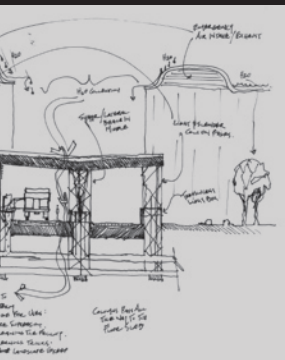
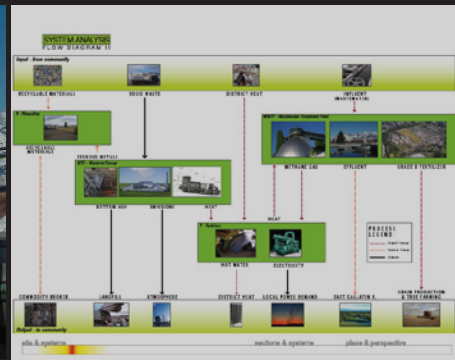
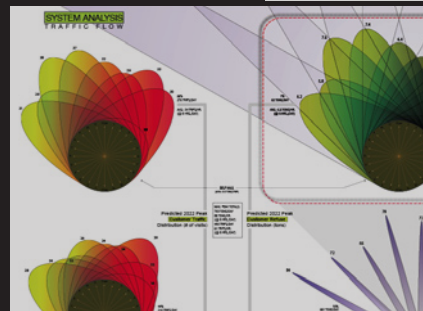
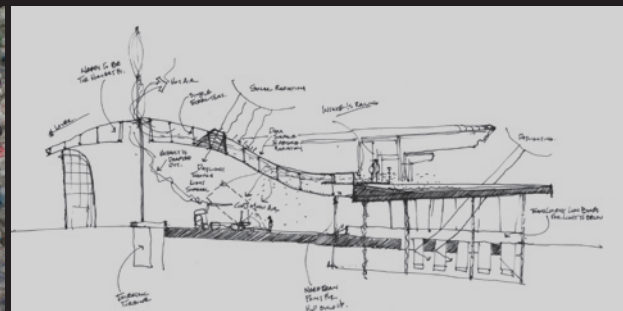
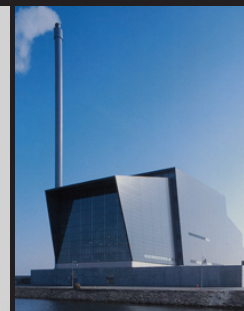
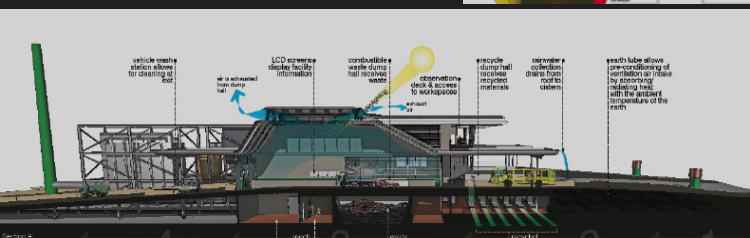
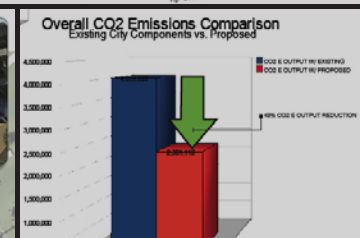




(re)Design

FOR A NEW ENERGY PARADIGM



(RE)DESIGN: FOR A NEW
ENERGY PARADIGM

by

Alexander Tripp Lewton

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Architecture

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 2008

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April 2008

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ABSTRACT

The design community faces immense pressures amidst diminishing energy supplies and anthropogenic climate change. Increasing ecological and sociopolitical instability demand a fundamental change in how we design for the present and future. In an effort to reduce and reverse the cause of this effect, designers are uniquely positioned to bring about much needed change. The impact of this vantage point is directly proportional to a designer's understanding of the components that conspire to bring about our current climate and energy crisis. These same components are the crucial players that hold the promise for a reinvention, or re-design, of our present situation. Of particular interest within this discourse are the woven elements of municipal government, social, technical and economic systems as they relate to existing practices of building and infrastructure energy use.

Within the U.S., many instances suggest the general public has lost sight of the industrial processes that support our way of life. The average U.S. citizen lacks even a basic understanding of their ecological 'footprint' and the industrial processes necessary to procure their quality of life. This gap in knowledge has resulted in a 'cultural numbness' for Americans while permitting these processes to remain disparate and disjointed. Poignant examples exist, however, ripe with intriguing solutions to reverse this trend, ranging from city wide energy conscious strategies to technological building efficiency solutions.

The design conclusion of this thesis is a site strategy seeking to synthesize the City of Bozeman's solid waste and wastewater treatment processes - with the ultimate intent to sensitize users to its inherent use and function. Within the context of this strategy is a detailed design for a high performing solid waste handling unit. Of the many complexities addressed in this proposal, the primary objectives are to 1) site plan synergies that maximize energy recovery from waste materials, 2) provide electricity and district heat production, 3) create safe, inviting, and high-efficiency spaces for handling solid waste while serving a balance of municipal and public uses, 4) design for modular expansion, demountability, deconstruction and/or reuse, 5) design safe and dignified work environments.

