[AHEAD]

PLANNING ~~AHREAD~~:
The Emergence Of Clean Energy Technology

by Alice Rosenberg
Bachelor of Arts in Humanities
Colgate University

SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARCHITECTURE

at the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
February 2010

Signature of Author: _____
Department of Architecture
January 15, 2010

Certified by: _____
Kent Larson
Principal Research Scientist, Computation
Thesis Supervisor

Accepted by: _____
Julian Bienart
Professor of Architecture
Chairman, Department Committee on Graduate Students

THESIS COMMITTEE

Advisor:
Kent Larson
Principal Research Scientist, Computation

Reader:
Andrew Scott
Associate Professor, Architectural Design

Reader:
Cynthia Brooks
President, Greenfield Environmental Trust Group, Inc

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ABSTRACT

The solar industry is bourgeoning in the United States, with new developments in photovoltaic research. This emerging field, abetted by government funding and subsidies, needs the capacity to explore new ideas and expand on existing technologies through facilities that enable and facilitate research and production. With increased threats of global warming, imminent climate change, and rising oil prices, solar power will be a critical component of America's future, and will require significant investment in the near term.

To facilitate the solar industry and emerging clean energy technologies, this thesis project proposes an incubator for start-up companies involved with silicon-based technologies, thin-film technologies, or organic PVs to occupy and invest in. The premise of the program is to provide a series of shared spaces – wet labs, clean rooms, conference spaces, reception areas, and other communal resources – along with private spaces, including offices, research facilities, and meeting rooms. The project is both a R&D facility as well as a demonstration laboratory for new technologies. Located 12 miles north of Boston at the Industr-Plex Superfund site in Woburn, Massachusetts, the design aims to revitalize and environmentally reinvigorate the local area.

Thesis Supervisor: Kent Larson
Title: Principal Research Scientist, Computation

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Massachusetts
toxic
imperative
benefit
production
private
also
companies
spaces
well
allow
ventilation
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operates
using
fuels
adaptable
long
brownfield
miles
One
two
Strategy
remnants
start-up
relatively
outside
façade
site
prototypical
office
role
examines
sites
left
substantial
parties
energy
order
along
configuration
Substances
investment
Superfund
continuum
serves
demonstration
administrative
new
situated
firstly
developing
laboratories
accommodate
semi-public
place
levels
development
expand
zone
facilitate
component
government
including
premise
Agency
clean
features
components
tower
scenario
permanent
natural
careful
needs
maximize
centuries
wide
therefore
visible
must
demands
design
industry
facility
garner
array
technologies
program
remediate
time
wet
Response
emerging
within
progress
provide
multiple
particular
deploy
Solar
solar
elements
enable
climate
light
become
Boston
Environmental
entails
work
Compensation
series
project
responsible
stages

I. BACKGROUND

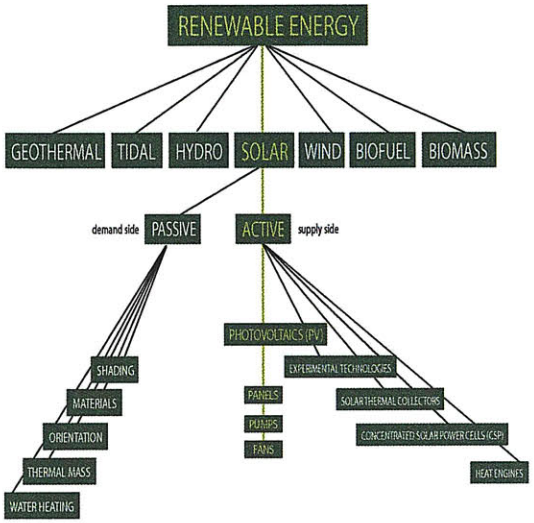
The Solar Industry

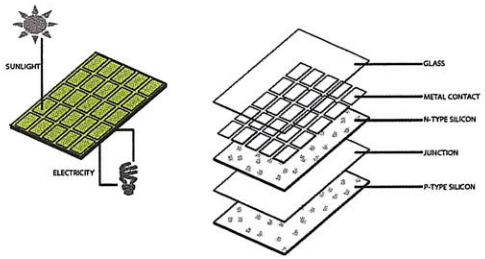
"Radically increased resource productivity is the cornerstone of natural capitalism because using resources more effectively has three significant benefits: It slows resource depletion at one end of the value chain, lowers pollution at the other end, and provides a basis to increase employment with meaningful jobs."

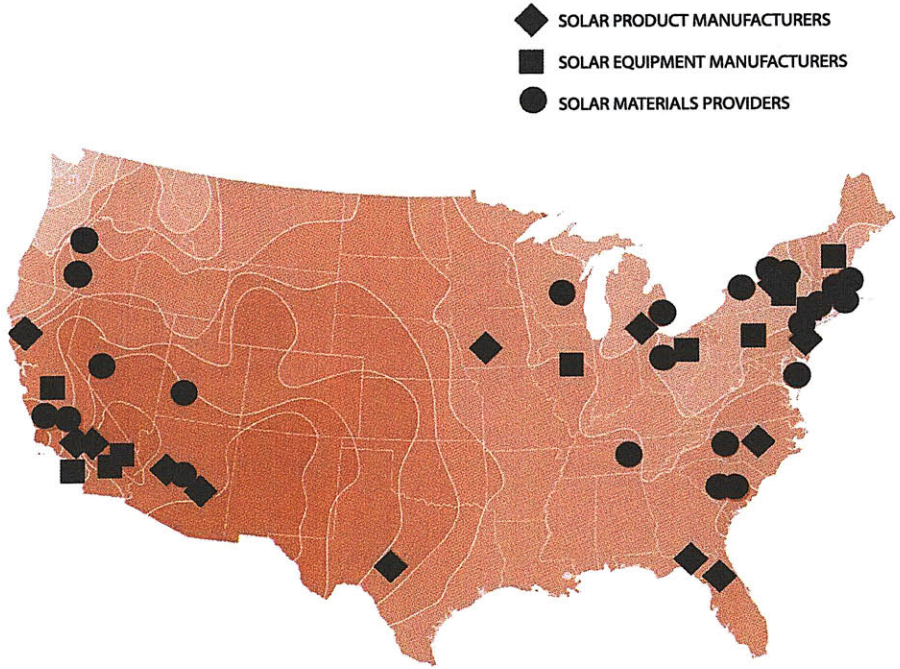
The solar industry is bourgeoning in the United States, with new developments in photovoltaic research. This emerging field, abetted by government funding and subsidies, needs the capacity to explore new ideas and expand on existing technologies through facilities that enable and facilitate research and production. With increased threats of global warming, imminent climate change, and rising oil prices, solar power will be a critical component of America's future, and will require significant investment in the near term.

"The cost of solar cells has been dropping for several decades and is expected to continue falling for the indefinite future. With each doubling of cumulative production, the manufacturing economics of scale drop the price an additional 20 percent."

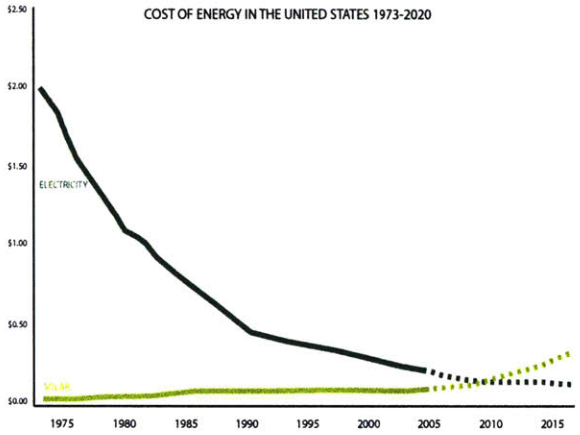
"The type of innovation changes through time. In the renewables sector, different energy sources have reached maturity at different points, and there have been different "generations" of innovation within particular renewable energy sources"

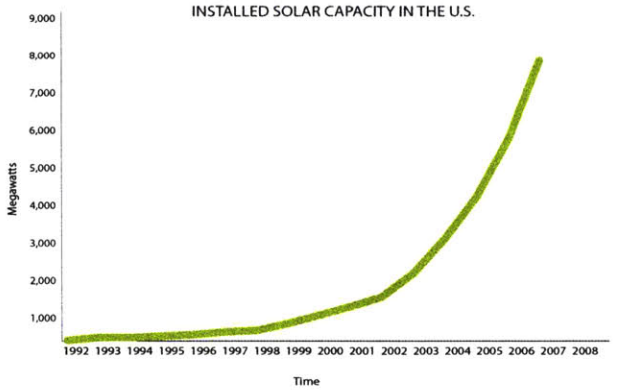

RENEWABLE ENERGY
GEOTHERMAL
TIDAL
HYDRO
SOLAR
WIND
BIOFUEL
BIOMASS
demand side
PASSIVE
ACTIVE
supply side
SHADING
MATERIALS
ORIENTATION
THERMAL MASS
WATER HEATING
PHOTOVOLTAICS (PV)
EXPERIMENTAL TECHNOLOGIES
PANELS
PUMPS
FANS
SOLAR THERMAL COLLECTORS
CONCENTRATED SOLAR POWER CELLS (CSP)
HEAT ENGINES


SUNLIGHT
ELECTRICITY
GLASS
METAL CONTACT
N-TYPE SILICON
JUNCTION
P-TYPE SILICON

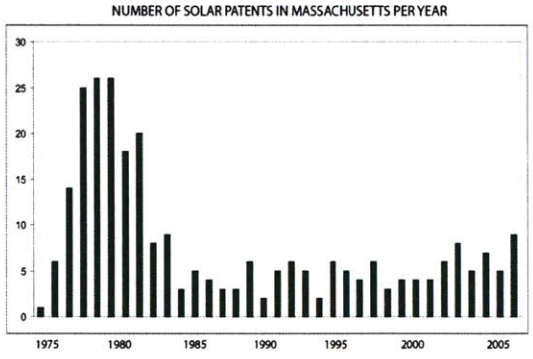

SOLAR PRODUCT MANUFACTURERS
SOLAR EQUIPMENT MANUFACTURERS
SOLAR MATERIALS PROVIDERS

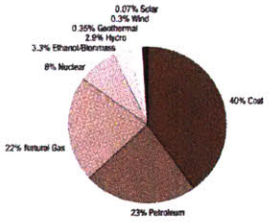
SOLAR ENERGY past and projectedprices

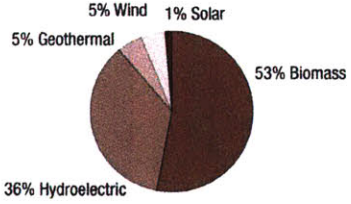




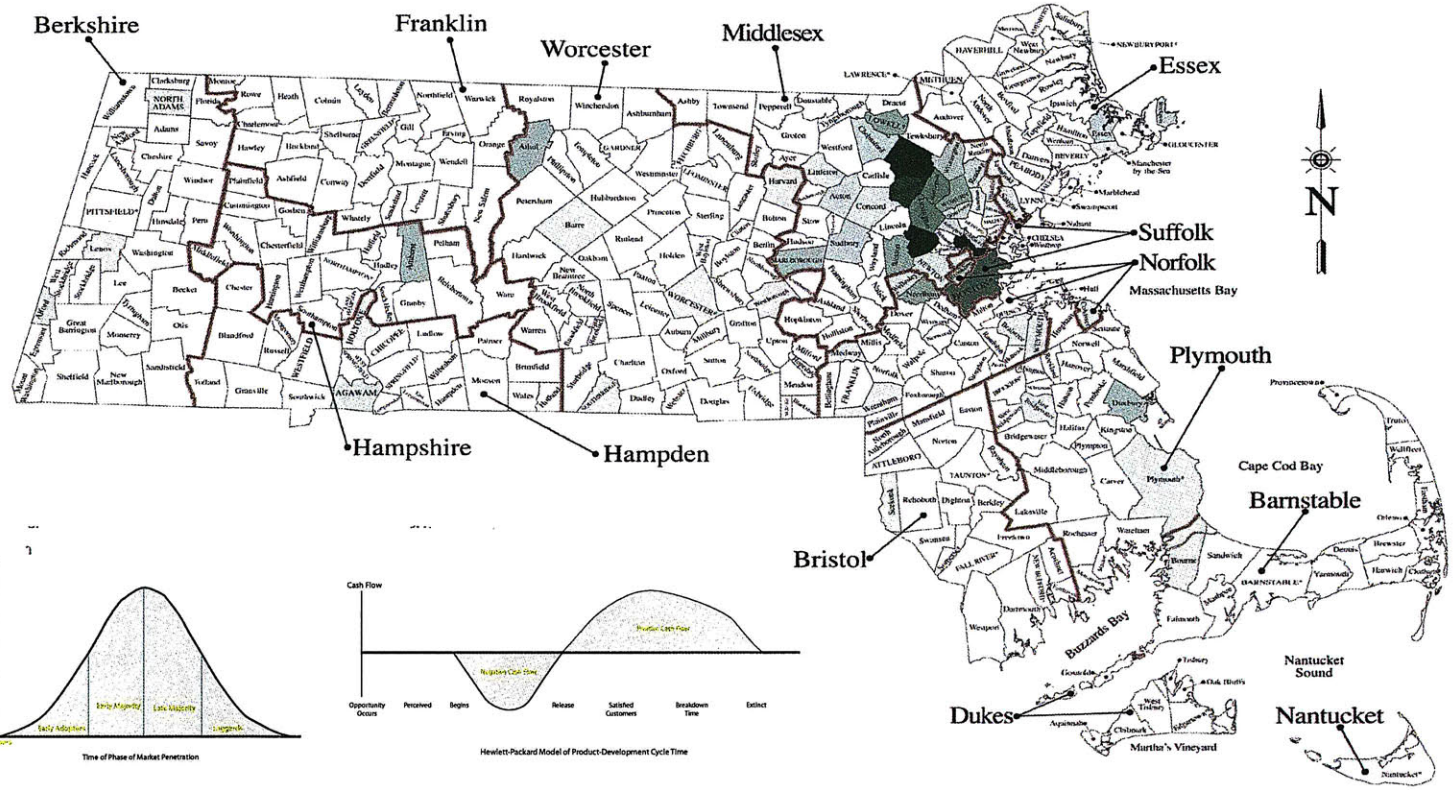
SOLAR PATENTS in Massachusetts by year







SOLAR PATENTS by town in Massachusetts

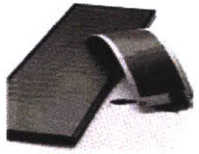


GENERATIONS OF SOLAR TECHNOLOGY

1. Silicon Based Technology

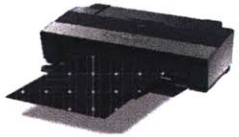
- semi-conductor process
- requires clean rooms for activity
- semi-conductor handling equipment
- uses saws and other machines
- Evergreen Technologies, Marlboro MA

