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## Developing Maker Economies in Post-Industrial Cities: Applying Commons Based Peer Production to Mycelium Biomaterials

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DEVELOPING MAKER ECONOMIES IN POST-INDUSTRIAL CITIES:  
APPLYING COMMONS BASED PEER PRODUCTION TO MYCELIUM BIOMATERIALS

A Thesis Presented

by

GRANT R. ROCCO

Submitted to the Graduate School of the  
University of Massachusetts Amherst in partial fulfillment  
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Stephen Schreiber, Department Head

DEDICATION

To Amy

## ACKNOWLEDGEMENTS

Thanks to Joseph and Kathleen for the guidance and tenacity.

Thanks to my parents for always supporting me.

## ABSTRACT

### DEVELOPING MAKER ECONOMIES IN POST-INDUSTRIAL CITIES: APPLYING COMMONS BASED PEER PRODUCTION TO MYCELIUM BIOMATERIALS

MAY 2015

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Our current system of research and production is no longer suitable for solving the problems we face today. As climate change threatens our cities and livelihoods, the global economic system preys on the weak. A more responsive, equitable, and resilient system needs to be implemented. Our post industrial cities are both products and victims of the boom-bust economies employed for the last few centuries.

While some communities have survived by converting to retail and services based economies, others have not been so fortunate and have become run-down husks of their former bustling selves. The key to revitalizing these cities is to create new industries that empower people, unlike the service economies that deride and devalue them. Peer to Peer (P2P) development models like open source software communities create platforms for people to collaborate on projects and share resources. On the scale of cities, the goal is to stimulate the growth of closed loop, local, micro-economies that are inherently more stable than traditional, centralized economic models.

Commons Based Peer Production (CBPP) is a term coined by Professor Yochai Benkler at Harvard Law School. It describes a new model of socio-economic production in which the labor of large numbers of people is coordinated (usually with the aid of the Internet) mostly without traditional hierarchical organization. It is based on low thresholds for participation, freely available modular tasks, and community verification of quality (peer governance). CBPP usually only applies to intellectual output, from software to libraries of quantitative data to human-readable documents (manuals, books, encyclopedias, reviews, blogs, periodicals, and more); however, this system can be adapted for physical manufacturing.

A P2P system of development for material goods must be explored through the production of a common resource. Mycelium is the "roots" of fungi. It can be grown anywhere with agricultural refuse as a substrate. It has properties that make it ideal for building insulation and it is environmentally innocuous. It is Cradle to Cradle certified, and it requires little specialized equipment to produce. As a consumer product, it has had trouble gaining traction in a notoriously stubborn market dominated by hydrocarbon based market leaders like extruded polystyrene (XPS). Mycelium products are ripe for development as a regenerative building material.

The goal is to increase the R-value of the material, decrease the cost of manufacturing, and carve out a market for this extraordinary product. The purpose of

applying a CBPP approach is to increase the speed of development and aid in market penetration. The strategy is to decentralize manufacturing of and experimentation with the product. This requires a robust network of production nodes. Essentially, this involves setting up franchises in select markets (like the Pioneer Valley), where there is a strong interest in local, sustainable products. The nodes would be small cooperative businesses that are licensed to produce the material as well as collect data on the manufacturing and performance of mycelium insulation. The data will then be used to improve the production process. The bulk of the thesis is in designing one such node in Greenfield, MA, located adjacent to the new John W. Olver Transit Center on Bank Row St.

## TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS.....	iv
ABSTRACT.....	v
LIST OF FIGURES .....	ix
CHAPTER	
1. INTRODUCTION: MAKER ECONOMIES.....	1
2. DECENTRALIZED NETWORK MODEL.....	6
3. COMMONS BASED PEER PRODUCTION.....	10
4. MYCELIUM INSULATION.....	16
5. CREATIVE COMMONS LICENSING.....	20
6. PEER GOVERNANCE .....	23
7. POST INDUSTRIAL CITIES AS TEST CASES.....	28
8. GREENFIELD, MA.....	30
9. SITE - EXISTING CONDITIONS.....	31
10. RESULTING DESIGN: INOCULUM COMMONS.....	36
11. CONCLUSION.....	52
BIBLIOGRAPHY.....	54

## LIST OF FIGURES

Figure	Page
1. Peer economy diagram.....	2
2. Roles within maker economies.....	5
3. Mapping of a social network.....	6
4. Computer model of the x-rays in the universe.....	7
5. Macroscopic image of mycelium hyphae.....	7
6. Mycelia network on a substrate.....	7
7. Example of Github workflow.....	13
8. Microscopic image of mycelium.....	16
9. Types of creative Commons Licenses.....	22
10. Example of cooperative decision making process.....	27
11. The Pioneer Valley and its cities.....	29
12. Existing front (East) façade.....	34
13. The South façade.....	34
14. The West façade.....	35
15. Inoculum Commons South façade.....	36
16. Site Plan.....	38
17. Program and production timeline.....	40
18. Programmatic spaces diagram.....	41
19. Materials diagram.....	42

20. Systems Diagram.....	44
21. Interior Rendering - 1st floor – Stair Core.....	45
22. Interior Rendering – 3 <sup>rd</sup> floor – Open Office Space.....	45
23. Interior Rendering – 2 <sup>nd</sup> floor – Flex Space/Lobby.....	46
24. Exterior Rendering – 1 <sup>st</sup> floor entrance.....	46
25. Exterior rendering – 2 <sup>nd</sup> floor – entrance plaza.....	47
26. Exterior Rendering – Olive Street Intersection.....	47
27. Building Section.....	48
28. Overall Building Axonometric.....	48
29. Floor Plans.....	49
30. 1 <sup>st</sup> floor plan and site topography.....	50
31. Exterior Elevations.....	61

## CHAPTER 1

### INTRODUCTION: LOCAL MAKER ECONOMIES

A maker economy is the integration and proliferation of maker culture into the framework of existing infrastructure. Maker culture emphasizes learning-through-doing (constructivism) in a social environment. Learning is informal, networked, peer-led, and shared openly. It embraces a wide range of domains from the high-tech (electronics, programming, computer-aided design [CAD]) to craft skills such as sewing, woodworking, and machining. Maker culture encourages experimentation, novel applications of technologies, and the exploration of intersections between traditionally separate domains and ways of working.<sup>1</sup> It is often motivated by fun and self-fulfillment. However, in the context of developing a local economy there has to be an element of production and trade.

Maker economies are composed of peers. Peers are both producers and consumers, creating a network of supply and demand for goods and services. This kind of approach is a reaction to the retail economies that currently dominate the American economic landscape. Local, diversified maker economies resist the boom-bust cycle of capitalism. A community can be made more resilient by maintaining a local network of markets to supply individual and collective needs. With the rise of 3D printing and digital fabrication, producers can respond to a demand quickly and at low cost.

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<sup>1</sup> Sharples, M., McAndrew, P., Weller, M., Ferguson, R., FitzGerald, E., Hirst, T., and Gaved, M. (2013). *Innovating Pedagogy 2013: Open University Innovation Report 2*. Milton Keynes: The Open University,

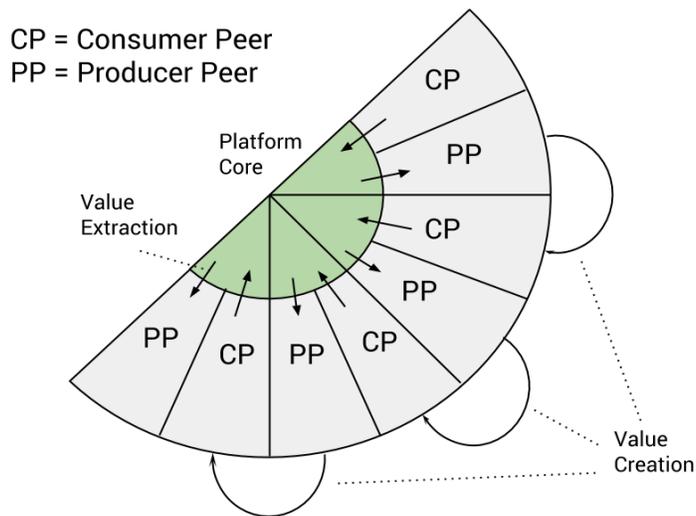


Figure 1: Peer economy diagram - Simone Cicero - Meedabyte.com

Prototyping or model making is one of the important steps to finalize a product design. It helps in conceptualization of a design. Before the start of full production a prototype is usually fabricated and tested. Manual prototyping by a skilled craftsman has been an age-old practice for many centuries. Second phase of prototyping started around mid-1970s, when a soft prototype modeled by 3D curves and surfaces could be stressed in virtual environment, simulated and tested with exact material and other properties. Third and the latest trend of prototyping, i.e., Rapid Prototyping (RP) by layer-by-layer material deposition, started during early 1980s with the enormous growth in Computer Aided Design and Manufacturing (CAD/CAM) technologies when almost unambiguous solid models with knitted information of edges and surfaces could define a product and also manufacture it by CNC machining.

The most complete research about the business models of Fab Labs so far comes from Peter Troxler, especially in his paper "Commons-based Peer Production of Physical Goods – Is There Room for a Hybrid Innovation Ecology?" (presented at the 3rd Free Culture Research Conference, October 2010 Berlin). Troxler found that in the current Fab Lab practice there is no single business model and the literature about it is quite poor. Studying 10 Fab Labs (out of 45 world wide), Troxler discovered that the labs were primarily offering infrastructures to students, and they were relatively passive in reaching out to other potential users (general public, companies, researchers). Usually Fab Labs are hosted at schools, research or innovation centers or are independent entities: funding comes from outside, from public sources or from their hosting institution while revenue from sponsoring or from users so far remained the exception; however, Fab Labs are requested to become self-sustaining within 2 to 4 years, but none of the labs studied had yet reached this stage. Most of the Fab Labs had their own employees, and a few were run by a faculty of their host university or were supported by volunteers.