(re)Design:
For a new energy paradigm

Introduction

Advance apologies to the reader are in order. As will soon be discovered, this thesis makes no attempt to mince the facts that describe our present climate and energy realities. There will be large amounts of turbulence and rough bumps along this journey to a clear vision for change. Descriptions of the 'gloom and doom' challenges our globe faces offer few opportunities to smile. Yet I believe strongly in the importance of an intense focus on the challenges that lay ahead. Without it we are, too often, distracted, mislead, or lulled away from the pressing challenges that require our attention.

Sadly, there remains no easy fix for our global predicament. Space colonization is not an option, a single 'techno-fix' is not an option, or living underground is not an option. We are faced with clear decisions. Accept the 'gloom and doom' as the new paradigm of choice – or change the way we live, think, and work to maintain a healthy and sustainable biosphere. I prefer the latter!

Fortunately, as an architecture student looking to a future career *in* architecture, I see tremendous opportunity for change. In fact, opportunities abound such that complexity becomes the true challenge. As I discuss and discover below, *energy issues are huge*. What follows is a passage through this complexity with as much of an attempt to assess and comprehend as could be mustered.



Figure 1.

This book has been deliberately laid out to ease this complexity.

This book may be seen, loosely, in its five different stages of thought. Stage one, or what I have come to call the 'gloom and doom' sections, is arranged in an effort to place the issues squarely on the table – we've got big problems with our climate and energy use. Stage two elicits reactions from the respective architectural, planning and municipal government communities – opportunity for response. In stage three, related sections outline a system in which energy reducing strategies are organized – wading through the complexity. Stage four contains examples of where these systems have been used, and explores issues arising from such attempts – response in action. Finally, in stage five, I discuss the project proposal and associated programming as a result of my findings – the need

for (re)Design.

Generally, the (re)Design concept implies the need to assess and change the way we live, in response to the pressures we are placing on the earth's biosphere. As implied by this universal definition, (re)Design infers that something that already exists is in need of reconsideration or re-design. It is a scaleable term, and can be used to refer to something as small as a rethinking of one's commuting options to the retrofitting of a one million square foot office building for greater energy efficiency. In the case of this thesis, I have applied the (re)Design objective to the municipal processes of waste management within the city of Bozeman, Montana - to cause dramatic reductions in greenhouse gas emitting energies.

It is time to (re)Design.

Thesis

By the end of 2006, over 400 mayors of cities across the U.S. had adopted the U.S. Mayors Climate Protection Agreement. On a municipal level, signing the agreement is a city's act of commitment to begin taking steps necessary to honor the Kyoto Protocol and reduce global warming emissions.¹ This is an enormous opportunity for change. While the U.S. Government has chosen not to sign the Kyoto Treaty, along with developing nations Australia, India and China, municipal governments across the U.S. are using their city's density and jurisdiction as opportunity to implement strategies for rapid and aggressive change. Fashioning a needed global response on a city level is supported by the fact that over 75 percent of Americans live in urbanized areas.² As cities implement incremental change within their political boundaries, the impacts of change can be magnified by a major proportion of the nation's population. To set a public response in motion, municipalities can use their infrastructure as a flagship for change. Without municipal determination made authentic with action (through the application of energy strategies on existing infrastructure) an adequate public response cannot be expected to emerge.

In June 2006, accompanied by the AIA, the U.S. Conference of Mayors adopted the 2030

Challenge.³ This resolution (#50) commits all members to target-based reductions in municipal nonrenewable energy consumption. Incremental energy use reductions are at the heart of the 2030 Challenge. It tasks all future buildings and an equal number of existing buildings for an immediate nonrenewable energy use reduction of 50 percent of the "regional average," followed by 10 percent reductions/decade, becoming carbon neutral by 2030.⁴ Such a target-based approach to reducing energy use and subsequent greenhouse gas emissions is ratified by the science of climate change; stem the dangerous climate-altering trend and stop a global climate temperature increase of anything over one degree Celsius by the year 2100.⁵

Buildings within the U.S. currently consume 48 percent of all nonrenewable energy produced. Of all the fossil fuel energy created in the world, U.S. buildings consume 12 percent of this total. It is projected that in the year 2030, 63 percent of the U.S. building stock (in 2030) had been in existence since, at least, 2007.⁶ Meanwhile, the combined energy use of the residential sector and transportation sector comprises over 50 percent of all energy consumed, nationwide. These facts, coupled with the efforts of the U.S. Conference of Mayors to make change on local city-wide scales,

indicate a crucial point of entry. U.S. municipalities have an unrivaled opportunity to promote change in a wholesale manner.

The real question is: How? How will cities implement Resolution #50 and the goals of the 2030 Challenge? How will municipalities immediately reduce their fossil fuel use – by half! It is a "challenge" indeed! In an effort to provide hard and fast strategies for change to cities caught in the vacuity of a commitment to Resolution #50, this



Figure 2.

proposal seeks to satisfy an urgent need. What follows are proposed tools for municipal governments caught in such vacuums and, ultimately, a systems integration approach as a partial 'solution' in response to the converging global crisis. This thesis will explore how to initiate an effective response to the converging global crisis of climate change and energy consumption using existing municipal residential infrastructure as a flagship for change.

The primary focus of this thesis will be to devise a method for the city of Bozeman to address the initial need to make 50 percent reductions in fossil fuel energy use and greenhouse gasses. The industrial processes of how both solid waste and wastewater is handled within municipal operations will be the epicenter of this method-based focus. While the ultimate application of such a method needs to be a city-wide implementation, in the

¹ <<http://usmayors.org/climateprotection>>

² US Census 1990.