2. Thin Film Technology

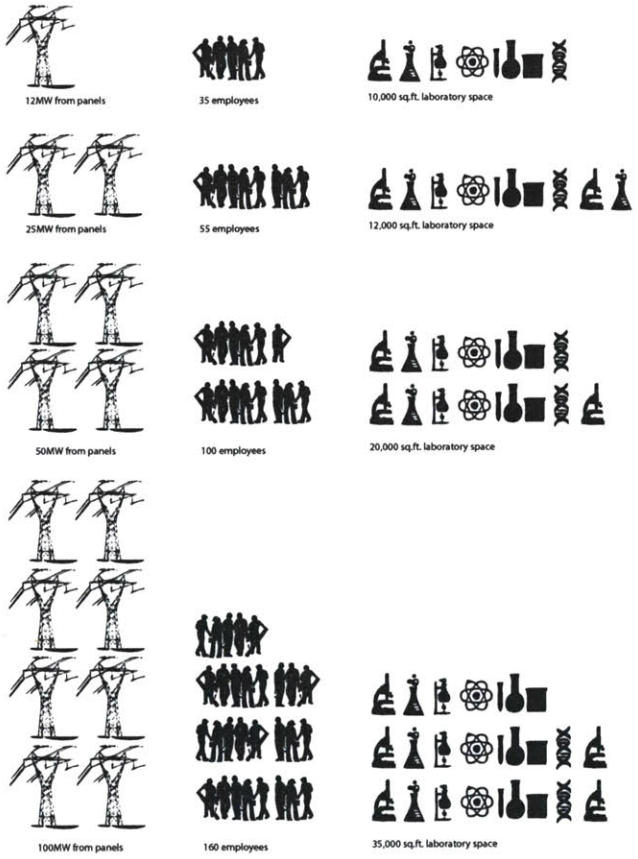


- requires wet room spaces
- uses glasses, metals, and other materials
- lots of heavy equipment and machines
- metalizations; vaccuum process
- Paratronix Inc, Attleboro MA

3. Organic PVs



- printing-like process
- uses plastics and similar materials
- more of a continuous process
- Konarka Technologies, Lowell MA

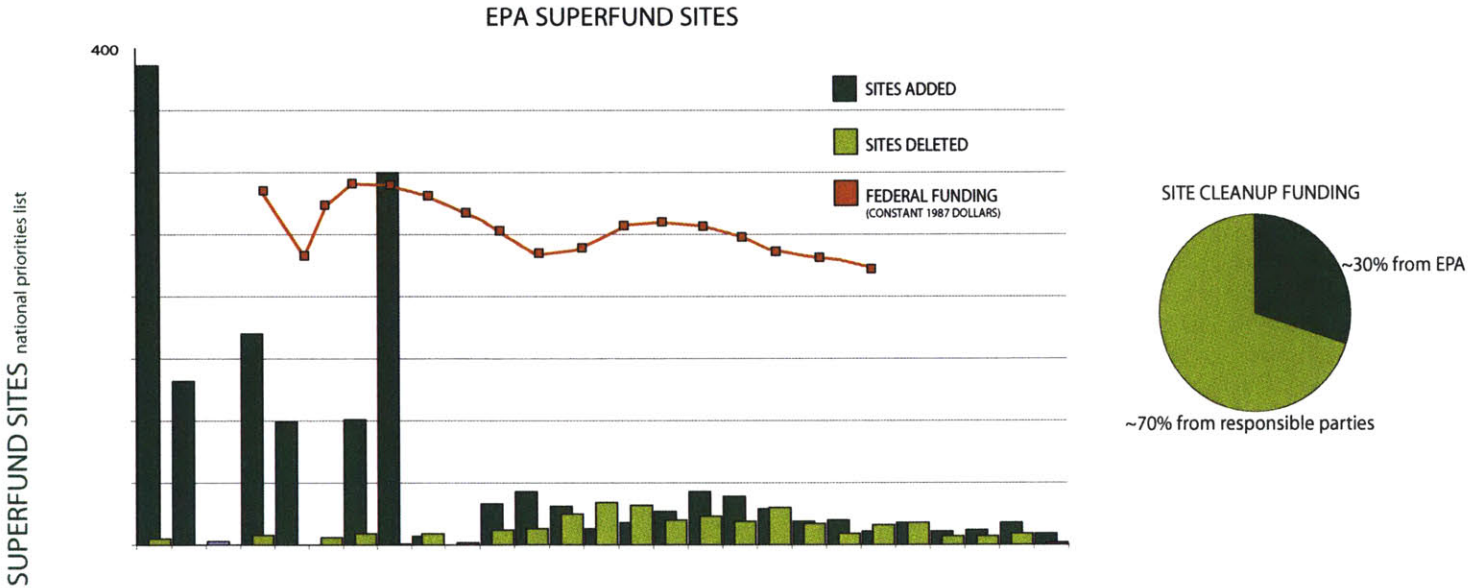


II. CONTEXT

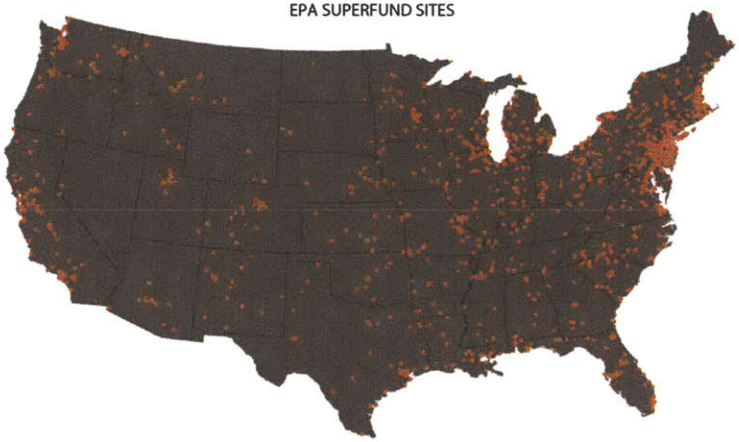
EPA Superfund Sites

Superfund: "America's unique statutory scheme to use the more draconian elements of tort law to compel private businesses and public entities to clean up hazardous waste sites" The National Priorities List (NPL) tracts the sites that most seriously threaten public health and the environment. "The Superfund program is the principal federal effort for cleaning up hazardous waste sites and protecting public health and the environment from releases of hazardous substances. The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) established the program, and the Superfund Amendments and Reauthorization Act of 1986 (SARA) amended"

Drawing authority and funds from the Superfund program, the Brownfields Economic Redevelopment Initiative provides funding assistance to characterize and clean up minimally contaminated sites, often idled or abandoned factories, as a prelude to their redevelopment. Issues include the Environmental Protection Agency's authority to set up the program and the proper disposition of appropriated funds.
The Superfund program is the principal federal effort for cleaning up inactive hazardous waste sites and protecting public health and the environment from releases of hazardous substances. "States define brownfield sites in different ways, but they usually echo EPA's definition, encompassing 'urban industrial or commercial facilities that are abandoned or underutilized due, in part, to environmental contamination or fear of contamination.'"


EPA SUPERFUND SITES
400
SUPERFUND SITES national priorities list
SITES ADDED
SITES DELETED
FEDERAL FUNDING
(CONSTANT 1987 DOLLARS)
SITE CLEANUP FUNDING
~30% from EPA
~70% from responsible parties

EPA SUPERFUND SITES



SUPERFUND SITES national priorities list remediation process

PRELIMINARY ASSESSMENT/
SITE INSPECTION

NATIONAL PRIORITIES LIST/
SITE LISTING PROCESS

REMEDIAL INVESTIGATION/
FEASIBILITY STUDY

RECORDS OF DECISION

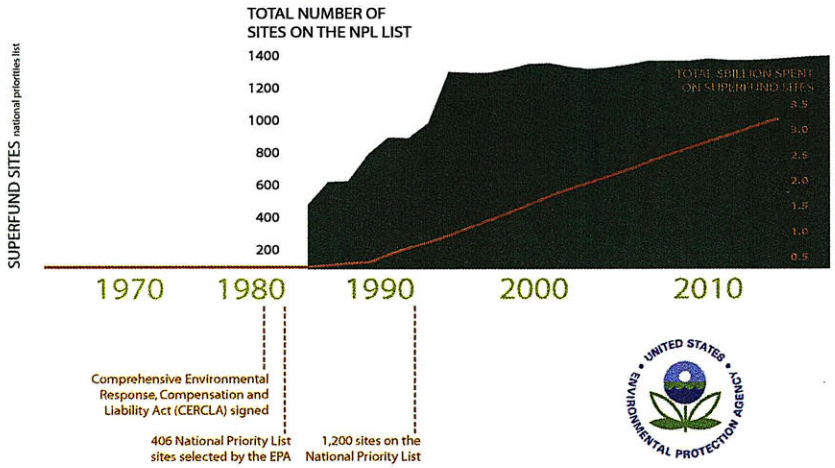
REMEDIAL DESIGN/ACTION

CONTRUCTION COMPLETION

POST CONSTRUCTION COMPLETION

NATIONAL PRIORITIES LIST
DELETION

REUSE


SUPERFUND SITES national priorities list
TOTAL NUMBER OF SITES ON THE NPL LIST
1400
1200
1000
800
600
400
200
TOTAL $BILLION SPENT ON SUPERFUND SITES
3.5
3.0
2.5
2.0
1.5
1.0
0.5
1970
1980
1990
2000
2010
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) signed
406 National Priority List sites selected by the EPA
1,200 sites on the National Priority List
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

CERCLA's impetus was the emerging realization that hazardous waste sites presented great risk to public health and the environment in all parts of the nation, that state and local governments did not have the capability to respond, and that existing federal environmental and disaster relief laws were inadequate. "In addition to being responsible for cleanup costs, polluters also must pay to restore natural resource damages at Superfund sites... The Agency for Toxic Substances and Disease Registry assesses the impact of hazardous substance releases on public health" CERCLA's purpose is to authorize the federal government to respond swiftly to hazardous substance emergencies and protect public health and the environment by cleaning up the nation's worst hazardous waste sites.

III. CASE STUDIES

1. Love Canal. Niagara Falls, New York

2. Times Beach. St. Louis County, Missouri

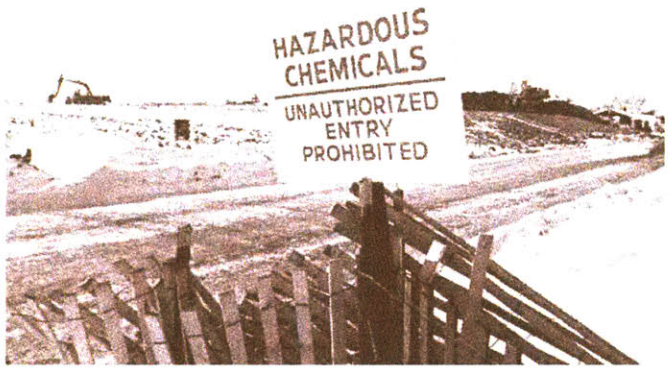
3. Picillo Farm. Coventry, Rhode Island

1. LOVE CANAL

Niagara Falls, New York

Love Canal, a small community near Niagra Falls, New York, is one of the early examples of a national controversy and environmental notoriety. Originally designed to be a 'model city', Love Canal lost much of its funding, became a dumping site for the city during the 1920's, and later a chemical waste site during the 1940's. 21,000 tons of toxic waste were buried in the abandoned "Love Canal" between 1942 and 1952, by Hooker Chemical. The City of Niagra Falls consequently allowed homes and a school to be built on this site, despite awareness of the hazardous materials. Consequently, a public health emergency was issued; burns, diseases, and birth defects were just some of the ensuing outcomes. "Among its legacies, Love Canal will likely long endure as a national symbol of a failure to exercise a sense of concern for future generations. It was indeed a situation where the inhabitants of Love Canal "overflowed into the wastes instead of the other way around."
Love Canal is an important case study because of its role with respect to the history of Superfunds and CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) . The public outcry and devastating repercussions from this environmental disaster helped spur the national efforts to address toxic contamination of land.

"The Love Canal site in Niagara Falls, New York, first brought the issue to national prominence when the state health commissioner declared a state of emergency there on August 2, 1987."


HAZARDOUS
CHEMICALS
UNAUTHORIZED
ENTRY
PROHIBITED

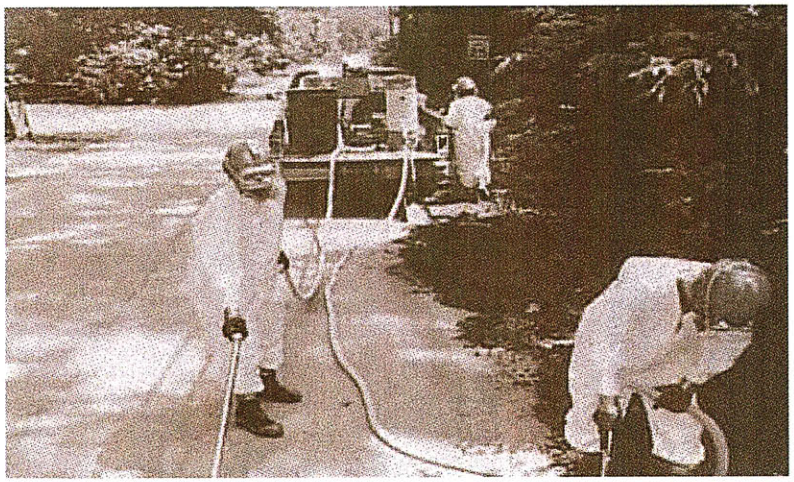

LOVE CANAL
WE'VE GOT BETTER
THINGS TO DO THAN
SIT AROUND AND BE
CONTAMINATED!!