Fab Labs usually use their own Internet presence as a marketing strategy; few of them actively engage in PR, and these ones attract also non-students as users. Furthermore, they had so far created a limited innovation ecosystem with few network and industry partners and few, if any sponsors, which got used rather rarely. All labs indicated their main business model was providing access to infrastructure that users would have no

access to otherwise, but most of them indicated that giving access to knowledge of the Fab Lab network and giving access to experts were equally part of their value proposition. Troxler pointed out then that there are two main business models (or value propositions) possible, namely Fab Labs providing facilities and Fab Labs providing innovation support.

Troxler further developed the concept of Fab Labs as innovation center within another paper, written together with Patricia Wolf: "Bending The Rules: The Fab Lab Innovation Ecology" presented at the 11th International CINet Conference, September 2010 Zurich. In this paper they identified four possible business models (Table 1.), among the intersections of open and closed intellectual property and Fab Lab as facility or as innovation support. Specifically, they propose the Fab Lab innovation ecology (a network of partners) as the most interesting, a Fab Lab with open intellectual property and aimed at facilitating innovation: more design thinking and stimulating innovation than just providing access and training. The primary clientele of this model are innovators, companies (particularly SMEs) and researchers, while the general public is not really important. Revenue will come from projects, services provided and partners engaging with the lab, rather than per hour or membership fees and possible sales of products or IP. The Fab Lab innovation ecosystem adds the linking with a network of knowledge and experience to cheap manufacturing technologies, creating value by capturing experience and feeding it back into the network.

Novel approaches to production and experimentation must work within existing policy and economic conditions to a certain degree. Traditional laws of economics still apply. To sustain an industry there must still be a demand for goods and competing parties to supply them. Worker cooperatives utilize this type of integration strategy.

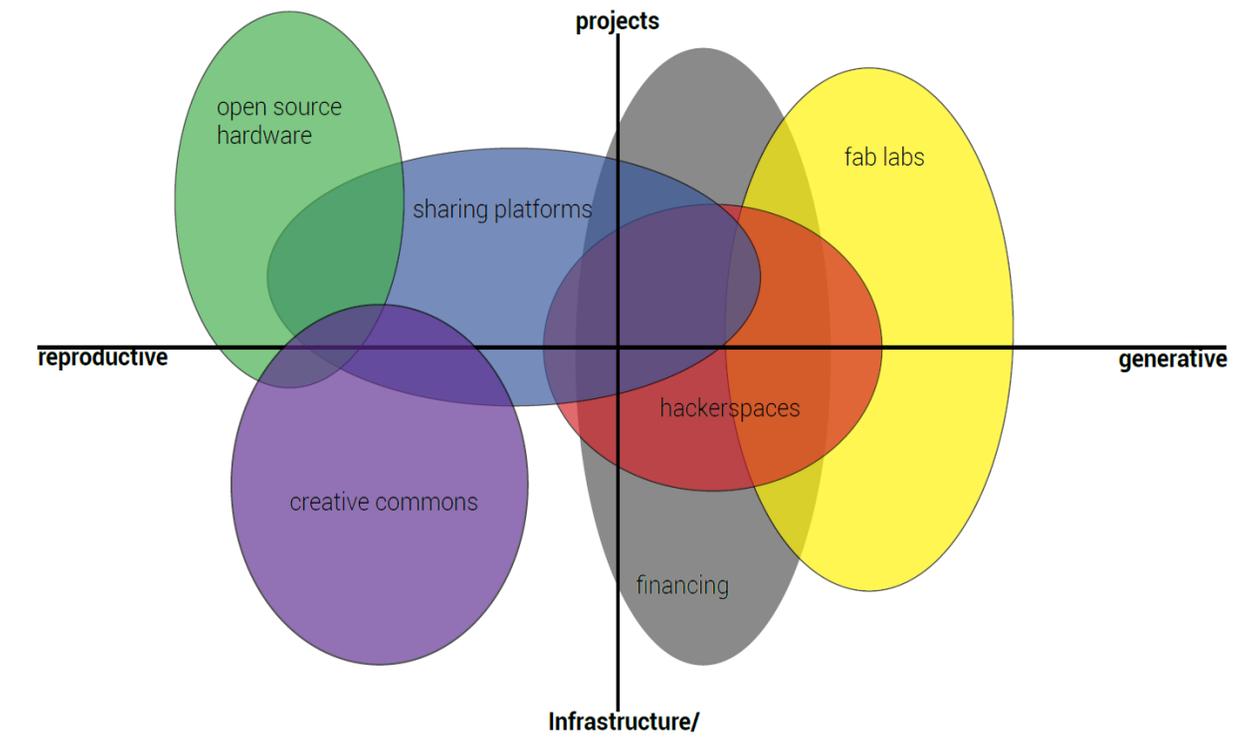


Figure 2. Roles in Maker Economies

## CHAPTER 2

### DECENTRALIZED NETWORK MODEL

The universe is not centralized. On many different scales our world is modeled as not a neat and orthographic system, but as a tangled network. The human scale of people, places, ideas can be represented by the structure of our social networks.

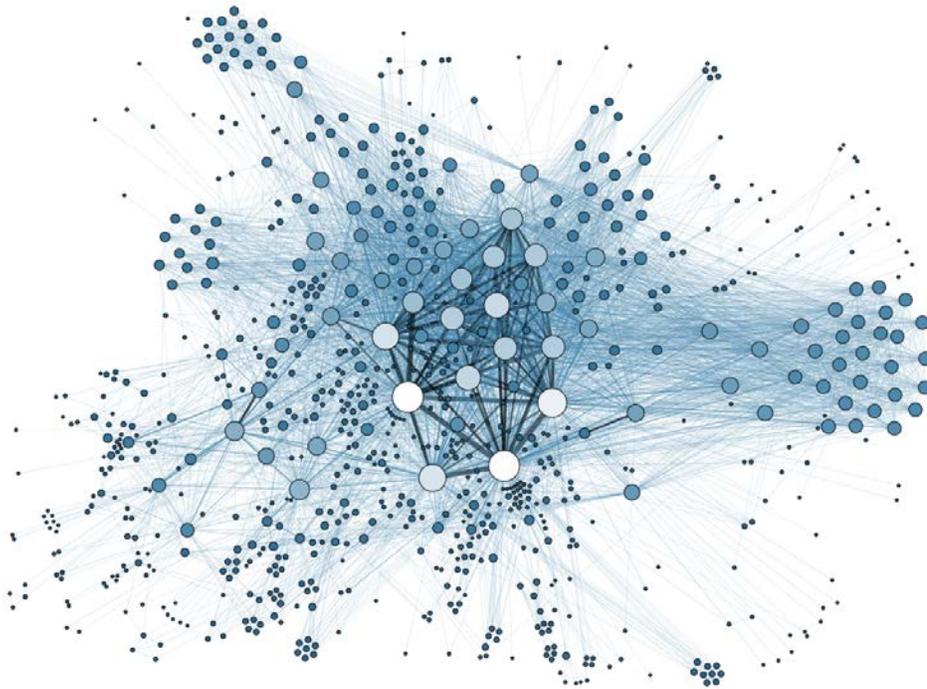


Figure 3. Mapping of a social network

On an astronomical scale galaxies, filled with billions of stars, seem enormous, but they only make up a small percentage of the material in the universe. They serve as nodes where gravity draws matter together. Computer simulations suggest that long filaments connect the distant galaxies. These web lines contain hydrogen gas left over from the start of the universe.

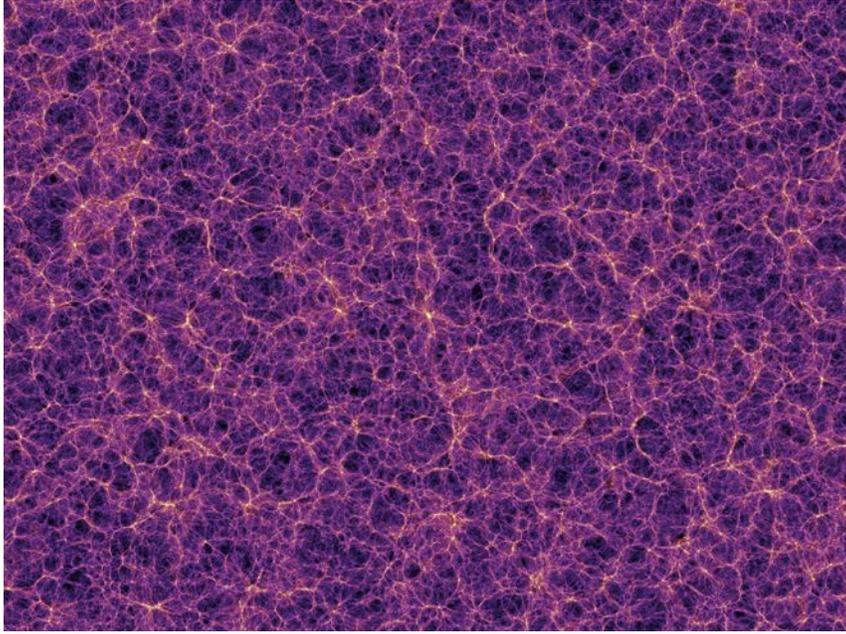


Figure 4. Computer model of the x-rays in the universe

On a microscopic scale we can observe the same type of organizational structure in the mycelium of fungi. Mycelium is a network of branching, thread-like hyphae. fungal colonies composed of mycelium are found in and on soil and many other substrates.



Figure 5. macroscopic image of mycelium hyphae



Figure 6. mycelial network on a substrate

Network centralization is an attempt to improve efficiency by taking advantage of potential economies of scale. decentralization is an attempt to improve speed and flexibility by reorganizing networks to increase local control and execution of service. There is currently a social and technological movement toward decentralization. The Internet and social networks have proven that the model is viable on a global scale.

