additional support structure. It is determining how complexity factors into the long-term objectives of your part can be critical in evaluating its ability to minimize its carbon footprint.

5. **Selecting the wrong AM process or material** – Not all additive processes and materials are made equal; some are better suited for certain types of parts and applications. Having a strong understanding of the part requirements can better position the designer’s ability to achieve certain tolerances, forms and minimize post-processing.

6. **Extraneous post-processing** – Post-processing is a downstream factor that needs to be considered at the forefront of a job. Support removal and cleanup can be labor-intensive or, in some cases, impossible depending on the complexity of geometry.
7. **Not enough post-processing** – Time and time again, people try to force tolerances out of additive machines. Some other manufacturing equipments (CNC mills) are better suited to provide dimensional accuracy and hold extreme tolerances during a post-process. If there are many critical features and not all of them can be printed in similar axial planes, this may be an indication that these features will require post-processing using a mill.

8. **Ignoring DfAM principles** – Designing for a manufacturing process is the building block for prototype success and further navigating the other manufacturing pitfalls. Internalizing these guidelines means parts will start to produce successful results earlier in the conceptual phase. If a DfAM principle deviation should occur, it should be informed by meeting an equipment limitation or parameter.

**AM Solutions**

Now that we know what to avoid, what can we do to prevent it? There is not necessarily a definitive answer for each pitfall, likely a consequence of how interwoven these pitfalls genuinely are. Although resolution will be application and operational specific, there are various strategies and digital tools (beyond GD) we can leverage in our journey to greener, more intelligent additive manufacturing.

**Design Strategies:**

- **Design for disassembly** – Less of an additive strategy and more deliberate action during the design phase, identifying features in your design that see significant wear throughout their usage and could potentially be connected, embedded or modular might help simplify the areas be printed. The art of disassembly is better suited for providing value to a part beyond its consumer life cycle, as individual components can be removed or replaced.

![Image: Lattice configuration in Netfabb optimized for structural loads/finite element analysis](image-url)

- **Infill Management** – There is currently no stand-alone optimizer or tool that does this automatically within Fusion 360. However, working across platforms, the lattice generation tool in Netfabb can manipulate and produce concentrated lattice structures based on the components finite element analysis. Beyond that, you will need to rely on user experience to determine when and where infills should be manipulated. Focus on changing density specific to certain regions based on their structural integrity and the type of prototype being created. Changes in infills can drastically influence print time.
• **Support Structure Optimization** – Supports are a byproduct of part orientation. The more supports volumetrically and area to be supported, the more material will be used. Support structures can also be parameterized to minimize printing time and density (e.g., increased layer heights, fill type, etc.). Run an orientation script (Netfabb) to get a better sense of how varying positions will impact material usage across the following:
  - **Supported Area** – Volumetric amount of part geometry that exceeds the overhang limit and will require a support structure
  - **Volume** – Volume of support structure that will be required across the entire part
  - **Outbox Volume** – Bounding box volume relative to the build platform. Could be a factor worth minimizing in certain additive technologies
  - **Height** – Distance (of support) from the build platform to the tallest part feature

![Image: Orientation optimizer in Netfabb, ranking key support considerations on the swing arm](image-url)
• **Packing** - Optimally arrange your geometry during a manufacturing process to enhance run-time and reduce material waste. Netfabb can correctly position and orient geometry within a build environment using their packing features to minimize runtimes and balance a build's density.
Operator Strategies

- **Minimize material usage** – Since the algorithm is positioning parts to minimize the surface area across a given material volume, the stock yield can be maximized. This limits the number of offcuts and remnants.

- **Material Graduation** – DO NOT run your initial prototype on your material of choice. We've seen more failures than I can count by individuals who were overly confident in their design. Use more recyclable materials in the beginning, working your way up to your material of choice (e.g., laser-cut an assembly using cardboard first vs. acrylic or wood, or 3D printing using thermoplastics before using a powder/metal-based system).

- **Prototype Fit, Form, and Function** – Target critical features to test, by isolating these sections of your parts and run a mini print job to verify their fit, form, and function.
  - **Dry run post-processing** – An extension of fit, form, and function testing, take the time to conduct a dry run on certain post-processes. This could include support removal, surface finish, and additional manufacturing in a post-operation. Many questions could be answered throughout this process, including how to hold on to your part during a post-op? Will there be surface quality issues in given regions? What types of tools will I need? How long can will post-processing take?

Sustainability in Other Manufacturing Methods

**Nesting**

Nesting is embedding parts within one another, or in the world of manufacturing - the optimal placements of parts in a contained volume. Although similar to packing, the distinction here is that nesting is specific to planar (2-axis) geometry, and packings is for three-dimensional volumes.

Nesting in Fusion evaluates and categorically organizes different geometry thickness into a series of packages. Upon completion, a report is generated on individual package findings. The user has a high degree of control over how these parts are embedded and situated within a sheet. Gone are the days where you manually need to place parts and configure what you think are the cut lines and best layout to maximize material yield.