2. TIMES BEACH

St. L<uis County, Missouri

Time Beach was a town outside of St. Louis, MO that was completely evacuated in 1983 because of a dioxin scare that became the subject of national controversy. The town, founded in 1925, had a dust problem, and in the 1970's the roads were sprayed with oil Loveand later paved. The oil contained dioxin levels, and later emerged in the 1980's during a devastating flood. The town was subsequently evacuated, and all residents were forced to abandon their homes due to the imminent threats of the chemicals.

Times Beach is an important case study because of its role with respect to the history of Superfunds and CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act). The public outcry and devastating repercussions from this environmental disaster helped spur the national efforts to address toxic contamination of land.

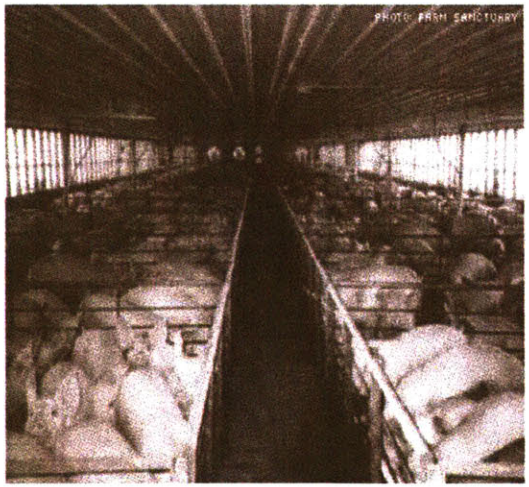


3. PICILLO FARM

Coventry, Rhode Island

The Picillo Pig Farm, in Coventry Rhode Island, was a 100-acre farm that literally exploded in 1977, and became Rhode Island's first official Super-fund site. The farm had become a dumping site of illegal chemicals during the 1970's, which were later discovered.

1977 when part of the farm exploded into an inferno that was visible for miles around. The brownfield site has since been signed into a project agreement with Allco Renewable Energy Group to turn the farm into a $45 million solar energy farm. Plans (as of 2008) include hundreds or 3x5 foot solar panels that would be motorized to face the sun, generating up to 8 megawatts of electricity. This proposal is currently the largest project planned for east of the Mississippi



IV. SITE: INDUSTRI-PLEX

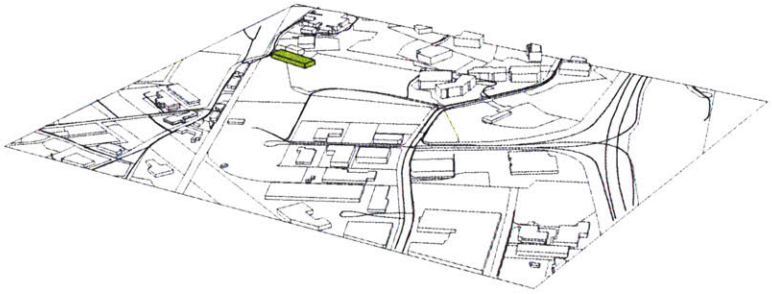
Woburn, Massachusetts

The Industri-Plex Superfund site, 12 miles northwest of Boston in Woburn, Massachusetts, is an ideal location for this prototypical project. Originally contaminated by toxic remnants from tanneries in the 19th and 20th centuries, the site offers a prime condition to remediate through careful design and planning. Conveniently situated at a commuter rail station and minutes away from a major highway (I-93), the proposed site provides an economically and environmentally viable option for re-appropriation

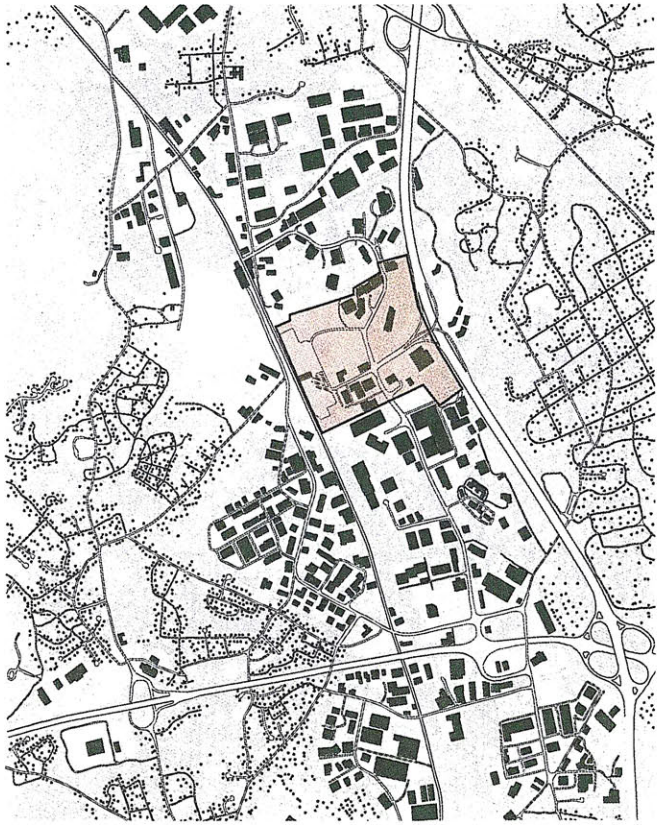
The Industri-Plex Superfund Site is a former chemical and glue manufacturing facility. Industri-plex was used for manufacturing chemicals such as lead-arsenic insecticides, acetic acid, and sulfuric acid for local textile, leather, and paper manufacturing industries from 1853 to 1931. Chemicals manufactured by other industries at the site include phenol, benzene, and toluene. Industri-plex was also used to manufacture glue from raw animal hide and chrome-tanned hide wastes from 1934 to 1969. The by-products and residues from these industries caused the soils within the site to become contaminated with elevated levels of metals, such as arsenic, lead and chrome. During the 1970s, the site was developed for industrial use. Excavations uncovered and mixed industrial by-products and wastes accumulated over 130 years. During this period, residues from animal hide wastes used in the manufacture of glue were relocated on-site from buried pits to piles near swampy areas on the property. Many of the animal hide piles and lagoons on-site were leaching toxic metals into the environment. In the 1980's, the site contained streams and ponds, a warehouse and office buildings, remnant manufacturing buildings, and hide waste deposits buried on the site. Animal hide residues are found on approximately 20 acres of the site in four different piles. Portions of the animal hide piles sloughed off, causing the release of hydrogen sulfide gases to the atmosphere and toxic metals to surrounding wetlands. Residences are located within 1,000 feet of the site, and more than 34,000 people live within 3 miles of the site.

Timeline and History of Woburn

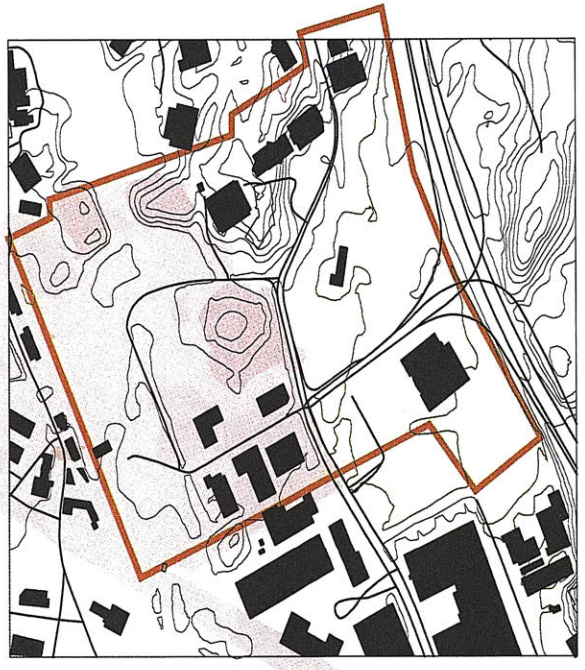
Regional Transportation



Site Axonometric



Woburn Site Plan



CLASS "A" LAND

uncontaminated soils

CLASS "B" LAND

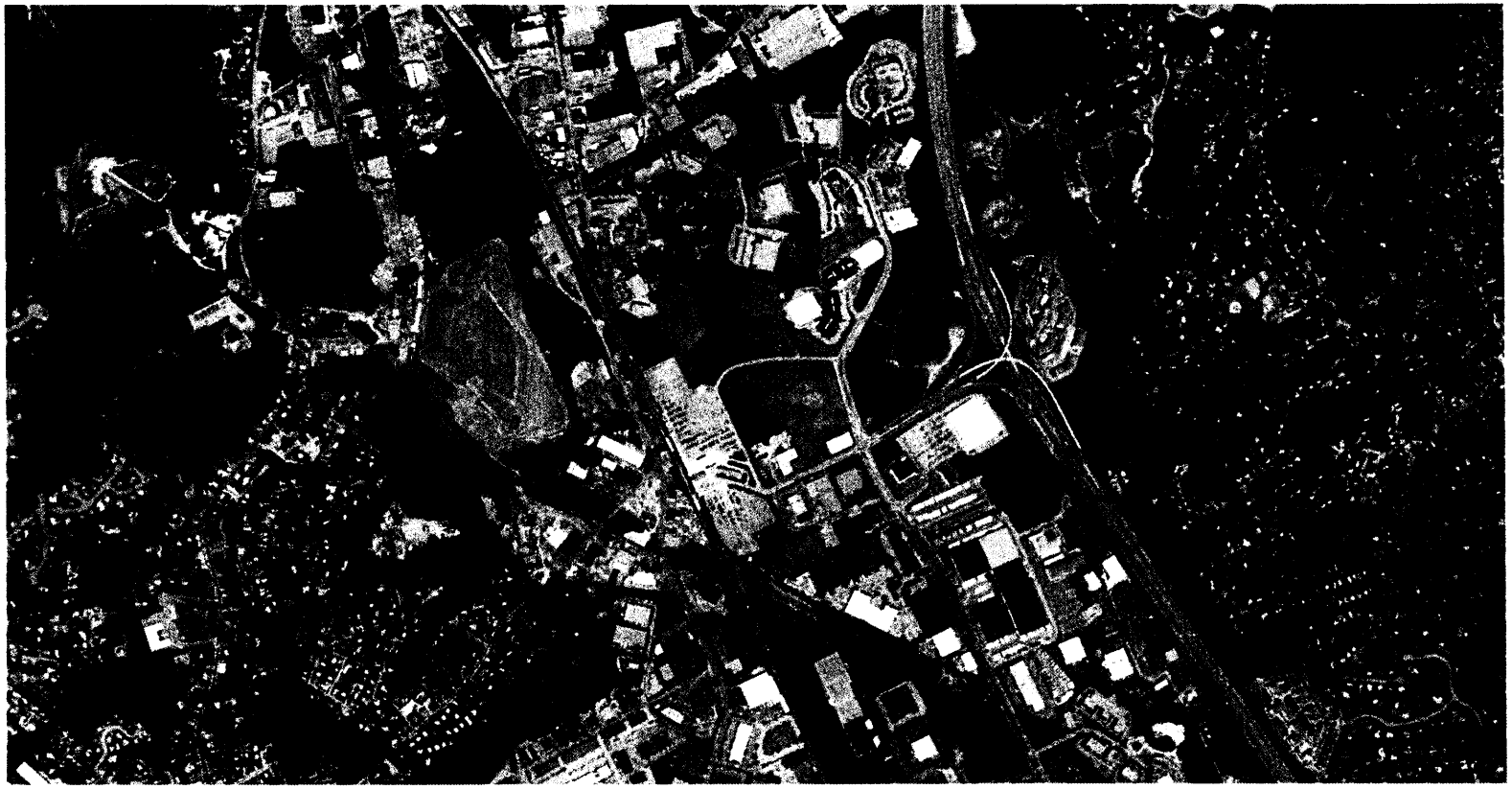
soils may contain contaminants less than conesnt decree action levels
(no cover required)

CLASS "C" LAND

soils may contain contaminants greater than conesnt decree action levels
(cover required)

CLASS "D" LAND

"hide piles"



Aerial of Woburn Site

V. PROGRAM ANALYSIS

Solar Industry Incubator

The United States Department of Energy has recently invested significant funding and effort towards the solar industry. It has enacted a series of initiatives and programs to help support this growing and imperative field. One major agenda is the Photovoltaic Technology Pre-Incubator: in 2008, the DOE announced $17.6 million that would be awarded to six early stage PV developers across the country. This funding is part of the 2009 American Recovery and Reinvestment Act.

"The goals of the project include promoting grid parity for PV technologies, transitioning innovative PV technologies into the prototype stage, and developing prototype PV concepts with manufacturing costs of less than $1/watt."

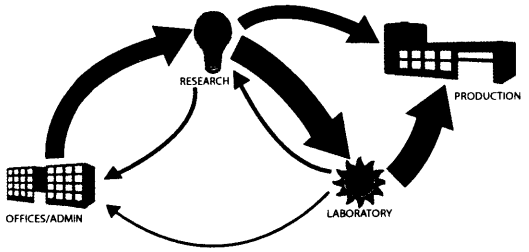
Another primary program is the Photovoltaic Technology Incubator project, which preceded the pre-incubator agenda. Both of these initiatives sponsor and encourage the development of new technologies within the photovoltaic realm. The solar industry is getting bigger, better, and brighter. On Feb 17, 2009, President Obama signed into law the American Recovery and Reinvestment Act, cementing his support of solar and other renewable energy sources. Billions of dollars will be invested in funding, tax incentives, loans, and grants to increase the use of solar energy, support energy efficiency, remove market barriers, and cultivate green jobs

"Up to $500,000 is available to small companies for turning their module-related technologies into prototypes. The Photovoltaic (PV) Technology Pre-Incubator solicitation, released on Jan. 27, 2009, is open to U.S. small businesses or teams led by a U.S. small business...This financial opportunity is administered by DOE's National Renewable Energy Laboratory (NREL)".