One of the most recent example of these movements is the decentralization of the electrical grid and the transition to renewable energy sources. Electricity was originally generated at remote hydroelectric dams or by burning coal in the city centers, delivering electricity to nearby buildings and recycling the waste heat to make steam to heat the same buildings. Rural houses had no access to power. Over time, coal plants grew in size, facing pressure to locate far from population because of their pollution. Transmission wires carried the electricity many miles to users with a 10 to 15 percent loss, a difficult but tolerable situation. Because it is not practical to transmit waste heat over long distances, the heat was vented. There was no good technology available for clean, local generation, so the wasted heat was a tradeoff for cleaner air in the cities. Eventually a huge grid was developed and the power industry built all-new generation in remote areas, far from users. All plants were specially designed and built on site, creating economies of scale. It cost less per unit of generation to build large plants than to build smaller plants. These conditions prevailed from 1910 through 1960, and everyone in the power industry and government came to assume that remote, central generation was optimal, that it would deliver power at the lowest cost versus other alternatives.

By contrast, distributed energy resource (DER) systems are decentralized, modular and more flexible technologies that are located close to the load they serve. DER systems typically use renewable energy sources, including, but not limited to, small hydro, biomass, biogas, solar power, wind power, geothermal power and increasingly play an important role for the electric power distribution system. A grid-connected device for electricity storage can also be classified as a DER system, and is often called a distributed energy storage system (DESS). By means of an interface, DER systems can be managed and coordinated within a smart grid. Distributed generation and storage enables collection of energy from many sources and may lower environmental impacts and improve security of supply.

All over the country, communities are developing their own energy resources locally. Through government incentives and a dramatically decreasing market cost, people are developing these decentralized systems for themselves and increasing their community resilience.

## CHAPTER 3

### COMMONS BASED PEER PRODUCTION

Commons-based peer production is a term coined by Harvard Law School professor Yochai Benkler to describe a new decentralized model of economic production in which the creative energy of large numbers of people is coordinated (usually with the aid of the internet) into large, meaningful projects, mostly without traditional hierarchical organization or financial compensation. He compares commons-based peer production to firm production (where a centralized decision process decides what has to be done and by whom) and market-based production (when tagging different prices to different jobs serves as an attractor to anyone interested in doing the job).

The term was first introduced in Benkler's seminal paper Coase's Penguin. His 2006 book, *The Wealth of Networks* expands significantly on these ideas.

*"People participate in peer production communities for a wide range of intrinsic and self-interested reasons....basically, people who participate in peer production communities love it. They feel passionate about their particular area of expertise and revel in creating something new or better."*<sup>2</sup>

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<sup>2</sup> Benkler, Yochai (2003). *Freedom in the Commons: Towards a Political Economy of Information*. *Duke Law Journal*, vol. 52, pp. 1245-1276.

Another definition, by Aaron Krowne from Free Software Magazine:

commons-based peer production. "*refers to any coordinated, (chiefly) internet-based effort whereby volunteers contribute project components, and there exists some process to combine them to produce a unified intellectual work. CBPP covers many different types of intellectual output, from software to libraries of quantitative data to human-readable documents (manuals, books, encyclopedias, reviews, blogs, periodicals, and more)*".<sup>3</sup>

By any measure, it is a mode of production that is **open** (access to participation), **transparent** (access to information), **decentralized** (allocation of resources) and **horizontal** (autonomy), involving many actors who use p2p communications (e.g. the Internet) to coordinate. These actors are both independent and interdependent. They may freely share material resources and the platform (infrastructure), their knowledge, and collaborative effort to provide solutions to problems.

The term "peer production" characterizes a subset of commons-based production practices. It refers to production systems that depend on individual action that is self-selected and decentralized, rather than hierarchically assigned.<sup>4</sup> Moreover, Benkler appoints

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<sup>3</sup> Krowne, Aaron (March 1, 2005). "The FUD based encyclopedia: Dismantling the Fear, Uncertainty and Doubt aimed at Wikipedia and other free knowledge sources". Free Software Magazine.

<sup>4</sup> Benkler, Yochai, and Helen Nissenbaum (2006). Commons-based Peer Production and Virtue. The Journal of Political Philosophy. Volume 14, Number 4, 2006, pp. 394–419.

two features related to the organization of the Commons-Based Peer Production which have to be mentioned: "Modularity" and "Granularity".

"Modularity" is a property of a project that describes the extent to which it can be broken down into smaller components, or modules, that can be independently produced before they are assembled into a whole. If modules are independent, individual contributors can choose what and when to contribute independently of each other. This maximizes their autonomy and flexibility to define the nature, extent, and timing of their participation in the project.

"Granularity" refers to the size of the modules, in terms of the time and effort that an individual must invest in producing them. The five minutes required for moderating a comment on Slashdot, or for metamoderating a moderator, is more fine-grained than the hours necessary to participate in writing a bug fix in an open-source project.

These two features are undoubtedly very important to understand the collaborative production. However, It must be stressed that they do not arise from purely organizational characteristics but largely from the potential of the Internet and digital information.

Examples of projects using commons-based peer production include:

- Linux, a computer operating system kernel
- Slashdot, a news and announcements website
- Wikipedia, an online encyclopedia
- Distributed Proofreaders, which proof reads public domain etexts for publication on Project Gutenberg
- SETI@home, a project which searches for extra terrestrial life
- Clickworkers, a citizen science program
- Sourceforge, a software development organization
- RepRap Project, a project to create an open-source self-copying 3D printer.
- Pirate Bay, a shared index of bittorrents (under legal scrutiny in Sweden as of February 2009)
- OpenStreetMap, a free map of the world
- Appropedia, a project for development of open-source-appropriate technology
- Wikiprogress, a project for collecting information and data on measuring the progress of societies
- Ushahidi, crowdsourced maps
- GROWL, an education network producing open materials and curricula
- GitHub , an online software development community
- Bitcoin, a virtual currency
- Shapeways, an online product development and prototyping platform

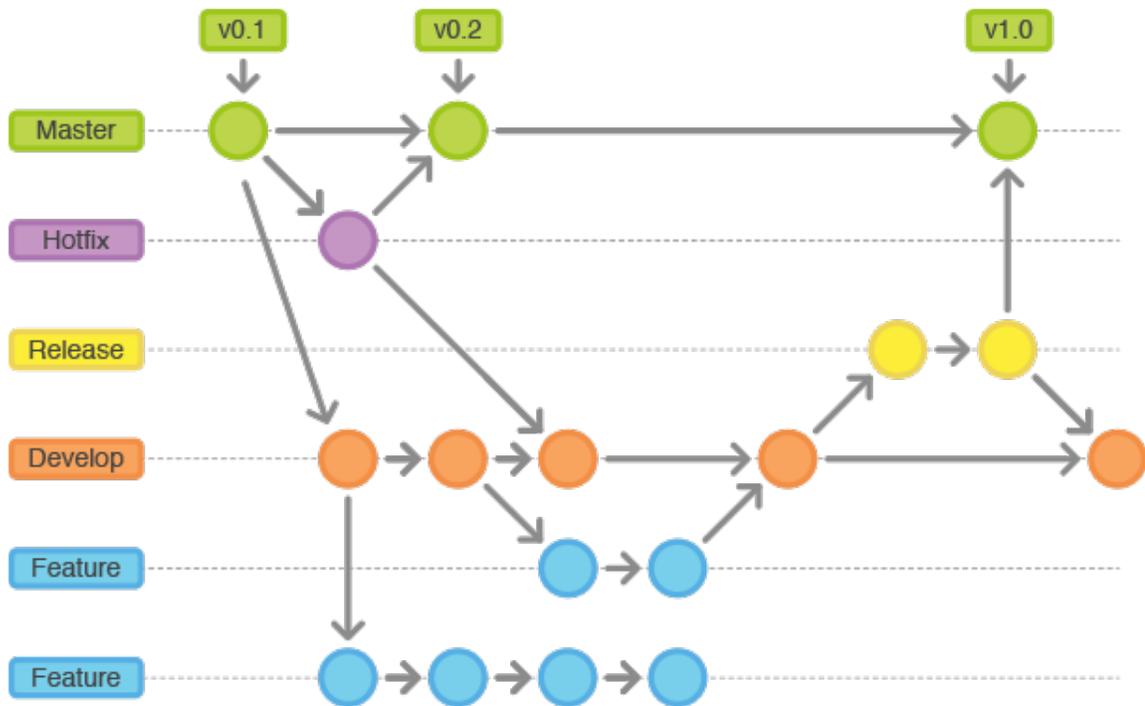


Figure 7. Example of a Github Workflow

Fabrication

The rise of commons-based peer production, i.e. individuals collaborating in producing cultural content, knowledge, and other information and indeed physical goods, is commonly attributed to ‘digital revolutions’, the broad availability of new information technologies. Benkler argues that ‘in the networked information economy—an economy of information, knowledge, and culture that flow through society over a ubiquitous, decentralized network—productivity and growth can be sustained in a pattern that differs fundamentally from the industrial information economy of the twentieth century in two crucial characteristics. First, nonmarket production can play a much more important role than it could in the physical economy. Second, radically decentralized production and

distribution, whether market-based or not, can similarly play a much more important role'<sup>5</sup>

Commons-based peer production is most widely practiced in the area of software development, of which such important programs as the Linux operating system and the Apache web server are the most prominent examples. Commons-based peer production has also moved beyond pure software and spread into other domains, from culture and education to knowledge discovery and sharing (e.g. the SETI@home project, Wikipedia, Open Street Map, Slashdot, or the Blender movies). Commons-based peer production might be 'born digital', yet it also leaves the purely digital domain. There are quite a number of fabbing projects (fabbing from fabrication), open source hardware projects that aim to produce tangible goods through a peer-production approach.