In many ways, this makes nesting a readily available and dynamic tool applicable to various manufacturing methods (e.g., waterjets cutting, laser cutting, sheet metal, CNC routing, etc.). Fusion 360 has a Nesting workspace.

**Sustainable Benefits of Nesting**

Nesting allows you to take very complex shapes and position them near each other in a very efficient way. There are a couple of significant benefits that can be accessed through the use of nesting.

- **Minimize material usage** – Since the algorithm is positioning parts to minimize the surface area across a given material volume, the stock yield can be maximized. This limits the number of offcuts and remnants.

  Considering the degree of control that can be exerted over how the parts stack and how offcuts and will appear following an operation (length or width of stock), a user will ensure remnants will remain of value to future operations.

- **Minimize runtime** – Due to the proximal nature of the optimized parts and the ability to orient geometry in a very efficient way, there is a direct impact on enhancing the operational runtime of a job. Basically, the machine needs to do less work moving across stock to reach specific components.
Key Resources

Sustainability Resources

- Autodesk Sustainability Report – Summary of all sustainability and foundation efforts across Autodesk and what tools you can leverage
- Don’t Recycle, Upcycle: Why Future Sustainability Requires a Circular Economy – YouTube Video on Circular Economy
- Ellen Macarthur Foundation – organization leading the charge on the Circular economy
- Venturewell – Training tools for designing more sustainable products
- All the ways recycling is broken and how to fix them – Fast company article
- UN Sustainable Development Goals - The Sustainable Development Goals are the blueprint for achieving a better and more sustainable future for all. They address the global challenges we face, including poverty, inequality, climate change, environmental degradation, peace, and justice. Learn more and take action.
- The Paris Agreement - The Paris Agreement builds upon the Convention and, for the first time, brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so.
- ISO 14000 Family – Environmental Management. For companies and organizations of any type that require practical tools to manage their environmental responsibilities, there’s the ISO 14000 family.

Favorite Sustainable Design & Manufacturing Companies

- IDEO – Design Thinking
- Cisco – Consumer Products
- Trane Technologies – HVAC Systems
- Electrolux – Consumer Electronics
- IKEA – Furniture
- Kingspan – Building Products
- Covestro – Polymers (process manufacturing)

Fusion 360

- Fusion 360 – Landing page for all things Fusion 360.
- Self-Paced Learning – Modules on all aspects of Fusion 360, including Simulation and Generative Design.
- Product Documentation – Written walkthrough on all aspects of Fusion 360.
- Fusion 360 Videos – YouTube webinar on different aspects of Fusion 360.
- Fusion 360 Blog – Latest updates on all things Fusion 360.
- Fusion 360 Fusion 360 Live: 3D Printing Workflow – Walkthrough on how to use the additive manufacturing slicer native to Fusion.
- Command Map – Fusion 360 plugin to aid in self-paced learning.

Generative Design

- Autodesk Generative Website – Main landing page for everything Generative Design.
- Customer Examples – Great examples of the diversity and capability of Generative Design.
- 2.5-axis Customer Use Case – 2.5 axis manufacturing constraints unlock the ability to manufacture GD parts in a very effective way subtractively. Here’s how one customer is doing it.
- Resource Center – Customer success stories, interesting articles, and white papers all in one place.
- Fusion 360 Live: Generative Design Tips & Tricks – Great and thorough walkthrough on all aspects of how to use and set up a Generative Design study.
• **Article: Generative Design: What Can It Do For Sustainability?** – Written by a member on the Autodesk Sustainability team and provides some really great questions and thought-provoking concepts.

Simulation
• **Fusion 360 Live: Simulation Basics** – Great walkthrough on how to all aspects of Simulation within Fusion 360. Including how to set up a study and leverage the workspace.

Netfabb
• **Advanced Additive Manufacturing in Fusion and Netfabb** – A guided walkthrough on a Fusion to Netfabb workflow. Includes automated orientations and support structure optimization within Netfabb.
• **Design for Additive Manufacturing: Lattices in Netfabb** – A guided walkthrough on how to set up and configure lattice/infill structures within Netfabb. Includes how to apply a finite element analysis to an infill structure.
• **Part Orientation** – Quick breakdown of some of the critical parameters within the orientation feature of Netfabb.
• **Netfabb Tutorial: 3D Printing Orientation** – A quick video on how to orient a part in Netfabb.
• **Packing** – A breakdown of the different types and parameters within Netfabb’s packing environment.
• **Netfabb Tutorial: Packing Demo** – An indepth walk through on how to leverage packing within Netfabb.

Nesting
• **Get More Out of Fusion 360 with Nesting** – A thorough walkthrough on how to leverage the nesting workspace in Fusion 360

Autodesk Technology Centers
• **Autodesk Technology Centers** – Landing page for anything and everything Technology Center related. Learn more about what it is, how it works, and how to apply.
• **Projects at the Autodesk Technology Centers** – Great examples of how organizations and customers are leveraging the Technology Centers and the residency program.
• **Proposal Application** – Apply to become a resident! Have any questions related to this form? Feel free to reach out to technology.centers@autodesk.com with any questions.