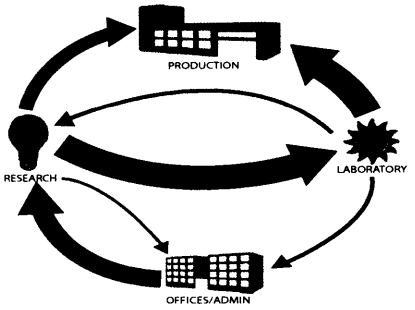
Technological innovation is critical to the advance of clean energy technologies. Along with policy mechanisms (such as taxes and subsidies) and external factors (such as public opinion and oil prices), technological progress will be crucial in order for solar production to become competitive with other forms of energy. This will require substantial innovation and improvement of current day technologies.

LABORATORY	8,000 sq.m	experimental workspaces and testing facilities. both indoor and outdoor space.
WET LAB SPACE	1,500 sq.m	
CLEAN ROOMS	1,500 sq.m	
OUTDOOR LAB	5,000 sq.m	
OFFICES	3,000 sq.m	space for companies to develop their businesses; administrative and organizational.
ADMINISTRATION	500 sq.m	
ACCOUNTING	500 sq.m	
SALES and PR	500 sq.m	
MARKETING	500 sq.m	
CONFERENCE RMS	1,000 sq.m	
RESEARCH	6,000 sq.m	facilities for product development and experimental research
ENGINEERING	3,000 sq.m	
TESTING FACILITIES	3,000 sq.m	
EDUCATION	1,000 sq.m	public component. outreach, museum, and interactive education spaces
DISPLAY SPACE	500 sq.m	
MUSEUM/PUBLIC	500 sq.m	
PRODUCTION	6,000 sq.m	manufacturing areas for component development and small scale distribution
EQUIPMENT	3,000 sq.m	
ASSEMBLY LINE	3,000 sq.m	
P OTHER	2,000 sq. m	shared and private resources necessary for builidng complex
RESTROOMS	300 sq.m	
PARKING	1,000 sq.m	
MECHANICAL	200 sq.m	
CERTIFICATION	500 sq.m	

Program Breakdown

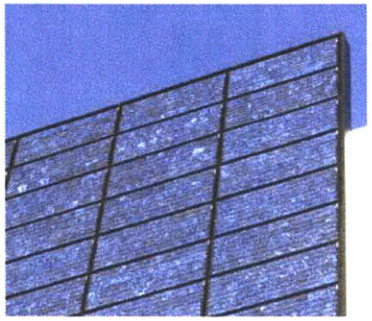


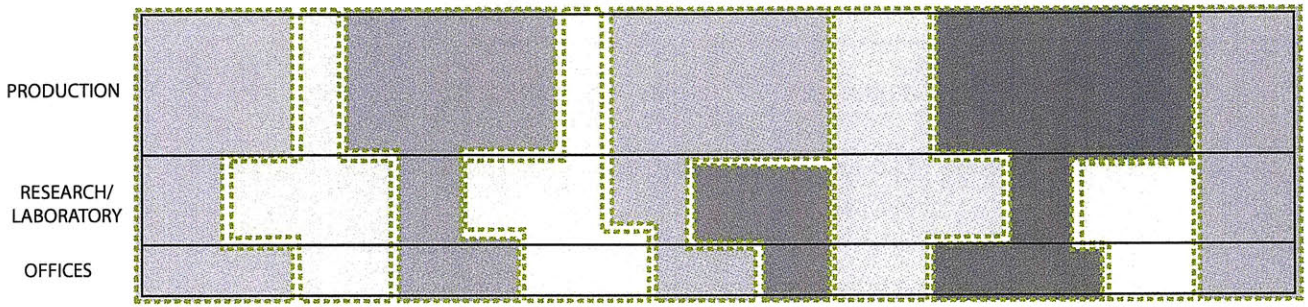
USER FLOWS



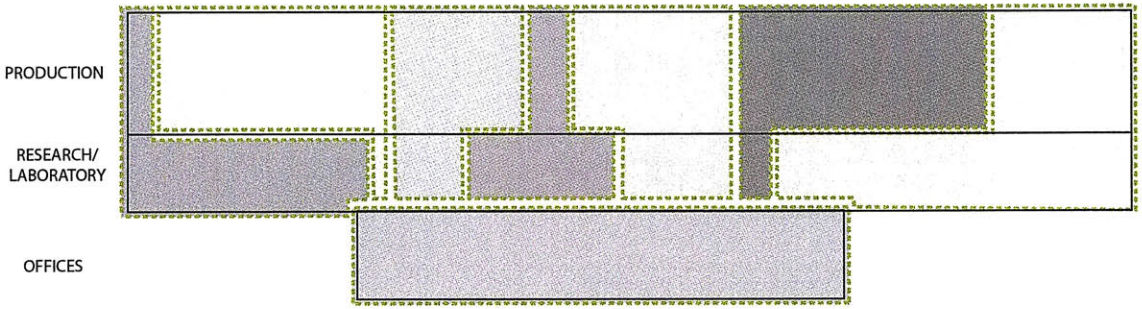
	STATIC DENSITY	ACTIVITY	USER FLOW	EQUIPMENT	MATERIAL FLOW	ADJACENCIES
OFFICES/ADMIN						
RESEARCH						
LABORATORY						
PRODUCTION						
DEMONSTRATION						