³ "Mayors Adopt AIA Position on Sustainability." *The Angle: News and Analysis from the AIA Government Advocacy Team*. 15 June 2006. 24 Mar. 2007. <http://www.aia.org/nwsltr_angle.cfm?pagename=angle_nwsltr_20060615&archive=1>

⁴ Mazria, Edward, "Adopting the 2030 Challenge." *Architecture 2030*. Viewed on 22 Mar. 2007. <http://www.2010imperative.org/2030_challenge.html>

⁵ Hansen, James. "A Threat to the Planet." *Global Warming, Climate Change and The Built Environment*. Viewed on 21 Mar. 2007. <<http://www.2010imperative.com/teach-in/hansen.html>>

⁶ In other words, if one traveled into the future to the year 2030, and looked around them, more than half of the existing buildings would be familiar to the viewer, as they were already in existence in 2007.

interest of managing scale and overwhelming complexity, this proposal will focus primarily on the particularities of these specific municipal processes as they relate to and overlap with varying degrees of use, both public and governmental involvement. This will be accomplished in a thorough process of data collection, assessment and (re)Design. This project is intended as an academic aid to Bozeman city planners. It will attempt to illuminate the true impacts of marginal design quality in a climate, quite literally, which is demanding a great deal more design perseverance than is currently being given.



1994



2005

Figure 3.

A Converging Crisis

Getting Warmer

It is now clear that a changing global climate is a reality for our future. In February 2007, the Intergovernmental Panel on Climate Change (IPCC) issued a summary of their fourth assessment on climate change. The summary, intended for policy makers, stipulated in clear terms with variable (though high) degrees of certainty that human caused global warming is in effect. The IPCC forged through digital climate modeling, exhaustive data collection, and analysis of virtual infinities of factors to make clear their science-based climate scenario predictions. Careful yet deliberate in its wording, this document warns of climate dangers that will be inevitable if human complacency reigns. The summary predicates a future for the earth's climate where we will experience increases in ocean temperatures, substantial shifts in continental average temperatures (temperature extremes), and changing wind patterns.⁷

Although the IPCC summary is careful to make general and user-friendly illustrations of its findings, a few pertinent data points seem worth discussing. Fundamentally, the IPCC targets carbon dioxide as having the greatest impact on human-caused greenhouse gasses. This is predominantly attributed to the burning of fossil fuels. Atmospheric

concentrations of the resulting carbon dioxide emissions are notably trending up on both long-term and short-term climate scales. The average growth-rate of carbon dioxide concentrations in the atmosphere from 1995-2005 has increased 35 percent from the average of the previous 45 years. As well, IPCC scientists indicate that our current concentration of carbon dioxide has exceeded the natural range as established over the past 650,000 years by as much as 110 percent. The IPCC climate computer modeling indicates that this atmospheric change will result in a 0.2 degree Celsius per decade global temperature increase. An average of all computer modeled climate scenarios estimates that, by the end of the 21st century, there will be a 2.8 degree Celsius climate increase from the beginning of the same century.⁸

According to Dr. James Hansen of NASA's Goddard Institute for Space Studies, to effectively reverse the human impacts on the earth's atmosphere a clear continuum of choices now exist - aggressive action to carbon reduction and sequestration at one end, with business-as-usual at the other. Significant reductions in carbon dioxide emissions are imperative to keep the earth's temperature from changing more than one degree Celsius by 2100. An increase in temperature beyond this (business-as-usual) will result in a three degree Celsius change by 2100 – the potential 'point of no return' for the

atmospheric equilibrium of the earth.⁹

According to the IPCC, expected climate changes, on a global scale, indicate a warming of land masses in the northern latitudes, increased desertification of land masses nearer to the equator, increased weather volatility and 'events,' contraction of snow cover, rising sea levels, and a likely retardation of ocean current systems.¹⁰ Varying regional differences will emerge within these global changes. In the U.S., most notable impacts will be felt in the drought stricken western states, as growing urban centers struggle to meet demands for water. Water storage problems (and associated legal problems with water rights) will become exacerbated as snow melt and runoff are occurring at remarkably earlier dates than in the past.¹¹ Rain now falls where snow once accumulated.

On a local level, the greater Bozeman area has already begun to experience spring temperatures that are as much as six degrees Fahrenheit warmer than in 1950. As a result of this warming, Bozeman and the rest of western Montana may experience dramatic impacts on three of its greatest resources – water, timber and wildlife. Dramatically expanding seasons of warm weather will cause longer melting periods, proliferation of wildfires, water scarcity, and decreasing self-sufficiency for the semi-arid region of greater Bozeman. With an increasing population and greater dependency on local and natural

⁷ Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2007: The Physical Science Basis: Summary for Policymakers*. United Nations, 10th Session of Working Group 1, Paris: February 2007.

⁸ Intergovernmental Panel on Climate Change (IPCC), February 2007.

⁹ Hansen.

¹⁰ Intergovernmental Panel on Climate Change (IPCC), February 2007.