Balka et al. went to great length to collect examples of open source hardware projects through their site <http://open-innovation-projects.org/> which they then used as basis for their quantitative studies. They find, 'that, in open design communities, tangible objects can be developed in very similar fashion to software; one could even say that people treat a design as source code to a physical object and change the object via changing the source'. but also that that 'open parts strategies in open design are crafted at the component level, rather than the level of the entire design'. and that 'the degree of openness

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<sup>5</sup> Benkler, Yochai (2006). *The Wealth of Networks. How Social Production Transforms Markets and Freedom*. New Haven and London: Yale University Press.

differs significantly between software and hardware components, in the sense that software is more transparent, accessible, and replicable than hardware'.<sup>6</sup>

Similarly, Torrone and Fried collected 13 examples of companies that are selling open source hardware and creating some kind of community around them. Those companies together, the authors estimate, generate a turnover of about US\$ 50m.<sup>7</sup> The authors reckon that there are currently about 200 open source hardware projects of this kind. They project the open source hardware community to reach US\$ 1b by 2015. Some of these communities have indeed seen an exponential growth recently, e.g. the RepRap community.

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<sup>6</sup> Balka, Kerstin, Christina Raasch, Cornelius Herstatt (2009). Open Source beyond software: An empirical investigation of the open design phenomenon. Paper presented at the R&D Management Conference 2009, Feldafing near Munich, Germany 14-16 October 2009.

<sup>7</sup> Torrone, Philip and Limor Fried (2010). Million Dollar Baby. Businesses Designing and Selling Open Source

## CHAPTER 4

### MYCELIUM INSULATION

The development of mycelium insulation materials is an ideal starting point for testing out CBPP in the physical realm. The materials needed are readily available and once identified and harnessed, a strain of fungi that works for the application can be cultivated indefinitely. The equipment needed to produce mycelium is relatively low-tech making the threshold for participation very low.

#### THE POTENTIAL OF FUNGI

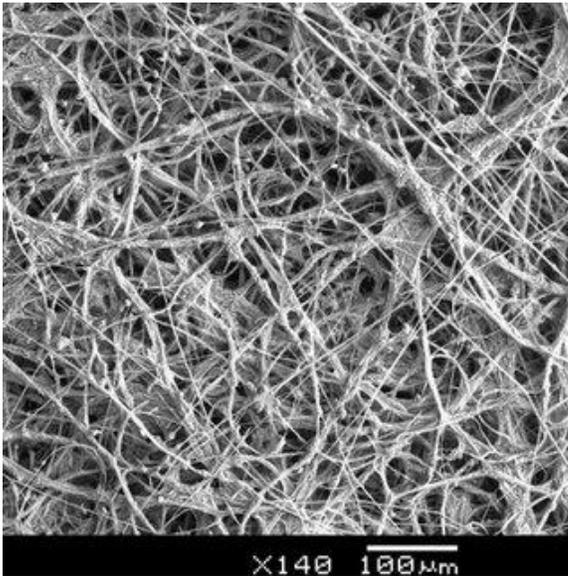


Figure 8: microscopic image of mycelium

This is microscopic image of mycelial structures found in all fungi. This structural system keeps fungi firmly in place while allowing them to maximize access to resources. They are to fungi what roots are to trees. This material is not only useful as a physical

product but also as a organizational model. Fungi form a planetary web. Mycelia absorb nutrients from their surroundings and can rapidly change their growth patterns and other behavior in response to the environment. It is a distributed network of cells that work together to achieve a number of goals. Our cities

Paul Stamets is a Mycologist and author who studies fungi in relation to solving a number of our most pressing adaptation and ecological integration issues. He has studied a number of ways that we can utilize fungi to decrease our ecological impact. He sees them as partnerships between species that we should be participating in more diligently.

- Fungi absorb hydrocarbons and break hydrogen-oxygen bonds (can be used to clean up oil spills)
- Fungi absorb and deactivate viruses and bacteria through organic antibiotics
- Fungi absorb chemical toxins rendering them inert
- Fungi are gateway organisms, vanguard species that open the door for other biological communities. (They can transform a medium that is unsuitable for life into a medium that is suitable for plants and animals to thrive.)

'Mushroom materials' are a novel class of renewable biomaterial grown from fungal mycelium and low-value non-food agricultural materials using a patented process developed by Evocative Design. After being left to grow in a former in a dark place for about five days during which time the fungal mycelial network binds the mixture, the resulting light

robust organic compostable material can be used to within many products, including building materials, thermal insulation panels and protective packaging.

The process uses an agricultural waste product such as cotton hulls, cleaning the material, heating it up, inoculating it to create growth of the fungal mycelium, growing the material for period of about five days, and finally heating it to make the fungus inert. During growth, the material's shape can be molded into various products including protective packaging, building products, apparel, car bumpers, or surfboards. The environmental footprint of the products is minimized through the use of agricultural waste, reliance on natural and non-controlled growth environments, and home compostable final products. The founders intention is that this technology should replace Styrofoam and other petroleum-based products that take many years to decompose, or never do so.

Mycoform structure can be grown from strains of fungi into a specific 3D fabricated geometry. The main objective of Mycoform is to establish a smart, self-sufficient, perpetual-motion construction technology. By combining fungal mycelia with varying types of organic substrates and carefully controlling their expansion within prefabricated molds, we will create the literal growth of structural materials. The Mycoform is grown from biological materials. The process is pollution free, and has the potential to contain a low embodied energy as part of a local ecosystem.

The polypore fungal species *Ganoderma lucidum* (Reishi), possesses enzymes that readily digest a wide variety of cellulose based organic byproducts. The rapid growth of branching mycelia results in a dense matrix capable of structural support. The fungal substance is combined with a strong and durable outer layer shield of compacted material such as recycled aluminum. The Mycoform Building Block production is a low-tech, low energy process. Few inexpensive readily available tools, free refuse and agricultural byproducts, 80 F and humidity is all that is needed to compact and grow a mycelium building block. The technology is easily transferable to the developing world where building materials are scarce and expensive. The New Museum model was grown in a period of 10 days in incubator starting with a mixture of oak pellet fuel, wheat bran, gypsum, and hydrogen peroxide resulting in a dense mycelium structure.

The Myco-insulation can be produced as a fully grown and dehydrated panel for easy installation in renovation projects. It can also be produced as a wet and live inoculum with fully viable spores in a substrate. This product can be packed into walls of new construction projects and grown on site.

## CHAPTER 5

### CREATIVE COMMONS LICENSING

To produce and experiment with the mycelium insulation, the network must engage in a system of licensing to coordinate tasks and to give credit where credit is due within the organization. There has to be a system of tracking peer and node contributions, while allowing peers to be compensated for their work. Creative Commons Licensing could be extended to cover this type of scientific development.

Creative Commons licensing is a set of licenses created by Lawrence Lessig, but also a worldwide movement to promote open access to intellectual content. If traditional copyright is based on the principle of "all rights reserved", then the CC licences are typified by the principle of "some rights reserved". The licenses offer 6 core options, whereby the combination of the attribution and share alike principles, correspond to the principles of the Copyleft movement and the General Public License.

Creative Commons license are based on copyright. So it applies to all works that are protected by copyright law. The kinds of works that are protected by copyright law are books, websites,

Blogs, photographs, films, videos, songs and other audio & visual recordings, for example. The Creative Commons model can also be extended to scientific research. CC enables the creator of a work to predefine different licensing possibilities on a step-by-step basis. Thus exchanging and using licenses can be simplified significantly – and without any tedious license research or contract negotiations. So everybody can freely use a work, or the licensing rights can be restricted for further usage. Yet CC also provides the possibility to specify the commercial usage of a work.

Creative Commons licenses give the ability to dictate how others may exercise copyright rights—such as the right of others to copy work, make derivative works or adaptations of work, to distribute work and/or make money from work. They do not give you the ability to restrict anything that is otherwise permitted by exceptions or limitations to copyright—including, importantly, fair use or fair dealing—nor do they give you the ability to control anything that is not protected by copyright law, such as facts and ideas.

One final thing to note about Creative Commons licenses is that they are all non-exclusive. This means that you can permit the general public to use your work under a Creative Commons license and then enter into a separate and different non-exclusive license with someone else, for example, in exchange for money.

This type of licensing is crucial to the mass proliferation of new technologies and ideas. It allows other people to use and develop an idea with the originator. It is a more

inclusive alternative to restrictive and oppressive copyright.

	Can someone use it commercially?	Can someone create new versions of it?
<b>Attribution</b> 		
<b>Share Alike</b> 		Yup, AND they must license the new work under a Share Alike license.
<b>No Derivatives</b> 		
<b>Non-Commercial</b> 		Yup, AND the new work must be non-commercial, but it can be under any non-commercial license.
<b>Non-Commercial Share Alike</b> 		Yup, AND they must license the new work under a Non-Commercial Share Alike license.
<b>Non-Commercial No Derivatives</b> 		

Figure 9: Types of Creative Commons licensing

## CHAPTER 6

### PEER GOVERNANCE

The nodes of the production network would be run as worker owned cooperatives. Worker cooperatives are business entities that are owned and controlled by their members, the people who work in them. All cooperatives operate in accordance with the Cooperative Principles and Values. The two central characteristics of worker cooperatives are: (1) worker-members invest in and own the business together, and it distributes surplus to them and (2) decision-making is democratic, adhering to the general principle of one member-one vote.

Cooperatives are the only form of business centered on membership, and member and community benefit is at the core of the cooperative model. Worker cooperative businesses are owned and run by their members, the people who work in them, and they operate for the benefit of these members.

The member benefits are multiple. A cooperative can be a way for people to start and own a small business together when they may lack the means or expertise to do so alone. Worker cooperative members can build assets in their cooperative business by retaining surplus every year in individual capital accounts. In a worker cooperative, workers own their jobs, so they decide how they are treated and how they want to operate the

business. Worker-owners also get a lot of practice making decisions, building their skills in a variety of areas, and participating democratically in a process to benefit the larger group. These are the skills and habits of engaged community members, and they don't stop at the workplace: you will often find worker-owners involved in the community in other ways.