Usage Breakdown



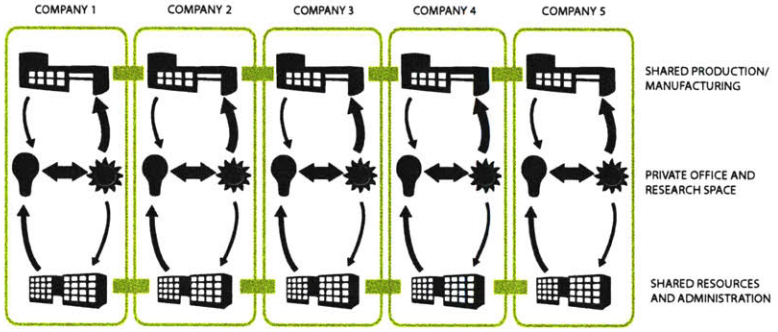


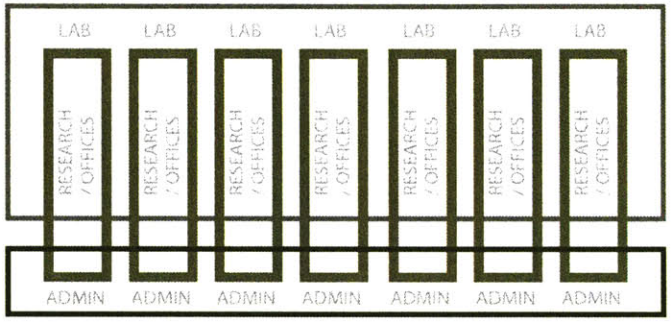
INDIVIDUAL COMPANIES

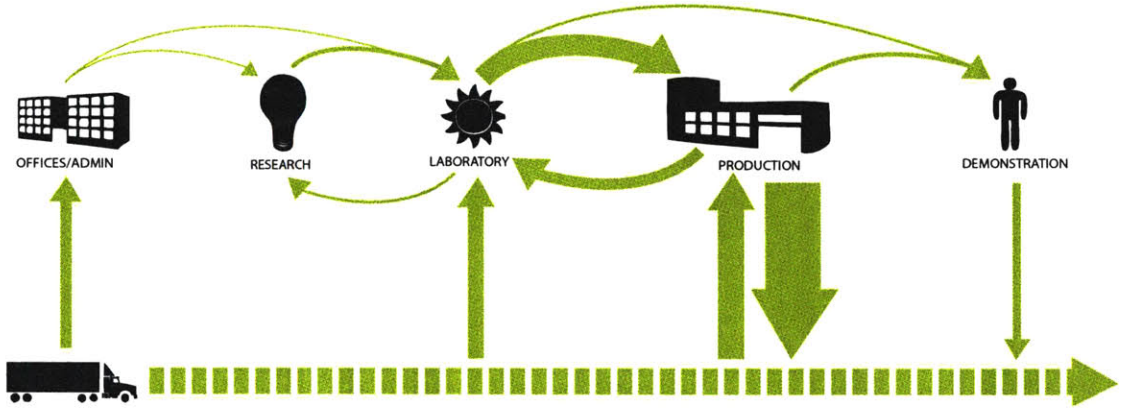


SHARED OFFICE SPACE

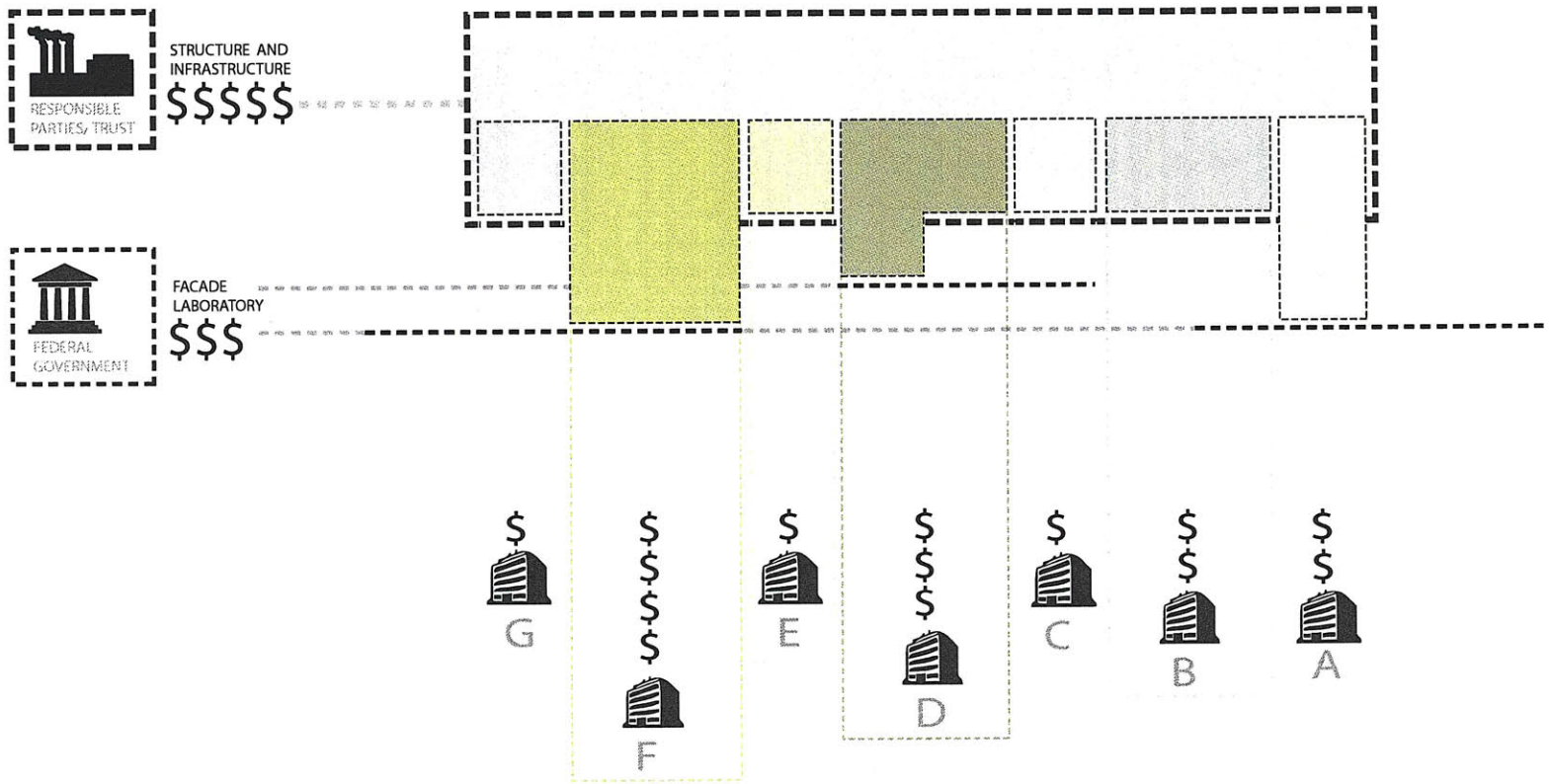
Potential Company Configurations



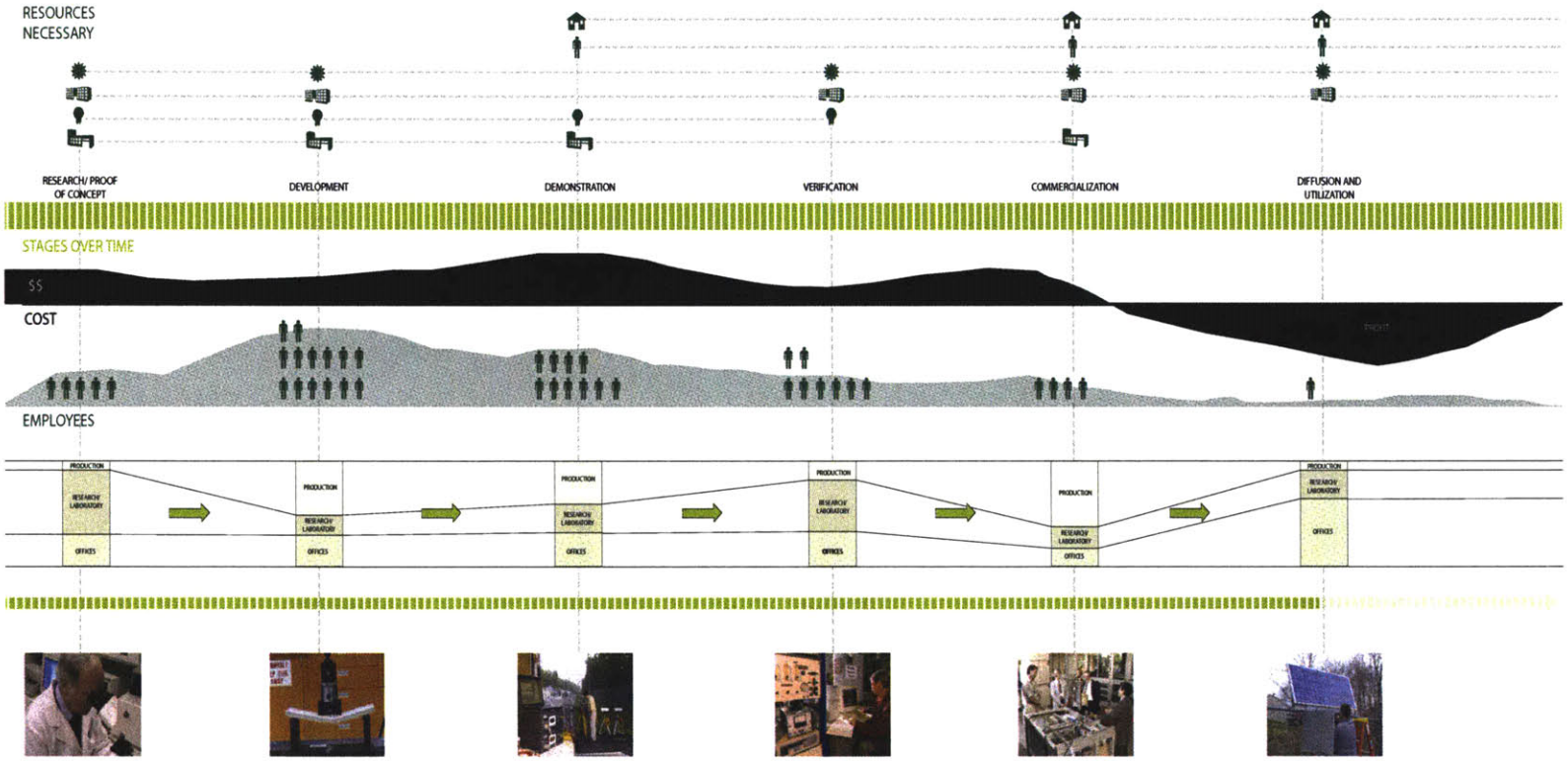




Material Flows

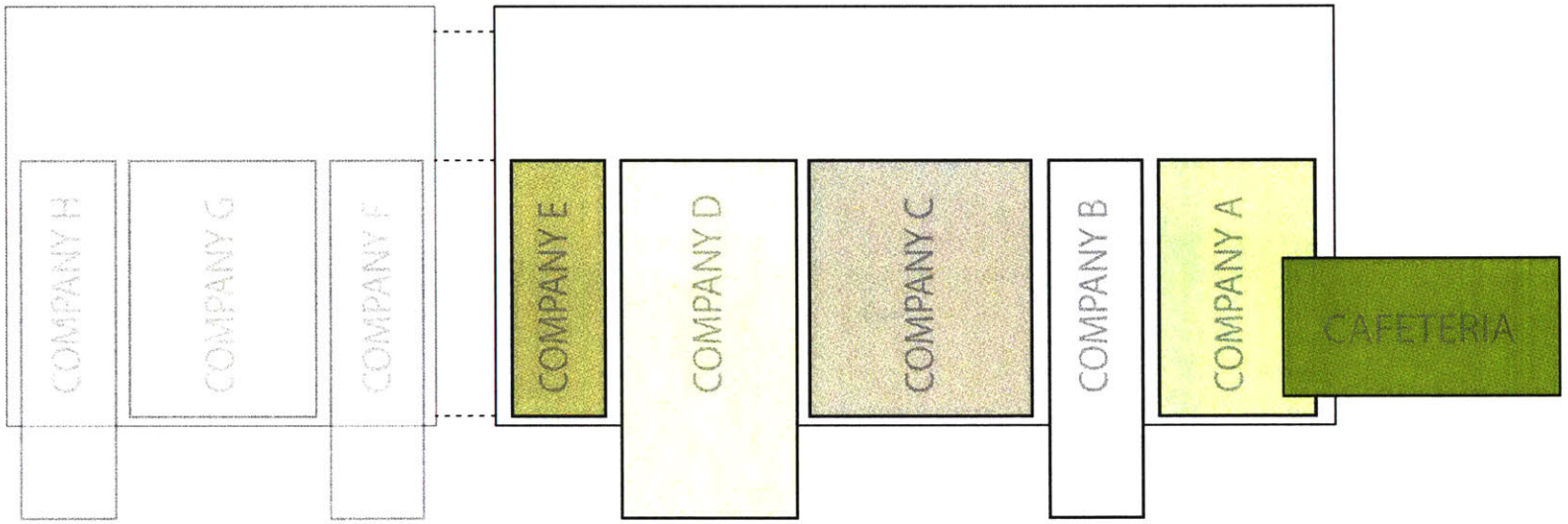


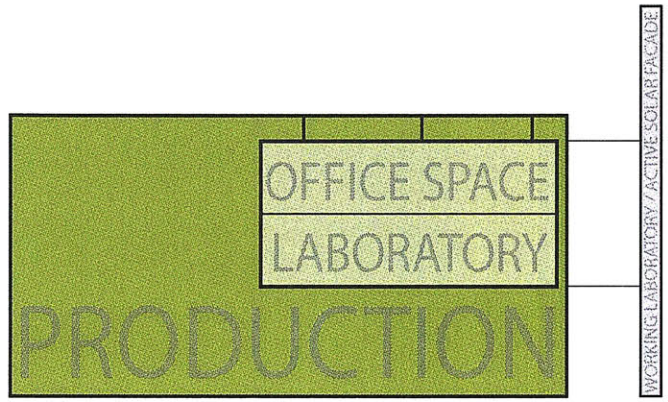
Economic Breakdown

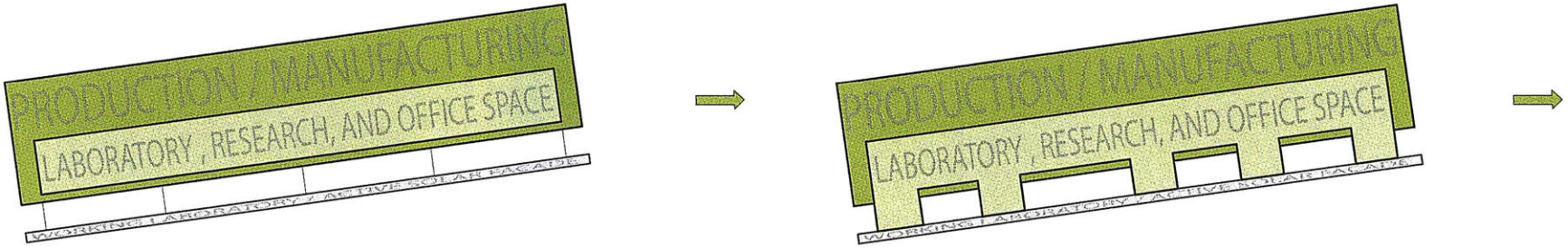


Research and Development Continuum

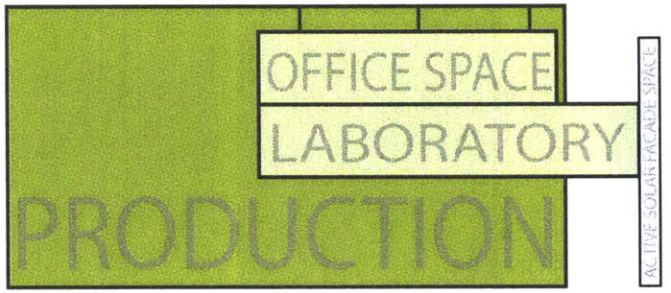
VI. DESIGN PROPOSAL

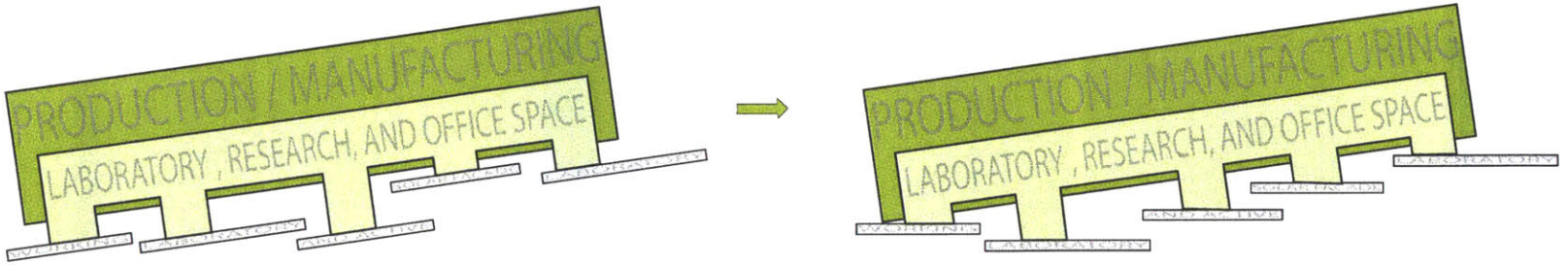


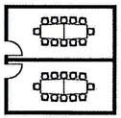




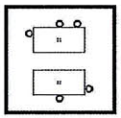
Design Concept


OFFICE SPACE
LABORATORY
PRODUCTION
ACTIVE SOLAR FACADE SPACE

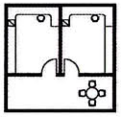

PRODUCTION / MANUFACTURING
LABORATORY , RESEARCH, AND OFFICE SPACE
PRODUCTION / MANUFACTURING
LABORATORY , RESEARCH, AND OFFICE SPACE