¹¹ Archibold, Randal and Kirk Johnson. "An Arid West No Longer Waits for Rain." New York times on the Web 4 April 2007. 4 April 2007. <<http://www.nytimes.com/2007/04/04/us/04drought.html>>



Figure 4.
resources for our continued prosperity, a wide range of responses to slow the causes of climate change is required.¹²

It is tempting to assume certain areas of the world will benefit by a warming climate. However, this misguided sentiment has all the trappings of apathy wrapped in a thin veil of convenience. Although initial effects of global warming may temporarily bring a more comfortable and prosperous regional climate, science has repeatedly shown that the earth functions as a set of interacting systems, all of which have crucial dependencies to the other. There is no discontinuity in the earth as an ecosystem. Eventually (and certainly within the 21st century) the detrimental millennial impacts¹³ of a human changed climate will far outweigh its fleeting benefits.¹⁴ Meanwhile, a reconciliation of the disproportionate contributions certain nations

have made to global warming is in order.

The U.S. and the Western European nations currently account for two-thirds of all carbon dioxide emissions.¹⁵ At the same time, the entire continent of Africa has made a mere three percent contribution of carbon dioxide emissions, yet its populations of more than 800 million will face increased conditions of drought and water shortages for decades to come. During this same period of time, industrialized nations will enjoy their wealth (built on the backs of their poor neighbors) to mitigate regional climate problems with water desalination plants, fortified levees, floating homes and genetically modified drought-resistant grains.¹⁶

The discrepant conditions that developing nations find themselves in is an age old plight. Yet it highlights the importance of a global ethic and accountability that must develop within industrialized nations. The disproportionate contributions these nations make to the climate change crisis require a disproportionate response to correct it. The tolerance of developing nations should not be tested further. As stated by President Yoweri Museveni of Uganda, "We have a message here to tell these countries, that you are causing aggression to us by causing global warming. Alaska will probably become good for agriculture, Siberia will probably become good for agriculture, but where does that leave Africa?"¹⁷

Ultimately, the global warming crisis will force difficult cross-continental changes in all cities and countries, developed and undeveloped nations alike - from Bozeman, Montana to Harare, Zimbabwe. As well, it is noteworthy that the IPCC 2007 summary is described by many as being a highly conservative document, potentially too optimistic. To many, the summary is a study that risks irrelevance in place of objectivity as it dares not to venture into the business of speculation.¹⁸ As a result, a number of less understood factors were not calculated in the study. Acknowledging that sea levels are rising faster and ice caps are thawing more quickly than predicted in previous studies are among the factors omitted from the study. This indicates a serious possibility that the IPCC's 2007 summary may be construed as too hopeful.¹⁹ Despite the outcome, the underlying message is simple. Our response time to the climate change crisis is either short – or shorter still. The following two decades are the precious few windows of opportunity we have left - what was once a reasonable time to respond has become a poignant scramble for hope. It's time to start scrambling.

The Real Energy Crisis

Peak-Oil production in the U.S. was remarkably predicted in 1957 by M. King Hubbert.

¹² Pederson, Greg. Presentation to Bozeman City Council on Climate Change, Nov. 26, 2006, viewed on January 12, 2007.

¹³ Intergovernmental Panel on Climate Change (IPCC), February 2007.

¹⁴ Revkin, Andrew. "Poor Nations to Bear Brunt as World Warms." New York times on the Web 1 April 2007. 1 April 2007. <<http://www.nytimes.com/2007/04/01/science/earth/01climate.html>>

¹⁵ Revkin.

¹⁶ Archibold.

¹⁷ Revkin.

¹⁸ Rosenthal, Elisabeth and Andrew Revkin. "Panel Issues Bleak Report on Climate Change." New York times on the Web 2 Feb 2007. 2 Feb 2007. <<http://www.nytimes.com/2007/02/02/science/earth/02cnd-climate.html>>

¹⁹ Dean, Cornelia. "Even Before Its Release, World Climate Report is Criticized as Too Optimistic." New York times on the Web 2 Feb. 2007. 2 Feb. 2007. <<http://www.nytimes.com/2007/02/02/science/02oceans.html>>

Hubbert's ground-breaking method for accurately assessing the 1970 peak clearly conveyed the dangers of sole reliance on a finite resource.²⁰ As well, the prediction made us acutely aware that creating such forecasts is not guesswork with limited accuracy – that predicting the world's oil production and subsequent depletion was within the abilities of practiced scientists. Hubbert's successful prediction brought validity to the process of forecasting supply.²¹

Hubbert continued his work and modified his forecasting models to apply them on a global scale. More recent figures continued with Hubbert's work - Colin Campbell (a past chief of research for Shell Oil), Kenneth Deffeyes of Princeton and University of Colorado's Albert Bartlett. The net result of their work indicated a peak in global oil production averaging sometime between 2000 and 2010.²²

While the U.S. Geological Survey estimates are more generous time predictions, they differ from the 'Hubbert camp' by only one to three decades. Whether the peak occurred in 2005, or it occurs in 2035, neither prediction provides much of a comforting time scale with which to react.²³ At its least, the peak-oil age will become a pressing issue for generations to come.²⁴ Worth noting are these particularly distressing facts:

1. Two trillion barrels of oil was the total amount of the earth's oil; thus far, the world has consumed one trillion barrels of this amount.
2. 27 billion barrels of oil per year are consumed globally; if consumed at its current rate, the final one trillion barrels will be gone in 37 years.
3. 28:1 was the ratio of energy produced over the expended energy to attain oil in 1916; 2:1 was the ratio in 2004.²⁵