Community benefits are clear too. Successful worker cooperatives tend to create long-term stable jobs, enact sustainable business practices, and develop linkages among different parts of the social economy. Worker-owned businesses have not only a direct stake in the local environment but the power to decide to do business in a way that is sustainable for us all. The worker cooperative movement is increasingly recognized as part of the larger movement for sustainability and a new economy based on people's needs.

Cooperatives have a long history as a way for working people to create good, dignified jobs that they control, particularly for people who lack access to business ownership or even stable work options. Organizations undertaking economic development to build wealth in poor communities and communities of color have used worker cooperatives as a powerful vehicle for addressing economic inequality. Worker cooperatives have been shown to provide better working conditions and wages for typically low-wage work, and to increase household wealth for low-income workers. Worker cooperatives can also play an important role in building movements for economic justice and social change.

As institutions where real democracy is practiced on a day to day basis, they are a model for the empowerment we will need to create the change we envision. As economic engines, they meet material needs, anchoring capital and jobs in communities.

The co-operative principles are guidelines by which co-operatives put their values into practice. The International worker cooperative federation CICOPA established basic standards for worker cooperatives in the World Declaration on Cooperative Worker Ownership at a meeting in Oslo, Norway in 2003.

### **1st Principle: Voluntary and Open Membership**

Co-operatives are voluntary organizations, open to all persons able to use their services and willing to accept the responsibilities of membership, without gender, social, racial, political or religious discrimination.

### **2nd Principle: Democratic Member Control**

Co-operatives are democratic organizations controlled by their members, who actively participate in setting their policies and making decisions. Men and women serving as elected representatives are accountable to the membership. In primary co-operatives members have equal voting rights (one member, one vote) and co-operatives at other levels are also organized in a democratic manner.

### **3rd Principle: Member Economic Participation**

Members contribute equitably to, and democratically control, the capital of their co-operative. At least part of that capital is usually the common property of the co-operative. Members usually receive limited compensation, if any, on capital subscribed as a condition of membership. Members allocate surpluses for any or all of the following purposes: developing their co-operative, possibly by setting up reserves, part of which at least would be indivisible; benefiting members in proportion to their transactions with the co-operative; and supporting other activities approved by the membership.

#### **4th Principle: Autonomy and Independence**

Co-operatives are autonomous, self-help organizations controlled by their members. If they enter into agreements with other organizations, including governments, or raise capital from external sources, they do so on terms that ensure democratic control by their members and maintain their co-operative autonomy.

#### **5th Principle: Education, Training and Information**

Co-operatives provide education and training for their members, elected representatives, managers, and employees so they can contribute effectively to the development of their co-operatives. They inform the general public - particularly young people and opinion leaders - about the nature and benefits of co-operation.

#### **6th Principle: Co-operation among Co-operatives**

Co-operatives serve their members most effectively and strengthen the co-operative movement by working together through local, national, regional and international structures.

## 7th Principle: Concern for Community

Co-operatives work for the sustainable development of their communities through policies approved by their members.

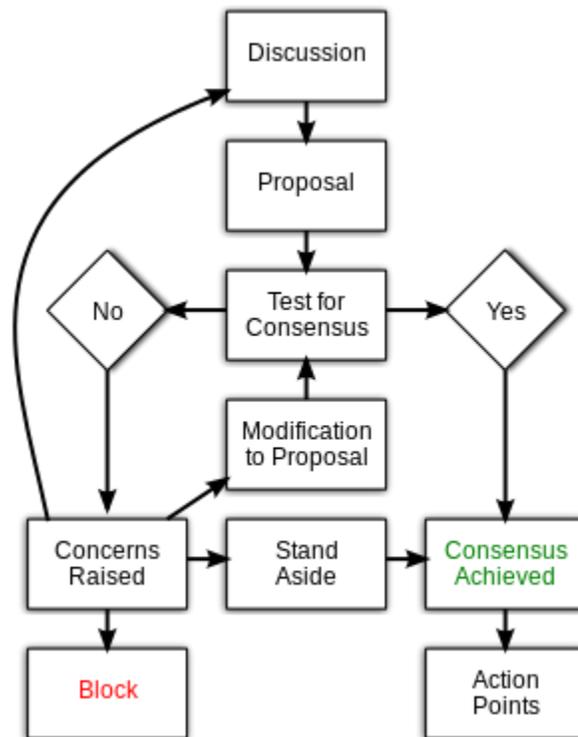


Figure 10: Example of cooperative decision making process

## CHAPTER 7

### POST-INDUSTRIAL CITIES AS TEST CASES

Post Industrial cities are great testing grounds for this type of development because there is a lot of existing infrastructure that is underutilized or in need of repair. These cities popped up during a manufacturing boom in the early 19th century, but are now shadows of the once vibrant and active industrial powerhouse. These cities are usually surrounded by vast agricultural areas that could provide the raw materials for new industries. The cities themselves have plenty of dross space that can be better utilized and vacant buildings that can be filled with productivity again.

The Pioneer Valley is rich in resources. The Connecticut River powered huge enterprises for over 100 years, and the fertile farmland in the valley has been well managed. There is so much potential within the existing infrastructure and building stock. With smart renovations and continued responsible environmental stewardship, the Valley can again support thriving industries.

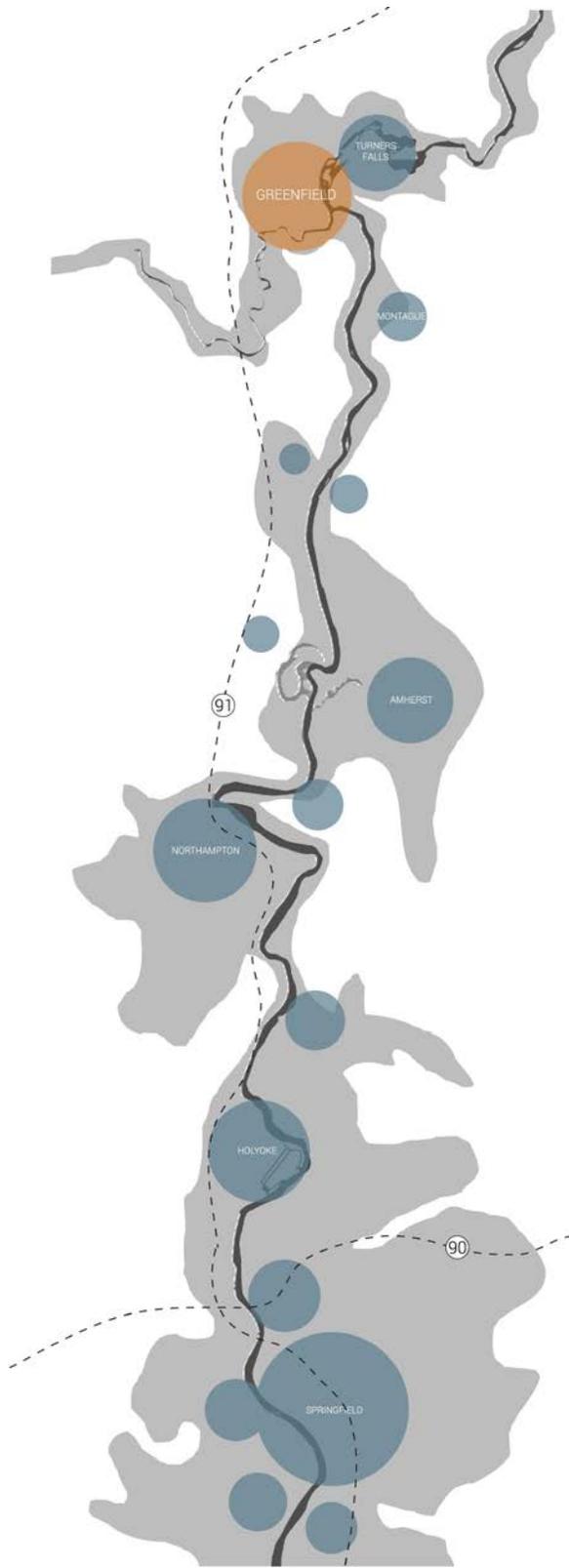


Figure 11: The Pioneer Valley and its cities

## CHAPTER 8

### GREENFIELD, MA

Greenfield is a city in Franklin County, Massachusetts, United States. It was first settled in 1686. The population was 17,456 at the 2010 census. It is the county seat of Franklin County. Greenfield is home to Greenfield Community College, the Pioneer Valley Symphony Orchestra, and the Franklin County Fair. In 1795 the South Hadley Canal opened, enabling boats to bypass the South Hadley falls and reach Greenfield via the Connecticut River.

Located at the confluence of the Deerfield and Green rivers, and not far from where they merge into the Connecticut River, Greenfield developed into a trade center. Falls provided water power for industry, and Greenfield grew into a prosperous mill town. John Russell established the Green River Works in 1834, hiring skilled German workers at what was the country's first cutlery factory. The Connecticut River Railroad was the first of several railways to enter the town, replacing the former canal trade. During the 19th and 20th centuries, Greenfield was one of the most important American centers of the tap and die business and was the home of Greenfield Tap & Die Company.

## CHAPTER 9

### SITE - EXISTING CONDITIONS

The Abercrombie Building was built in the late nineteenth century. It supported the mostly agricultural economies of the region by assisting in the transport of goods. Now generations later, as part of the burgeoning downtown scene, The Junction brings together outstanding educational institutions, cultural offerings, and spectacular surroundings.

Greenfield is the center of life in the northern Pioneer Valley. Located at the intersection of Interstate 91 and the famous Mohawk Trail, Greenfield is a hub of commerce and culture. Visitors to Greenfield's quintessential American Main Street can enjoy dining, shopping, entertainment, history, architecture, and recreation by simply taking a stroll. Educational institutions include innovative public schools, distinguished private schools, and a college. As a growing city, Greenfield has been chosen for tens of millions of dollars in new private and public investment.