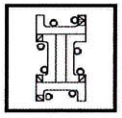
CONFERENCE ROOMS



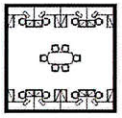
LABORATORY SPACE



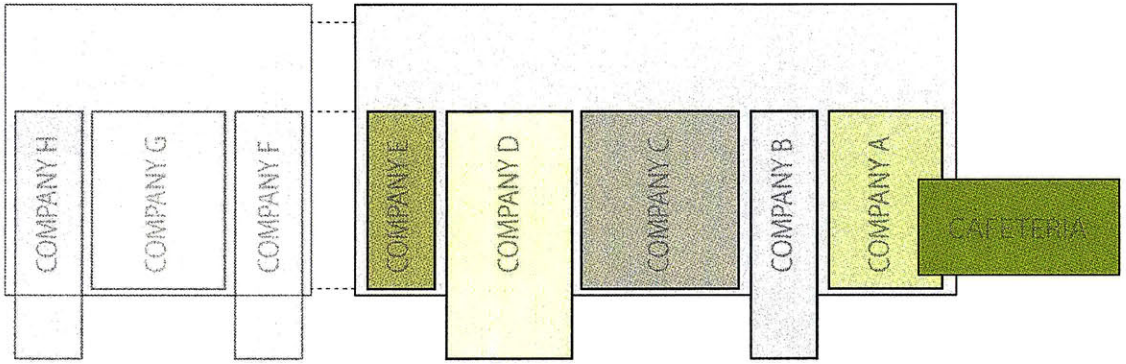
PRIVATE OFFICES



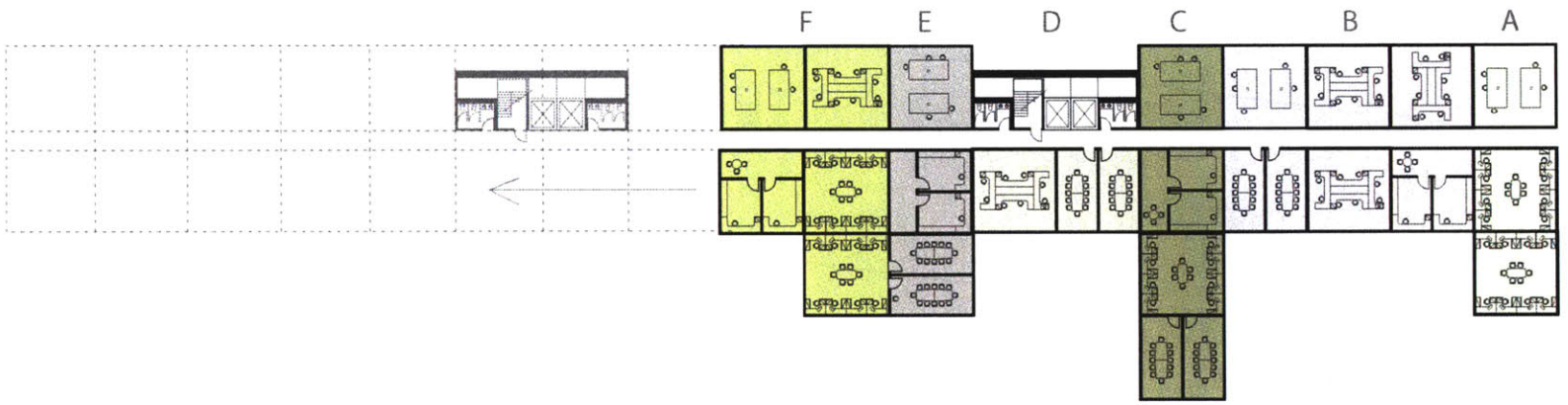
RESEARCH FACILITIES



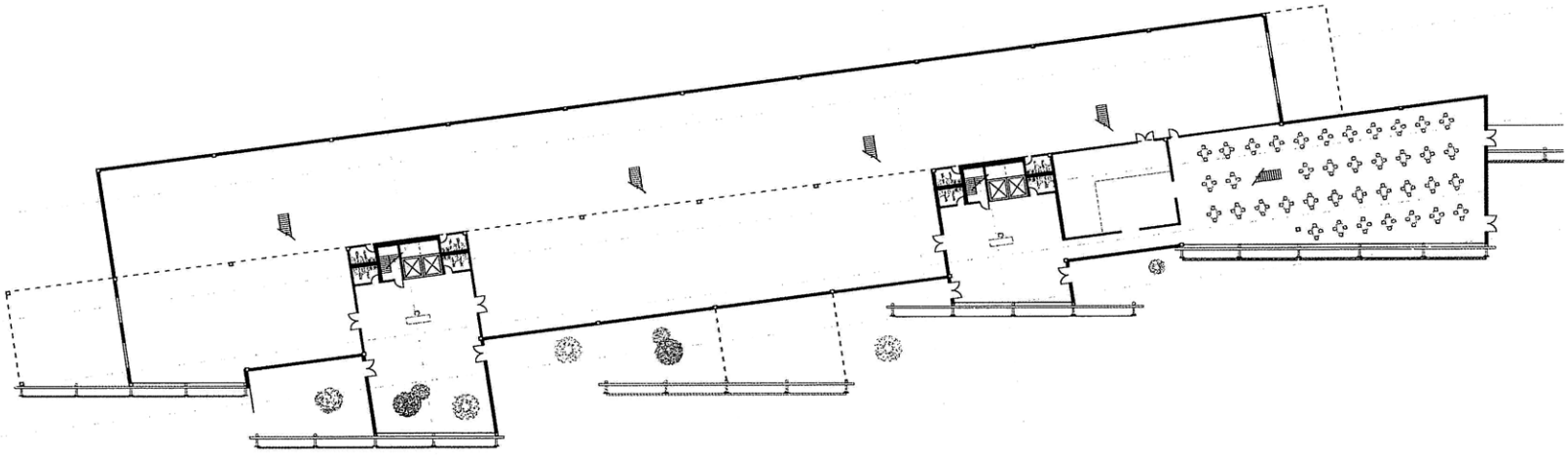
ADMINISTRATION



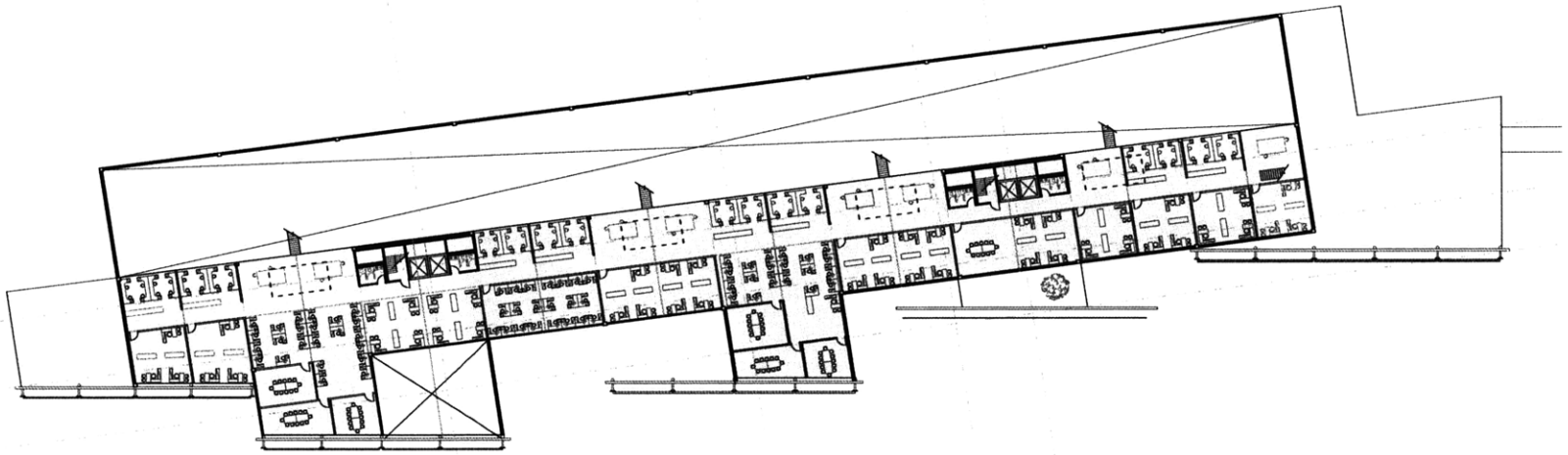
Toolkit of Spatial Configurations



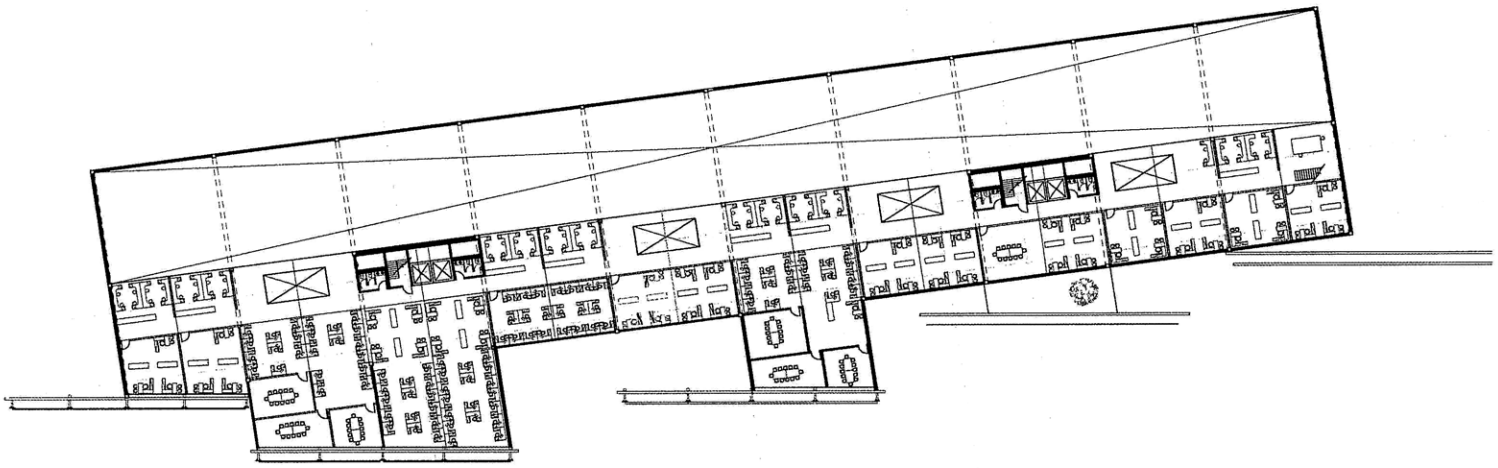
Potential Allocation of Spaces



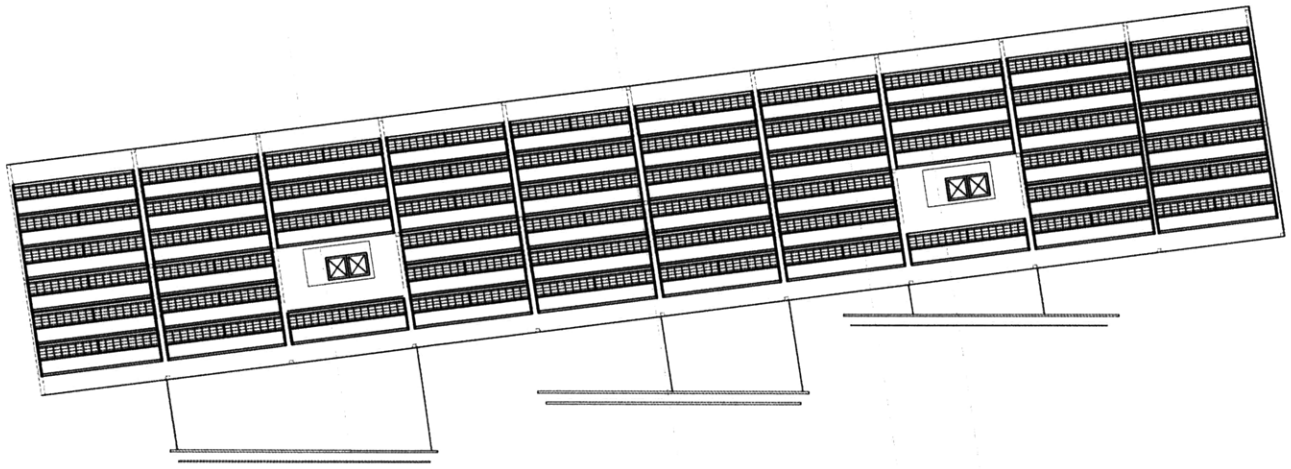
Ground Floor Plan



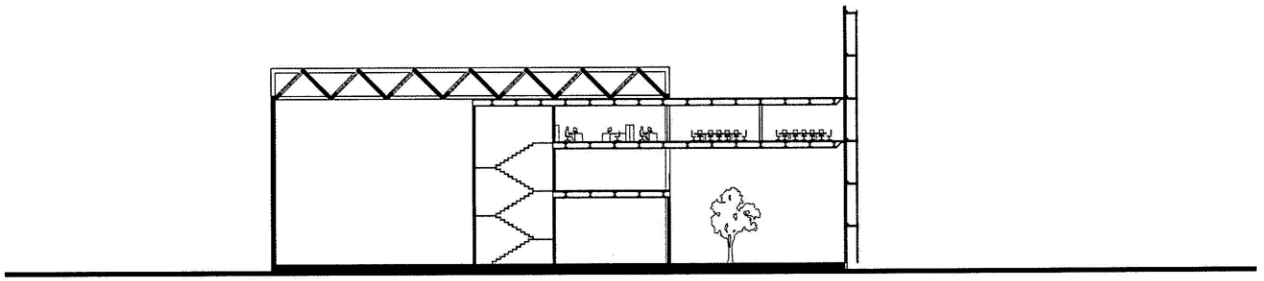
First Floor Plan

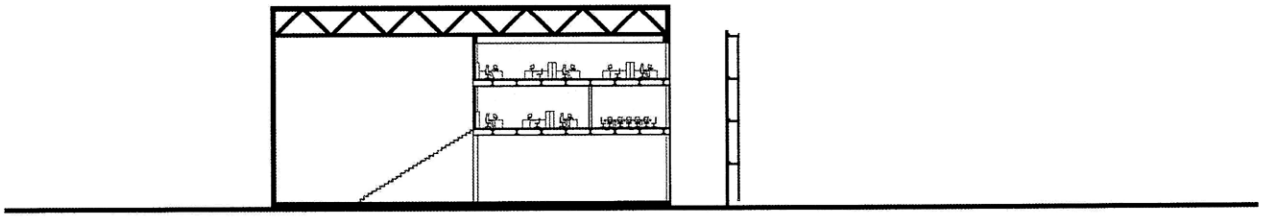