Underlying these figures is the message that the acquisition of fossil fuels in a post-peak era is an exhaustive and eventually futile process. Sooner or later, for reasons of deteriorating quality, decreasing

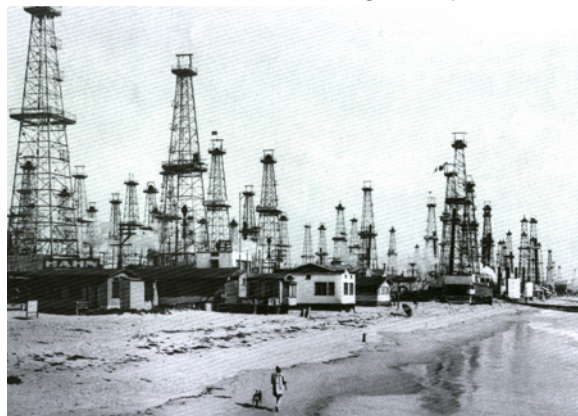


Figure 5.

oil field pressure, and increasing geopolitical conflict, production becomes a net loss.²⁶

Industrialized nations, such as the U.S., rely upon petroleum as the beating heart for economic growth and prosperity.²⁷ With the event of peak-oil, the Industrial Revolution will be undone. James Kunstler, in *The Long Emergency*, illuminates the vast difficulties that lay ahead. Global oil depletion, Kunstler states, will bring about "massive potential for system failures of all kinds, social, economic, and political. Peak [oil] is quite literally a tipping point. Beyond peak, things unravel and the center does not hold. Beyond peak, all bets are off about civilization's future."²⁸ While his message can be seen as fanatical in a few areas, Kunstler's well supported arguments raise a multitude of concerns that threaten to reverse both standards of living and subsequent quality of life. Within the U.S., if continued, our current system of living will eventually prove to fail us.²⁹

Cheap fossil fuels and their blatant consumption, a two trillion dollar per year global economy³⁰, have allowed Americans to establish livelihoods predicated on a one-time free-for-all entirely fueled by a nonrenewable resource. Kunstler believes we are 'sleepwalking' into a future for which we remain critically under-prepared. Economies of trade, based predominantly on service and leisure industries, have replaced those of industrial manufacturing and food production.³¹ Primary and

²⁰ Kunstler, 41-43.

²¹ Orr, David W. *Design on the Edge: The Making of a High-Performance Building*. Cambridge: The MIT Press, 2006, 177-178.

²² Kunstler, 48-49.

²³ As if to confirm theories of a global decrease in oil supply, it was recently reported that the United Arab Emirates have put 250 million dollars into alternative fuels research (see Fattah, Hassan. "Abu Dhabi Explores Energy Alternatives." New York times on the Web 18 Mar. 2007. 18 Mar. 2007. <<http://www.nytimes.com/2007/03/18/world/middleeast/18abudhabi.html>>). At the same time venture capital invested in U.S. based alternative fuels companies totaled 2.4 Billion. (see Krauss, Clifford. "Venture Capitalists Want

to Put Some Algae in Your Tank." New York times on the Web. 3 Mar. 2007. 3 Mar. 2007. <<http://www.nytimes.com/2007/03/07/business/07algae.html>>).

²⁴ Orr, 178.

²⁵ Kunstler, 66-67.

²⁶ Kunstler, 49-50.

²⁷ Yergin, 779.

²⁸ Kunstler, 65.

²⁹ Kunstler, 65.

³⁰ Orr, 177.

³¹ Kunstler, 56.

secondary education has become not much more than an expensive means for childcare.³² Higher education has become a “consumer activity” for students engaged in the knowledge economy while reinforcing the public notion that all future problems can be solved through the development and application of new technologies.³³ This “cultural inertia” has brought most Americans to believe in an inherent destiny completely removed from the realities associated with diminishing oil supplies.³⁴ Combined with the environmental impacts of fossil fuel consumption, this is the heart of the crisis and should be of great concern for present and future designers.

Bozeman is not immune. With an observed car ownership ratio of over two per family, 60,000 auto trips in and out of city limits occurring each day, an infantile bus system, and a shortage of bicycling lanes on major thoroughfares, there is room for great improvement. Bozeman is a central player in the paradigm of daily commutes to ‘satellite communities’ such as Big Sky and the Yellowstone

Club and a major accomplice to the mass perforation of the rural landscape by development. Planners, architects, engineers, scientists and educators can all make positive contributions to reverse these trends.



Figure 6.

We can, and must, begin working toward creative solutions for remediation.

U.S. building energy use and production, while not predominantly derived from oil, should take the obvious cues from the plights of a peak-oil age. Roughly 40 percent of all U.S. energy production is entirely reliant on natural gas and crude oil supplies.³⁵ The hard reality for Americans is that both of these resources are in diminishing supply. Crude oil, as discussed above, despite its ease of transport will eventually dry up, while natural gas production within the U.S. is already post-peak and very difficult to transport from overseas suppliers. The heavy reliance of U.S. energy production on diminishing nonrenewable fuels may result in a tendency to return to nuclear and/or coal power – both technologies being rife with substantial ecological impacts of their own.