The Bank Row Urban Renewal Zone has turned historic downtown buildings into new storefronts and loft apartments. New infrastructure includes a regional transit center and proposed Amtrak service along the Burlington-New York-Washington corridor. 56 Bank Row, Greenfield is directly across the street from the Franklin County Transit Center, the home of Amtrak's High-Speed Rail Station and a block from the intersection of Main Street and Bank Row -the historic center of Greenfield.

The Abercrombie building is a three-story red brick masonry building with a full basement and two-story penthouse structure. The building has been used as a warehouse throughout its life, and consists of completely open floors with exposed post and beam structural elements and brick masonry walls. The large wood members are in extremely good condition for their age, although some areas have deteriorated due to water infiltration, most notably in the basement. The fourth and fifth floors are contained within the confines of the rooftop structure.

The main entrance is located on the east façade, and is accessed directly from the Bank Row sidewalk. A small wooden stair at the southeast corner of the building leads up to a shallow landing/loading dock that runs halfway across the façade. A single entry door to the building is located on the south side of the landing, while a freight door opening is located centrally within the façade. The small loading dock has been altered multiple times over the years to accommodate various vehicles, and as a result is much smaller than the historic dock that was built for horse delivery.

A separate freight door is located at the rear of the building on the west façade, originally intended for unloading goods from the railroad that runs directly behind the building. The rear door has been blocked in and converted to a conventional door and the platform that once serviced this door has been removed, leaving a "floating" door. The existing entrances to the building are not original and have no historic value; furthermore, they do not meet accessibility requirements.

A full-width shed roof is suspended from cables and further supported by corner posts on the east façade facing the street. The shed roof does not appear to be original as historic photographs depict an older, original structure, as well as a second photograph that shows this structure having collapsed due to a heavy snowfall.

The Abercrombie building was used as a warehouse up until the week prior to the new owner's closing in August 2008. For the past 40 years the JS Smith Company used it to receive goods manufactured overseas and then to redistribute those goods to other destinations. At the height of their business all three lower floors were utilized but the penthouse was not. For the past 20 years, as labor costs increased, using the upper floors was further limited as the movement of goods required using the conveyor belt with a crew of four people to move the pallets. In recent history, the use of this building has been limited as each time a semi-truck backed up to the building the sidewalk and half of Bank Row would need to be closed down temporarily to accommodate the size of the trailer.

The original function of the fourth and fifth floors has not been determined but since the original owner built this structure, it is assumed to relate to the storage of grain. Historic photos show the original circulation centering around the movement of goods which took place in the center of the building with a freight elevator and conveyor belt system. The goods would come in from the trains, be stored and then sent out the freight door on the street. Wood floors are found throughout the building, but have experienced significant damage and deterioration from years of wear followed by years of deferred maintenance.



Figure 12: Existing front (East) facade



Figure 13: The South facade



Figure 14: The West facade

CHAPTER 10

RESULTING DESIGN: INOCULUM COMMONS



Figure 15: Inoculum Commons South Facade

## NARRATIVE

Inoculum commons will be a new kind of production space for Greenfield. It will produce a new, revolutionary product, as well as helping to develop new industries for the Pioneer Valley. The most characteristic elements of the new building will be the growths and voids incorporated into the existing building. The existing building will act as a substrate for new spaces that will facilitate the transition into a peer production economy.

The public will enter in the 2nd floor via a bridge from further up the hill of Bank Row. The mycelium production spaces are more private and located on the first floor. The new site plan features a 16' tall retaining wall to the north of the building creating a 40' wide plaza where the hillside was. This new plaza will act as an outdoor workspace as well as a truck access zone for deliveries. The site to the south of the building features constructed wetlands for the living machine and a walking bridge that spans over the wetlands, and creates access from the lower Bank Row hill.



Figure 16: Site Plan

## PROGRAM

The program decisions were driven by a distinction between human occupied spaces and fungal spaces. Humans need light, but the fungi need dark to grow to their full potential. The program was further separated into spaces for the myco-insulation production and spaces that can be transitioned into development for future industries called "peer project spaces".

**Two inoculation chambers** - inoculation of agricultural substrate. One space will produce inoculum to be grown in the growth chamber. While the other space will produce a wet inoculum for sale to the general public for in-wall growth.

**Growing chamber** - for growth of insulation wall panels.

**Baking chamber** - for dehydration after the growth cycle.

**Loading / substrate storage** - space for raw material intake and storage.

**Offices** - for day to day business administration

**Open office space** - for mycelium experimentation and eventually for incubation of next generation industries when the mycelium product is market viable.

**Digital fabrication lab** - to create forms for mycelium growth molds. In the future, the tools would be used to develop next generation products

**Hackerspace** - for maintenance of the production network and development of better communication and organization methods.

**Wood shop + metal shop** - to create molds for inoculum and future product development.

**Biology lab** - for testing the mycelium product during various stages of production.

**lobby / flex space** - for displaying new developments and a large gathering space for workshops and classes.

**Living Machine** - for bioremediation of grey and black water used in the building



Figure 17: Program and production timeline

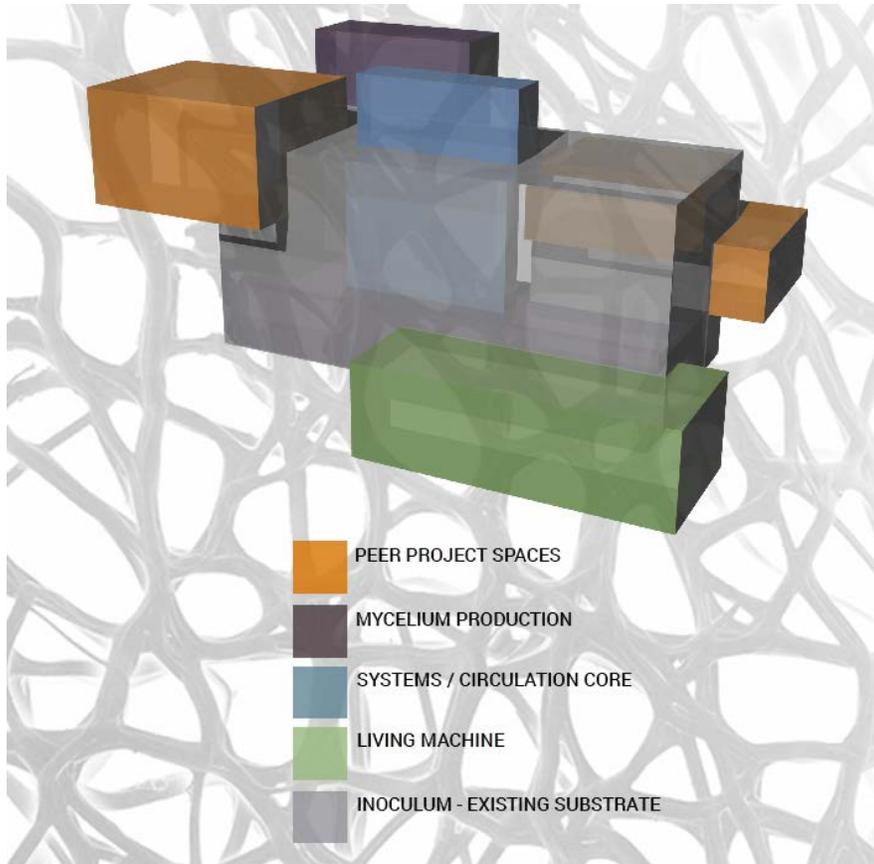


Figure 18: Programmatic spaces diagram

## MATERIALS AND METHODS

The renovation of the existing building will use the same mycelium wall panels that it will be producing for Greenfield. The wall assembly will consist of the existing brick walls and the panels attached to the existing brick with furring strips. The new wall assemblies will be Mycelium SIP (Structural Insulated Panels) with a standing seam metal exterior finish. The floors will be concrete a metal deck and embedded radiant heating tubing. The ceilings will be finished with the reclaimed wood from the existing floors.