Second Floor Plan

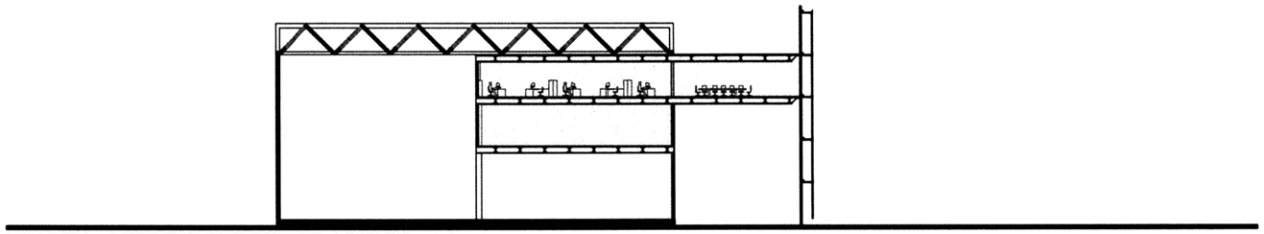


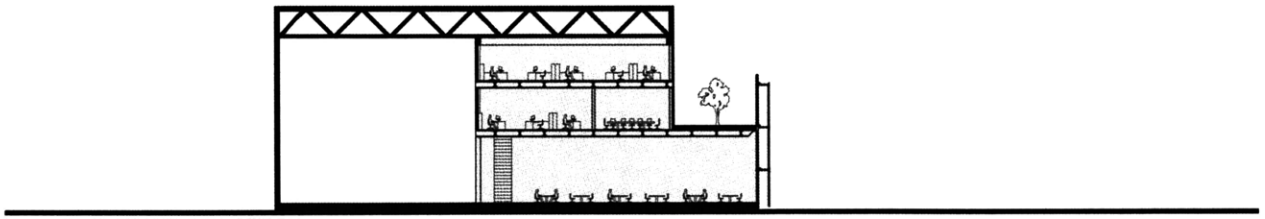
Roof Plan



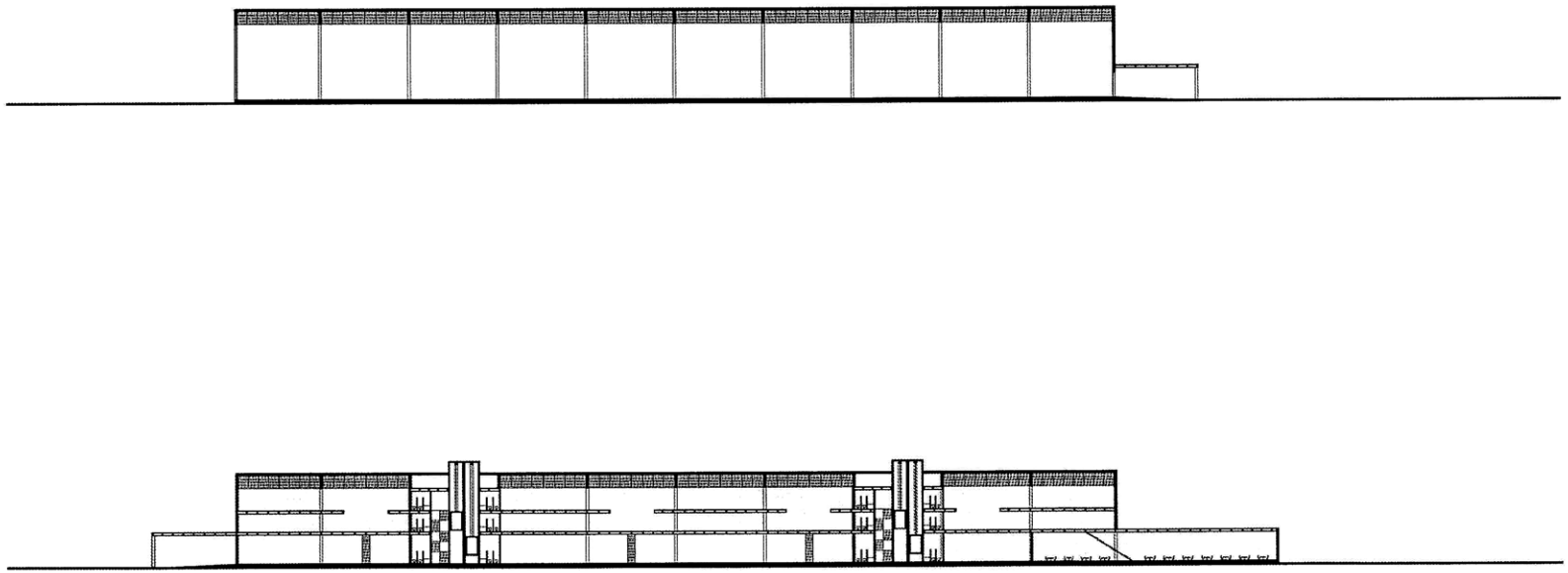


Cross Sections

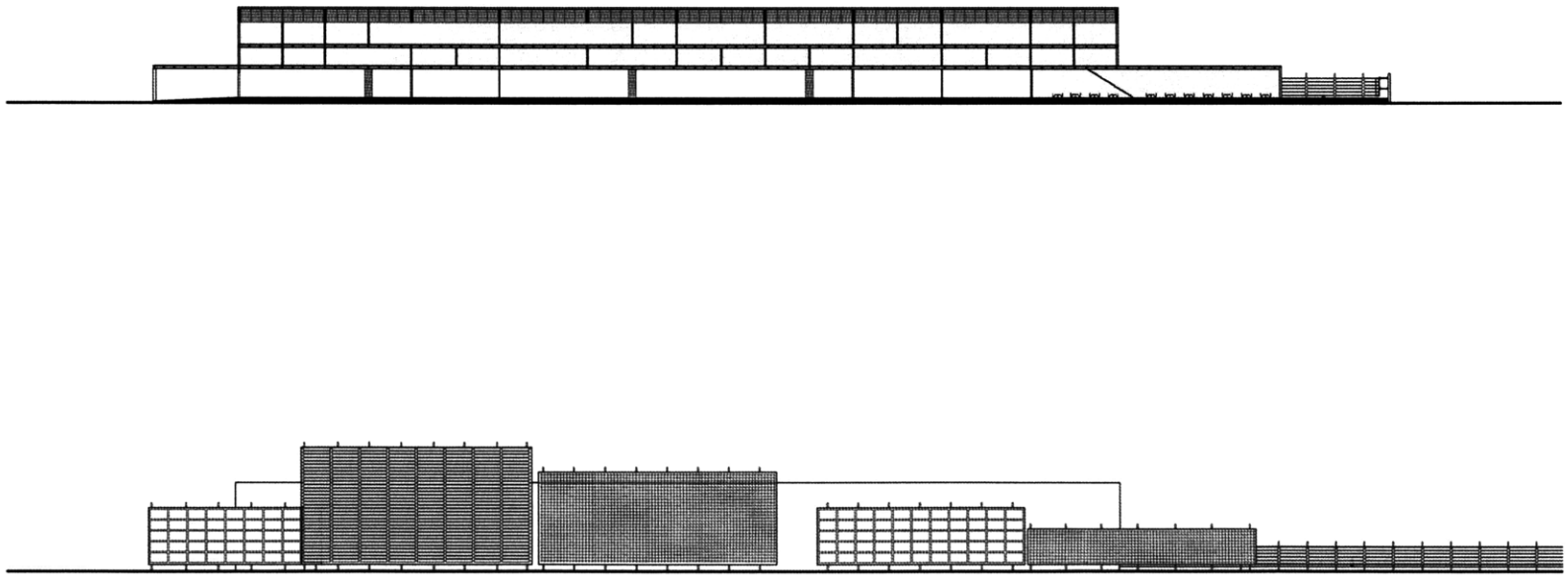




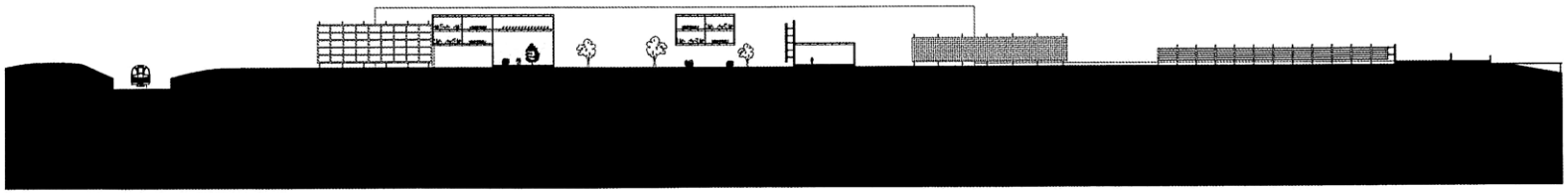
Cross Sections



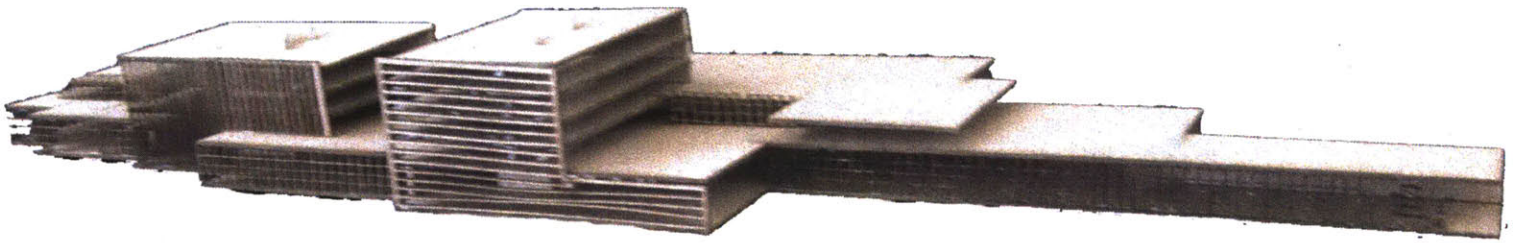
Longitudinal Sections

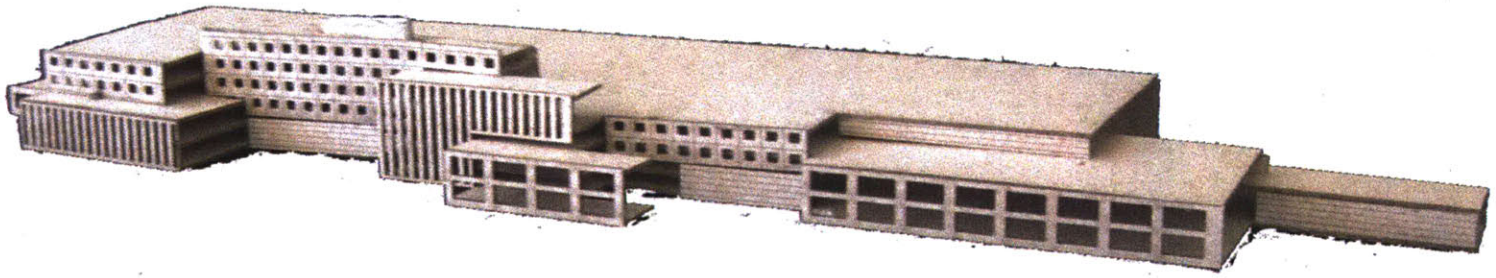


Longitudinal Sections

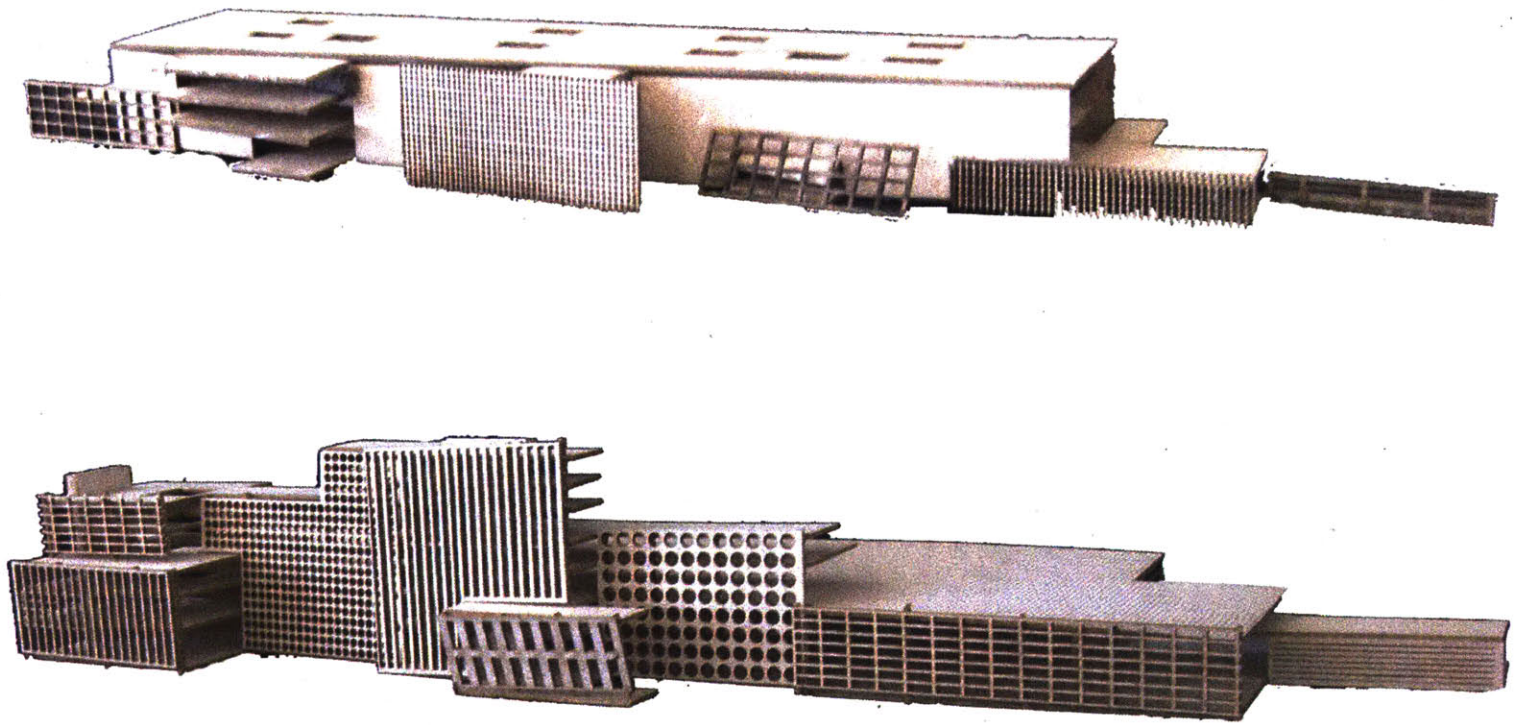


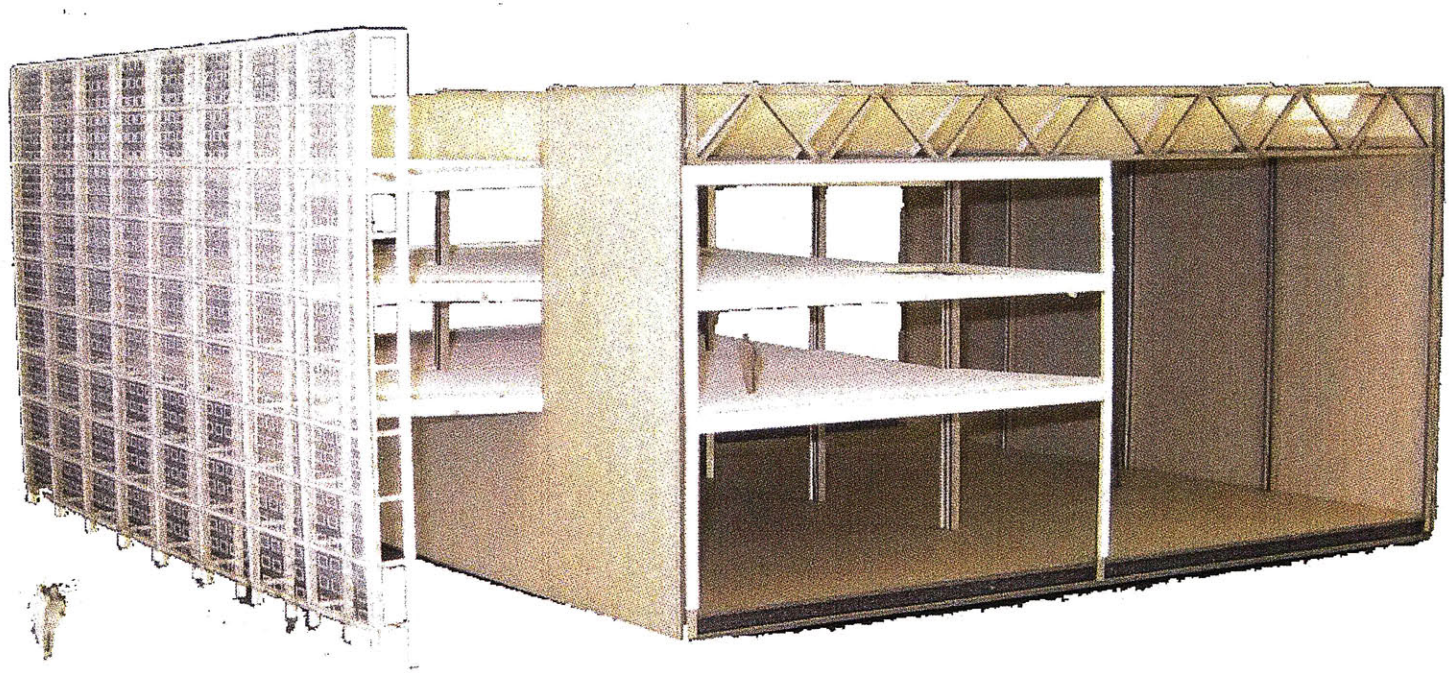
Site Section



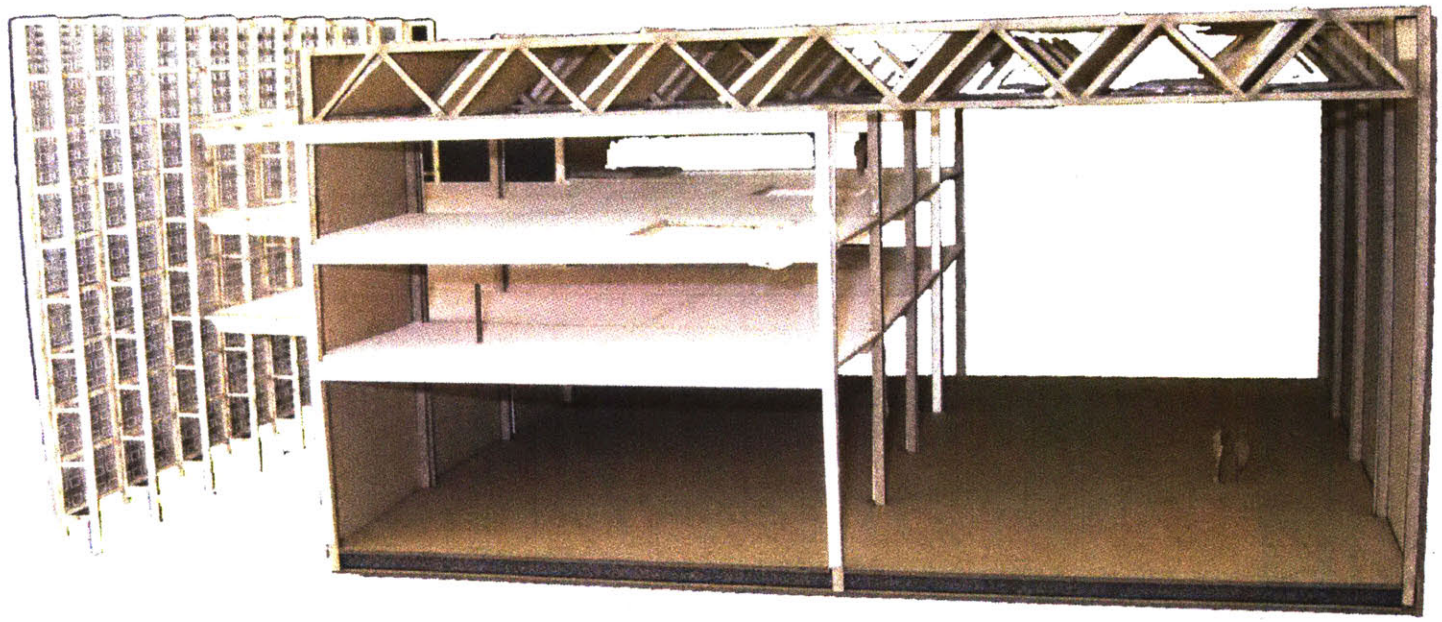


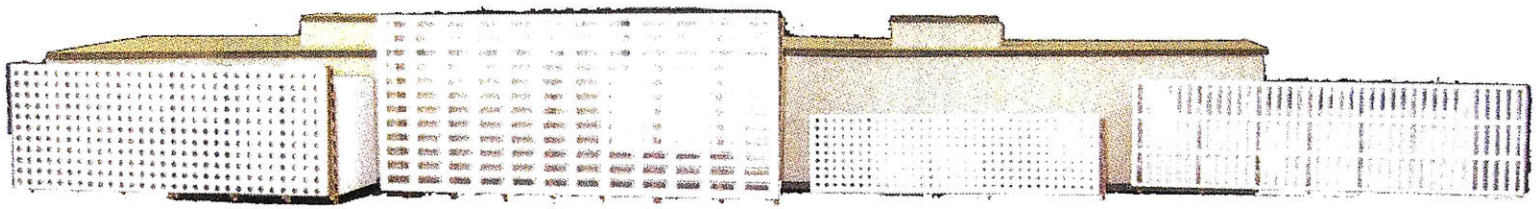
Study Models