While the hopeful maintain that a shift to renewable energy is viable, current nonrenewable energy production has held a remarkable flatness, with only minor peaks and valleys, over the past half century.³⁶ Current nonrenewable energy production is only 6 percent of net U.S. energy production (renewable and nonrenewable). If dramatic increases in renewable production, and subsequent technology, cannot be coupled with an intense campaign to increase efficiency of use, the U.S. will see an inevitable return to a nuclear and coal energy program. This paper will assert that Americans can do better and will not accept the ‘easy solutions’ of relying on plentiful coal supplies and the promise of clean nuclear energy (think: acid rain, Chernobyl). Despite the tentative promise of carbon sequestration systems and the cheap cost of coal, coal fired power generation remains the leader in point source carbon emissions for electricity production in the U.S.³⁷ Placing an even greater reliance upon this form of energy production will only expedite its human impacts on climate change and postpone a fundamental and inevitable need to change the culture of consumption.

Clearly, a desperate and demanding event is unfolding. Tectonic shifts in both climate and traditional energy production will require a human responsiveness, on local and national levels,

³² Kunstler, 271.

³³ Kunstler, 274.

³⁴ Kunstler, 26.

³⁵ <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec1_6.pdf>

³⁶ <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec1_6.pdf>

³⁷ United States. Energy Information Admin. *Emissions of Greenhouse Gases in the United States 2005*. November 2006, 16. <<ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057305.pdf>>

unrivaled by past calamities. This converging crisis will demand a re-development in understanding the human impacts of producing and consuming energy. Our relationship with these principles of energy must begin to transcend the complacent understanding Americans possess of the series of events and impacts that conspire to light, cool and heat our buildings. Future uses of the word 'energy' assume an all encompassing and holistic concept of energy, from source to use and all its subsequent impacts.

It is desired that this thesis not omit the instruments of our energy use paradigm; doing so would ignore the characteristics of brute force by which we dig, pick, probe and burn our way through the earth's fuels to make our current lifestyles possible. This includes, but is not limited to, geopolitical conflicts of acquisition, cultural conditions of use, global climate affects of consumption,³⁸ and discrepancies between populations who have abundant access to energy and those who do not. Though this thesis dares not tackle each of these instruments of the fossil fuel energy paradigm, they remain at the core of our future challenges and promise to become ghoulish versions of their former selves if we fail to grasp this converging crisis with a holistic and systems-based approach. What may be seen in a remedial manner is, in fact, that of an ethical confrontation. It is now very clear; we pose



Figure 7.

a threat to ourselves and the planet we live on. The earth's 'resources' are available for our use. How will we use them? Will we squander them wastefully, in ways that are harmful to us and the planet? Will we use them, carefully and strategically, like a precious gift?³⁹ Either choice has ethical implications that will be judged by future generations. How will this generation respond to the converging crisis?⁴⁰

³⁸ Kats, Greg. "The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force." Capital E, Department of Health Services, Lawrence Berkeley, October 2003, 30. <<http://www.usgbc.org/Docs/News/News477.pdf>>

³⁹ Geshwiler, Mildred, ed. *ASHRAE GreenGuide*. New York: Butterworth-Heinemann, 2006, 25.

⁴⁰ Luebke, Chris. "Doing is Believing." Global Warming, Climate Change and The Built Environment. Viewed on 24 Mar. 2007. <<http://www.2010imperative.com/teach-in/luebke.html>>



The City Responds

U.S. Municipal governments must take action to set an example for what is expected to meet the energy efficiency needs of tomorrow, today. Having signed onto the U.S. Mayor's Climate Protection Agreement and the 2030 Challenge, a city is expected to remain within the stated goals of the organization and commit to an immediate 50 percent reduction in energy use. This presents an opportunity for the city to put 'teeth' into their initiated resolutions.

In its seventy-third annual meeting of 2005, the U.S. Conference of Mayors (USCM) officially endorsed a Climate Protection Agreement seeking to equip U.S. cities with the necessary momentum to address global warming. The USCM recognized the disproportionate contributions cities made to greenhouse gasses and the subsequent impacts of climate change along with the related effects it will have on cities. Based upon a moral obligation⁴¹ to the health of their cities and the future, select mayors have transformed their response to the climate crisis from an imposing, seemingly impossible global task, to that of an achievable goal. The following year, in 2006 the USCM has pushed even further by adopting

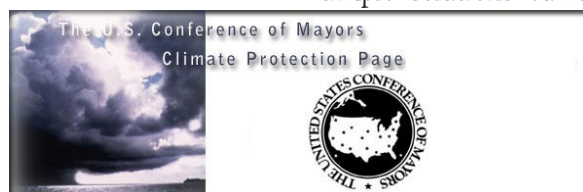


Figure 8.

the 2030 Challenge. The "challenge" urges each Conference member to galvanize their commitment by using target-based action to produce rapid and immediate municipal change. The 2030 Challenge presents an opportunity for municipalities to assess their infrastructure's use of fossil fuels in hopes of immediately reducing a reliance on them by half. If cities cannot lead this charge, they can hardly expect their community members to follow.

To make the dramatic reductions of fossil fuel use, as previously mentioned, municipalities will be hard pressed. While reducing energy waste is a factor, making a 50 percent reduction in nonrenewable use will require more than the simple solutions currently recommended by the

USCM.⁴² Beyond these initial solutions lie the opportunities to affect change in fundamental and critical ways. Developing an energy strategy as an integrated approach of the technical, social, economic and political systems, municipalities can take the critical steps necessary to dramatically reduce their heavy reliance on fossil fuels. No greater opportunity exists for such an application than within the built environment.