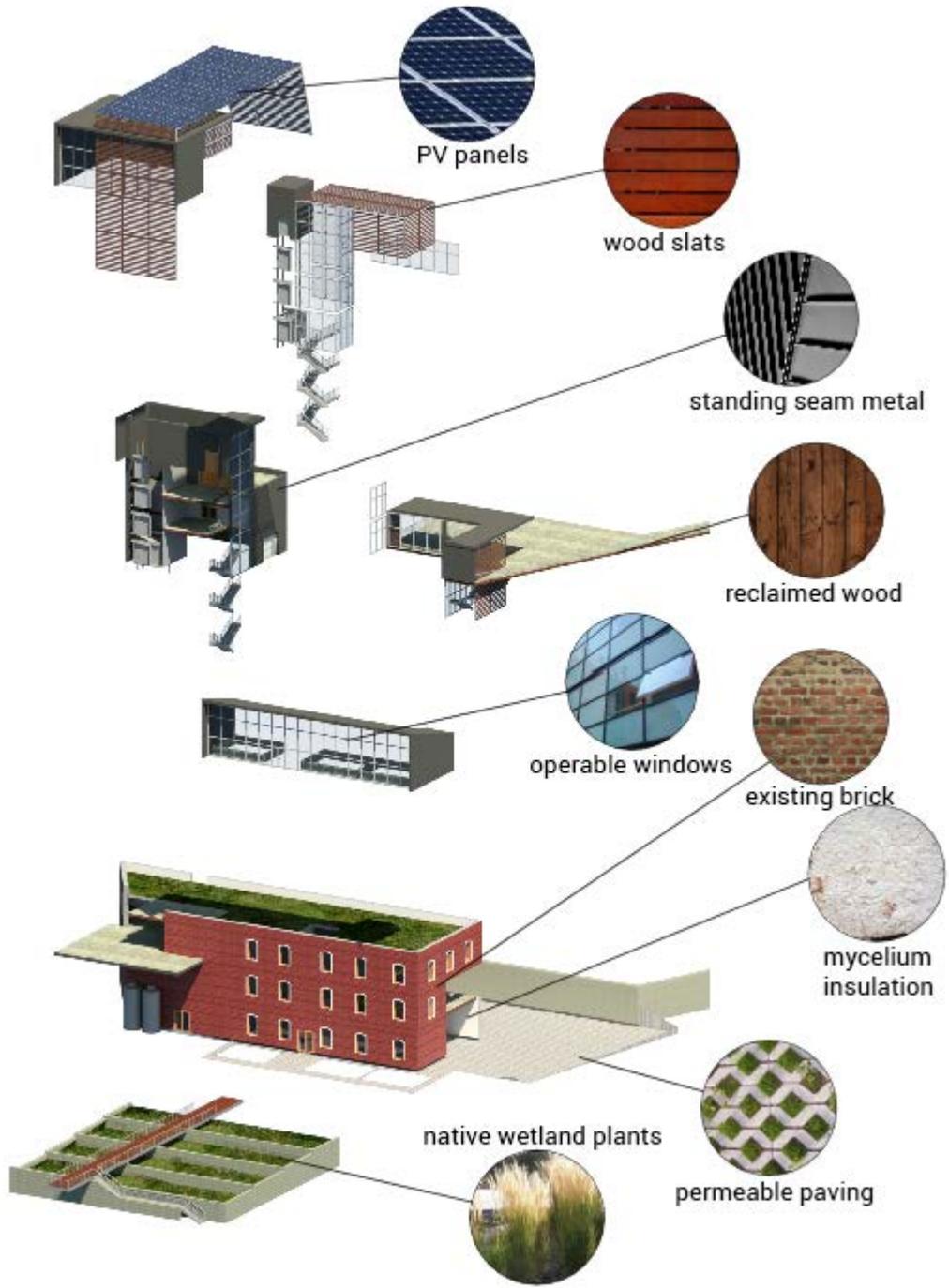


Figure 19: Materials Diagram

## BUILDING SYSTEMS

The new building will be as energy efficient as possible. The wall assemblies will be R- 30, the roof will be R-50. The radiant heating system is an excellent way to zone the heating spaces allowing smarter use of heating potential. Daylighting is brought in through large windows punched into the existing facade, while exterior shading devices reduce overexposure.

The mycelium production spaces will have a separate heating and ventilation system in order to isolate any particles that are beneficial for the mycelium, but may be unhealthy for regular human occupation. The rest of the building will be ventilated with a Heat Recovery Ventilator (HRV) which will conserve and recycle energy used in the building.

The green roof will reduce storm water runoff as well as reducing the heat island effect. The water that does run off will be collected and recycled into the greywater system. The living machine will bio remediate building greywater and black water. The system starts in the toilets and other plumbing fixtures. From there the black water goes into a septic tank that helps to separate out the solids. The water is then held in an anoxic holding tank as the organic compounds begin to breakdown. The water is then pumped into the constructed wetlands where plants and bacteria begin to breakdown phosphates and nitrates in the water. The water is then recirculated through a system of interior artificial lagoons where the nitrates and phosphates are further broken down until the water is allowed to either be released into the watershed or used as non-potable water in the building.

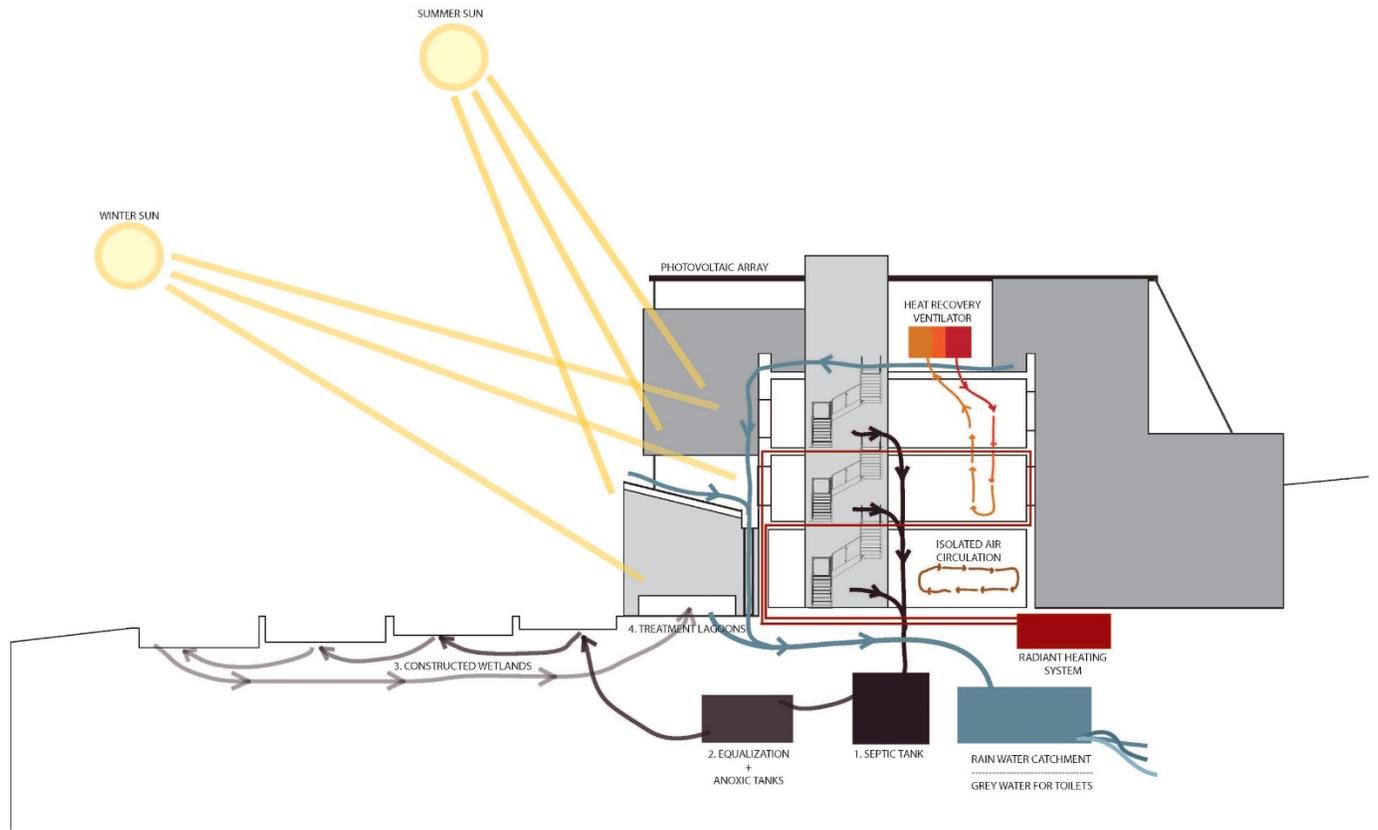


Figure 20: Systems Diagram



Figure 21: Interior Rendering - 1<sup>st</sup> floor - stair core



Figure 22: Interior Rendering - 3<sup>rd</sup> floor - Open Office Spaces



Figure 23: Interior Rendering – 2<sup>nd</sup> floor – Flex Space/Lobby



Figure 24: Exterior Rendering – 1<sup>st</sup> Floor Entrance



Figure 25: Exterior Rendering – 2<sup>nd</sup> floor – Entrance Plaza



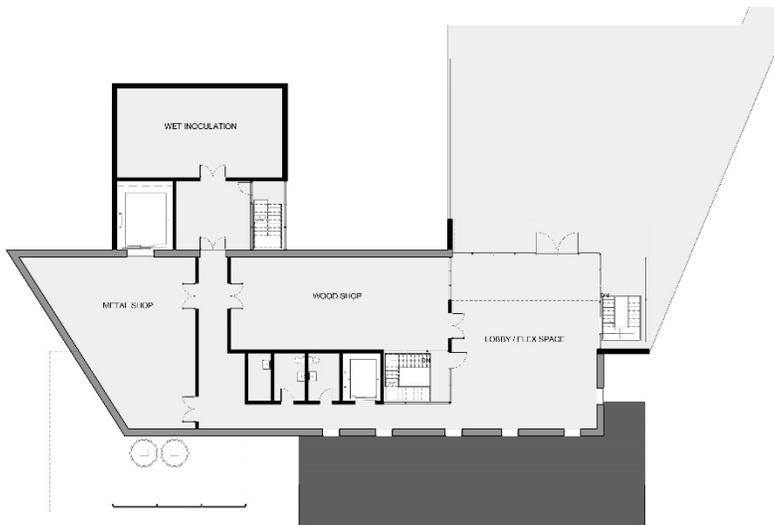
Figure 26: Exterior Rendering – Olive Street Intersection



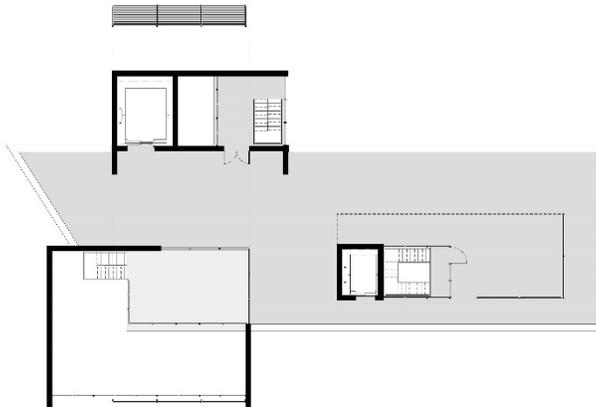
Figure 27: Building Section



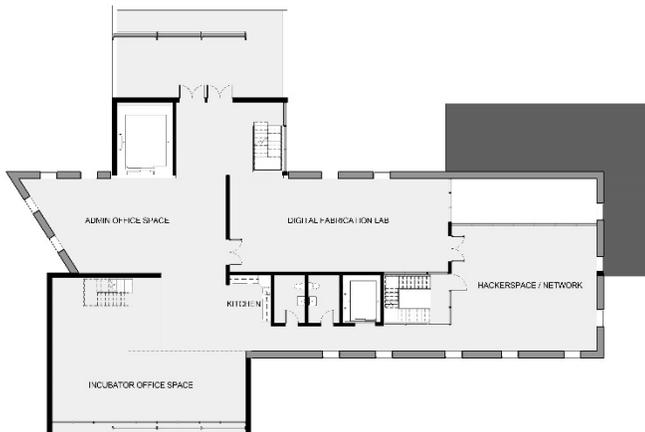
Figure 28: Overall Building Axonometric



Level 2  
302' x 142'