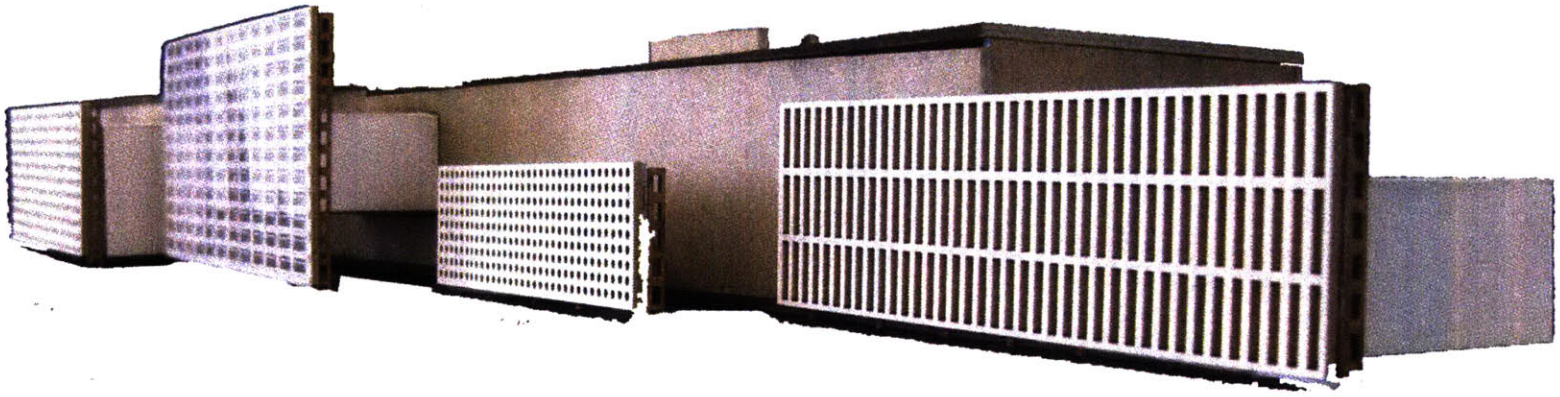


Sectional Model

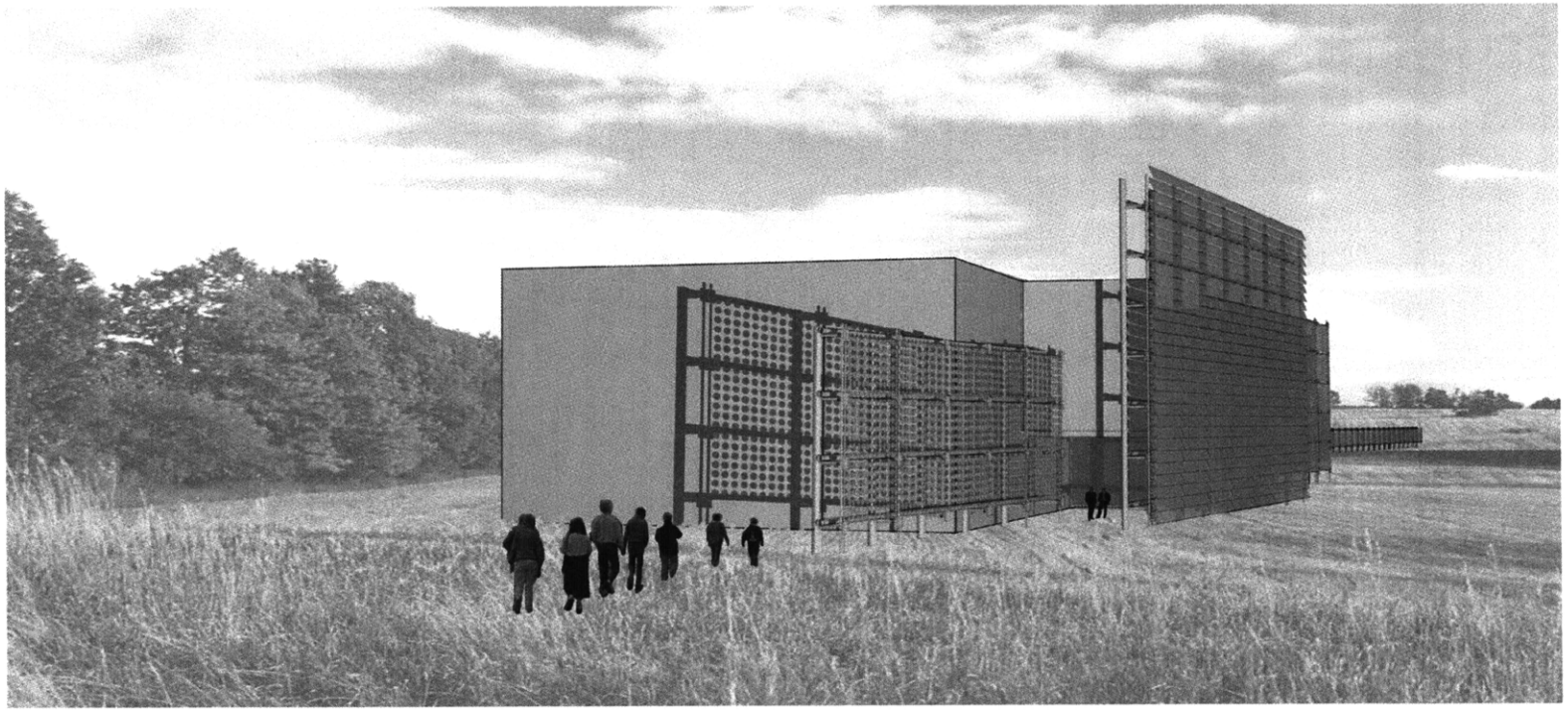




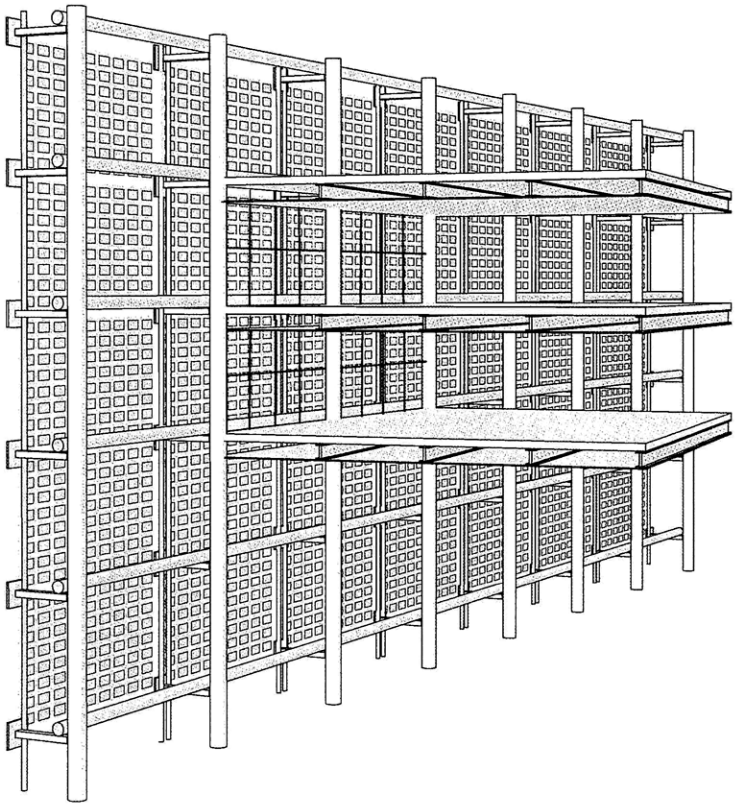
Building Model



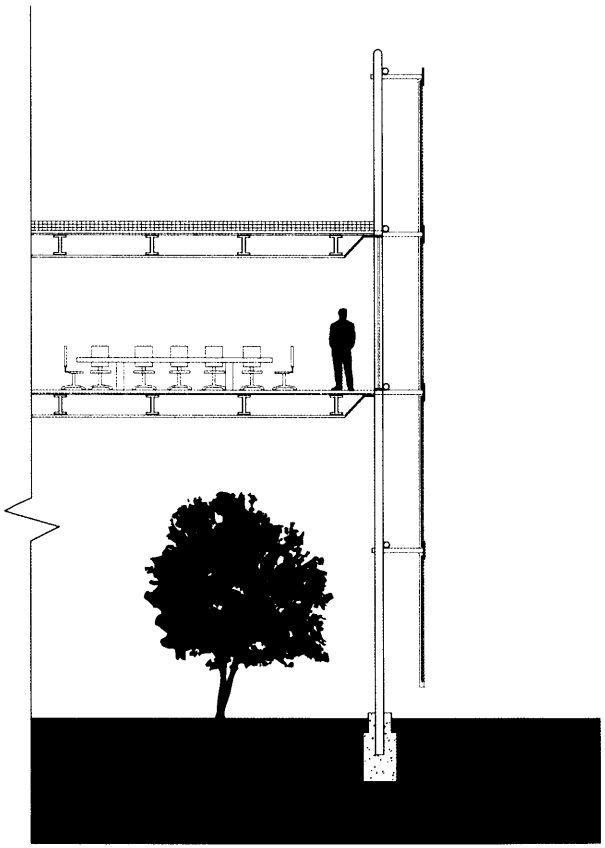
Site Plan



Exterior Perspective



Wall Detail



Wall Section

VII. Image Credits

1. Solar Images. http://www.solarnavigator.net/solar_panels.htm
   http://www.newscientist.com/blog/technology/2006/07/solar-power-goes-mainstream.html

2. Love Canal Images. http://en.wikipedia.org/wiki/Love_Canal
   http://www.pacificspirit.org/news/labels/Alaska.html
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