In November 2006, Bozeman city council

members unanimously signed the city of Bozeman onto the U.S. Mayors Climate Protection Agreement. Making municipal infrastructures into flagships for change, particularly within its industrial operations and services, will allow cities such as Bozeman to fulfill a moral responsibility by actively responding to the converging crisis. At the same time, this can generate interest and action with its future inhabitants to maintain the necessary momentum for such a response. The necessity to sustain such interest might help city governments avoid the overall tendency to repeat history and be 'lulled' back into inaction. Sadly, conservation behavior stemming from the 1970's and early 1980's oil embargoes seems to have been partially 'lulled' out of the general public.

The 1970's are of the few times in U.S. history when Americans made notable efforts to reduce dependence on fossil fuel energy. Consumption behavior was affected by government entities through innovation, rationing, conservation and demand reductions. This highlights the importance of government action for leading an organized effort to mobilize



Figure 9.

⁴¹ Hansen.

⁴² On their official website is a list titled "Top Fifteen Things YOU Can Do To Reduce Global Warming!" Listed recommendations include using less hot water, buying ENERGY STAR appliances, and planting trees (to name a few). <<http://usmayors.org/climateprotection>>

rapid change. More importantly, however, were the curious solutions to accomplishing the goals of rapid energy conservation. Modifying daylight savings hours and establishing a national speed limit were far from obvious government 'tools,' yet neared poetic in the 'cost-benefit' balance of implementation to ensure mass compliance (the necessary ingredient for affecting rapid change).

Concurrently, what followed the energy crisis years was a steep rise in overall renewable energy consumption in the mid 1980's. A conjecture might be made that this was a 'rebound' from the impacts of the preceding energy crisis. This steep rise peaked in 1985 at a maximum of 8.4 percent of all energy consumption in the U.S. and we remain below this peak even today.⁴³ However, this figure indicates both the commercial and political will of the nation (in the 1970's) to turn to technology when faced with crisis.

The world now faces a crisis, as previously mentioned, that differ from the challenges encountered by Americans during the oil embargo of the 1970's and early 1980's. Worth noting, however, is the effectiveness of government's response to crisis. Though 'market forces' are needed to affect deep change, as auto manufacturers did in the 1970's and early 1980's,⁴⁴ the forces of government have an ability to initiate rapid change.⁴⁵

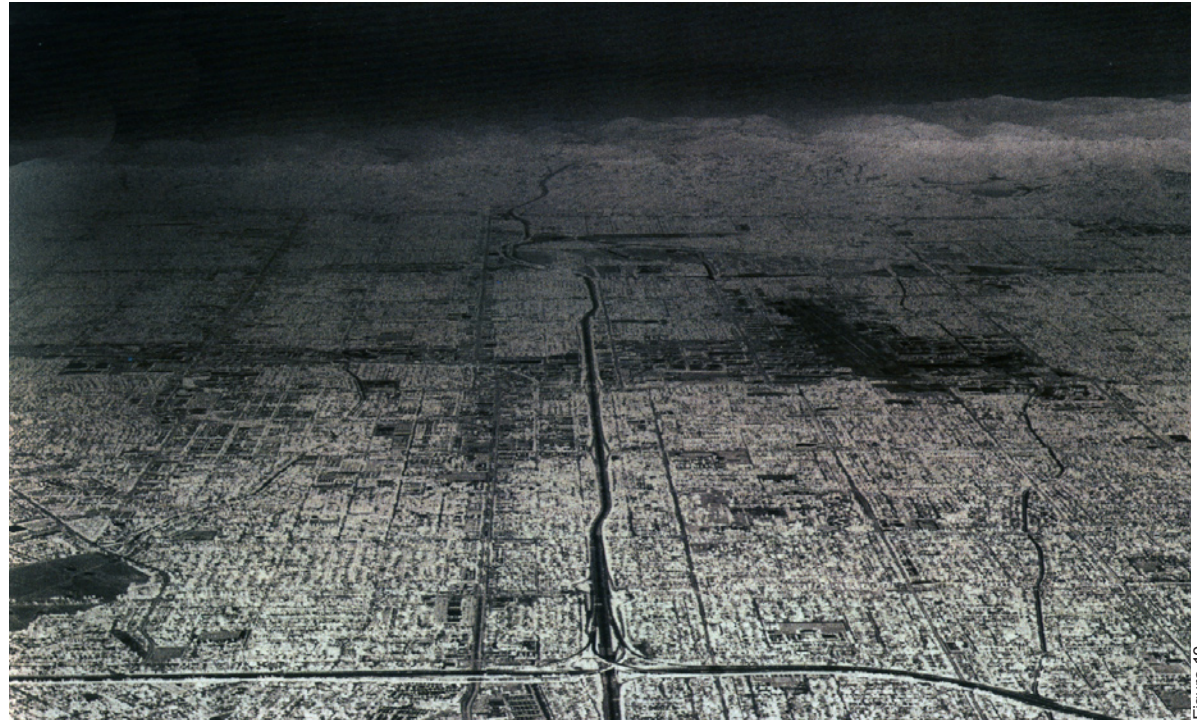


Figure 10.