Level 4  
302' x 142'



Level 3  
302' x 142'

Figure 29: Floor Plans

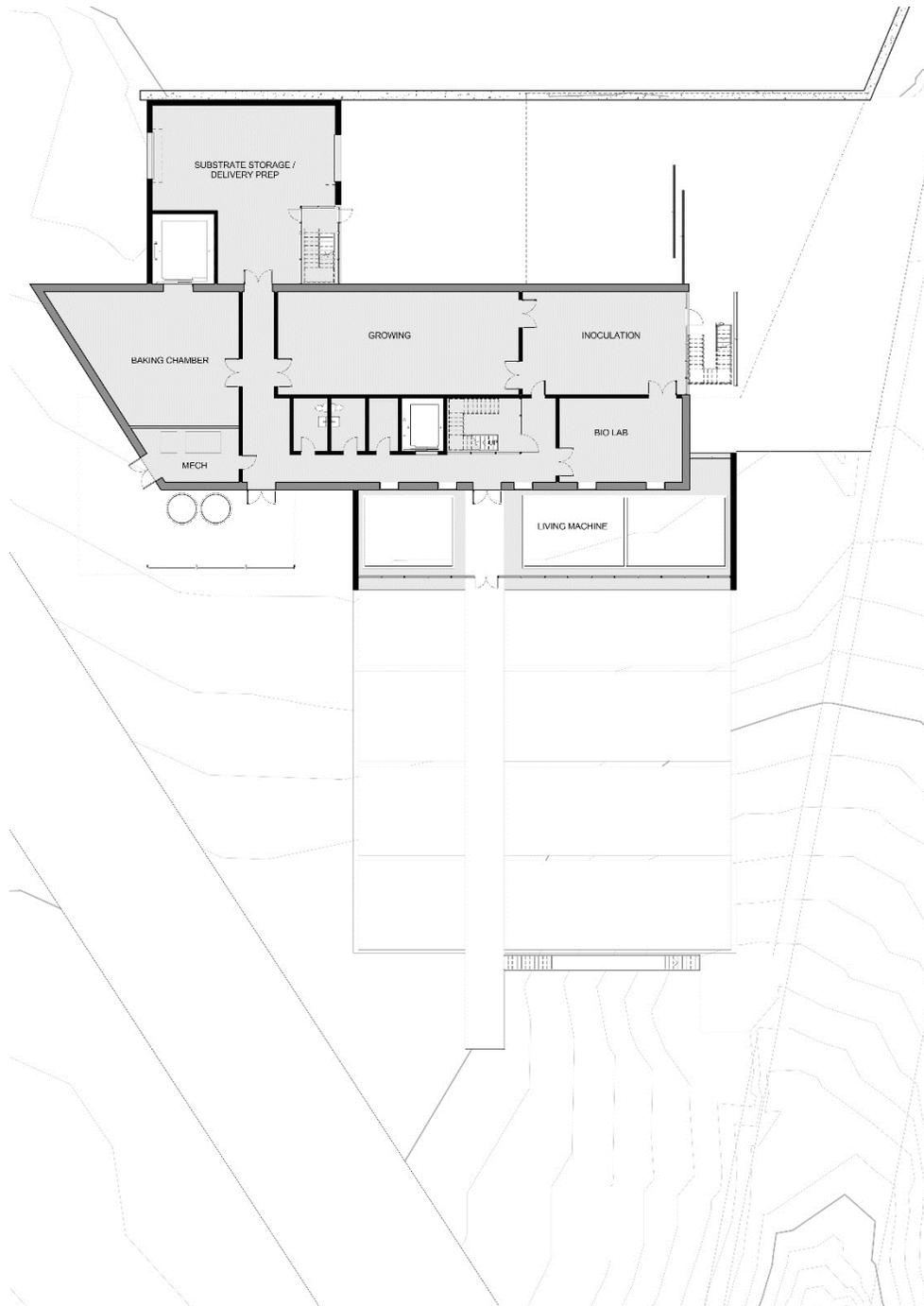


Figure 30: 1st floor plan and site topography

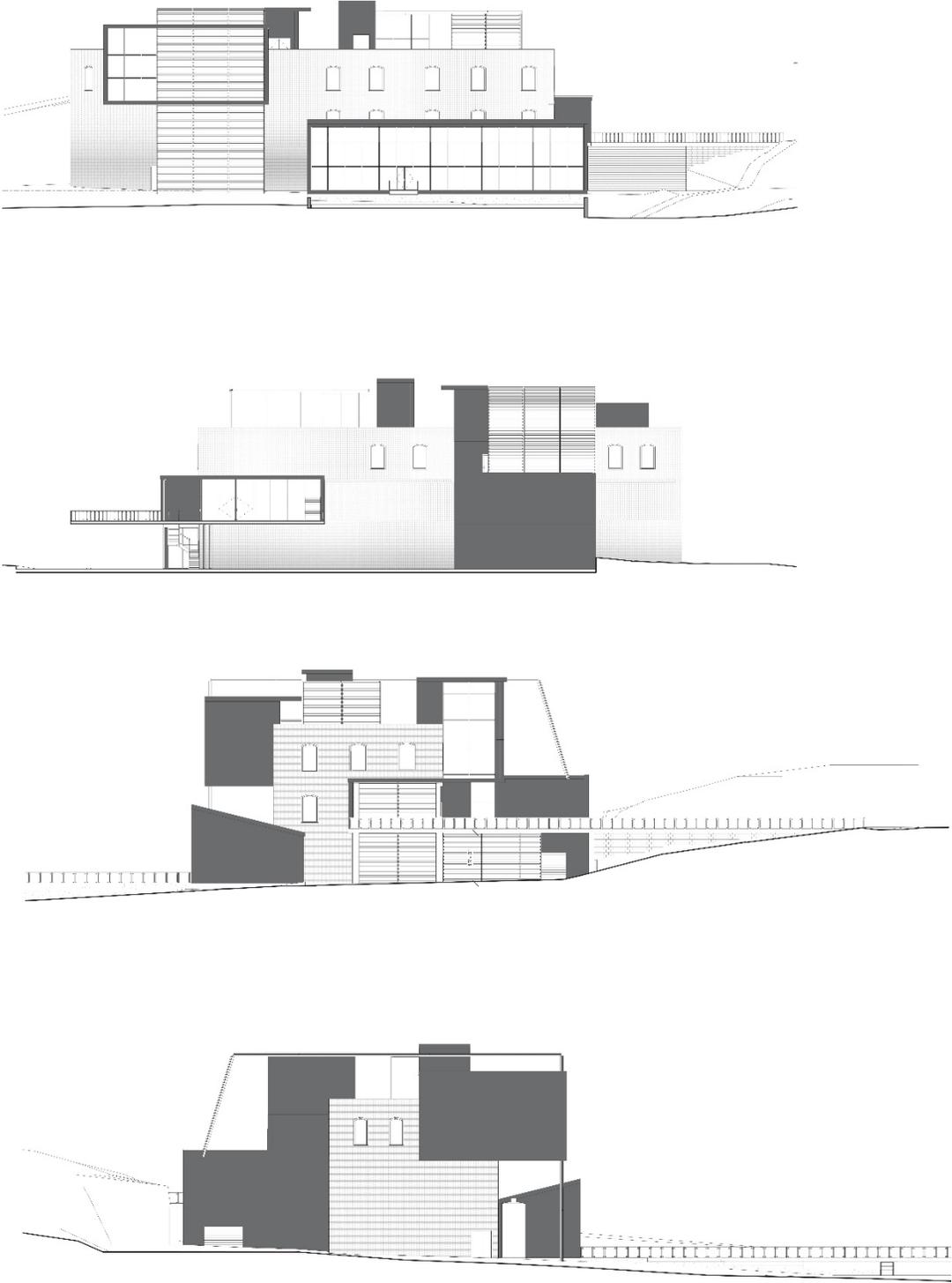


Figure 31 – Exterior Elevations

## CHAPTER 11

### CONCLUSION

Throughout this thesis process I have explored many different concepts and been fascinated by the complexity of the project. I have tried to represent the main tenets of my research through the finished design with varying levels of success. My interests are broad and varied, so it has been a constant struggle to distill this project down to the elements that work within the site and the program. There are some conceptual elements that I may have done well to disregard such as the mycelium production on site which may possibly not be suitable for an old brick building. There are other elements that maybe I should have highlighted more like what goes into a successful business incubation space. There are still some unanswered questions like what kind of structural system would be suitable to reinforce the existing brick walls and enable the growths and voids to exist within the building shell.

The driving force of the project was an analogy based on the function and structure of fungi. The existing building is the substrate or the inoculum from which new growth and new life emerges. I tried to carry this analogy throughout the physical form and within the larger concept of the network of similar buildings. This analogy became a meta-concept that I began to see not only within the form and materials of the building, but all around me in my daily and scholastic observations.

The idea of the growths onto existing buildings is particularly promising as we begin

to renovate these old industrial buildings all over the northeast. A system of freestanding growths with very specific functions could be a kit of parts that attach to existing buildings to help them engage with a decentralized economy.

Nevertheless, creating decentralized systems is going to be a major development process as we transition into a more resilient and equitable world. Mycelium is an amazing material that needs to be developed into a viable market product. Whether or not this is a viable solution is inconsequential. It is merely a stepping stone in an endless journey. There is no one solution to the problems we face on this planet, so I am going to continue to explore. This project is a reflection of myself as an individual and I am moving toward a more sustainable and regenerative future.

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