Within the U.S., energy consumption per capita is 40 percent greater than Australia, the second greatest per capita consumer.⁴⁶ The advent of cheap fossil fuels and, until recently, a lackadaisical approach to the human impacts on climate change has created a culture of energy-consumption that may leave future generations aghast. Opportunities for cities to 'rethink' their current energy consumption patterns are ripe for

good design – particularly for the existing building stock. Local governments, planners and designers are all fundamental players in curbing this trend, wielding tools capable of integrating the seemingly unrelated parts of a problem into a cohesive whole.

⁴³ United States Department of Energy. 25th Anniversary of the 1973 Oil Embargo: Energy Trends Since the First Major U.S. Energy Crisis. Washington D.C.: Energy Information Administration, August 1998. In 2005, nonrenewable energy consumption remained at 6 percent. Presumably, this figure may continue to rise. (see <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec10_2.pdf>)

⁴⁴ A historic decrease in the size and fuel efficiency of automobiles made by the "Big Three" in the late 1970's and early 1980's indicated the commitment of major economic forces to reduce, on the demand side, reliance on fossil fuel energy.

⁴⁵ 'Deep change' infers any change where resounding economic impacts may occur as a result of 'rapid change,' where mobilization of the masses is initiated, though still waiting to be supported by an economic response.

⁴⁶ International Monetary Fund (IMF). <www.imf.org>

63 Percent: A case for the existing building

63 percent of the total number of U.S. buildings projected to exist by 2035 already exists. With this in mind, consider the following:

- In 2000, roughly 80 percent of the U.S. population resided in urban areas.⁴⁷
- 22 percent of U.S. net energy use is consumed by the residential sector.⁴⁸
- The transportation sector consumes 28 percent of U.S. net energy use.⁴⁹
- 20 percent of all building related energy is used for materials, transport, and construction; the rest, 80 percent, is consumed for operations and maintenance (heating, cooling, lighting...etc.) over the lifetime of the building.⁵⁰
- 32 percent of the energy used in an average U.S. residence is for space heating (the largest single amount); with water heating, lighting, space cooling and refrigeration trailing, respectively, at 13, 12, 11, and 8 percent.⁵¹

These figures indicate that, within cold weather climes, big impacts for reducing energy use can be made to existing residences in cities. (re)Design objectives will be most pointed with a focus on assessment and response measures for space heating



Figure 11. and transportation impacts in the residential sector (the combination of which comprise over 50 percent of total U.S. energy consumption). This can occur when we recognize the need to decrease reliance on fossil fuel energy, specifically for transportation and home heating purposes. However, this cannot happen without city government commitment to assessment and accountability strategies that far exceed their current energy codes.

Clearly, a radical response to delivering energy solutions, that work, must address how to power and service the existing residential building stock along

with that of newly constructed homes. (re)Design of the current built landscape for energy efficiency is a monumental challenge. Lacking the clean-slate-effect of design and construction on new energy efficient buildings, the existing housing stock will demand a kind of critical and quantitative thinking that accounts for 'embedded values' of an existing design. These values reside on the simple-complex continuum of quantification; some are simple to quantify, others too complex and nearly impossible (with our current methods of assessment), becoming more of an informed 'guess' than a true assessment. It is relatively simple to measure energy consumption in Btu's per square foot or embodied energy in simple measures for existing buildings. However, less simple is a measurement of variables to inform a complex decision. Does one demolish the existing building (a.k.a. energy 'hog') and replace it with something more energy efficient? How much energy will be used/lost, how much gained? Or does one completely overhaul the building, while keeping the shell intact? What are the positive/negative energy impacts of doing this? How about making slight modifications (i.e. adjust window placements, install photovoltaic panels...etc)? As well, what of the 'embedded values' of culture, of history or of habit? The list continues on.

The core question of such an inquisition is:

⁴⁷ <<http://www.census.gov/statab/hist/HS-02.pdf>>

⁴⁸ <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec2_2.pdf>

⁴⁹ <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec2_2.pdf>

⁵⁰ Mazria.

⁵¹ <<http://buildingsdatabook.eren.doe.gov/docs/1.2.3.pdf>>

what is the best energy-based choice that can be made, with regard to redesigning the existing built environment? Amidst all of the variables, the decision making process for becoming 'energy-efficient'⁵² is as elusive as it is complex. Thus, when applied on a city-wide scale, assessment and implementation of energy use plans become an overwhelming task for city governments. Yet the problem of the existing building will not disappear. Unlike eras of previous energy crisis, where a return to stable energy prices promised to be around the corner and the problems of climate change remained undiscovered, the future will demand an answer to the question: what will become of the 63 percent?



Figure 12.

⁵² 'Energy efficient,' is a reference to the kind of efficiency that is necessary to reduce consumption (and emissions) by an immediate 50 percent, as prescribed by the 2030 Challenge.

Leadership through design

The U.S. Federal Government's lack of leadership and public remediation for the disturbing changes at our doorstep provides an entry point for leadership from designers.⁵³ While designers must design for the present, they must equally be equipped to design for the future. This requires a commitment to the development of principles and practices as a response to unpredictable challenges of the future. As William McDonough states, design is the highest form of leadership⁵⁴:

you can be the best captain in the world, the best navigator; but if the ship is not seaworthy you are going down. And so the designer of the ship is the leader. And therefore leaders must become designers, designers must become leaders.

As cities begin to forge ahead to mitigate the impacts of the converging crisis, leadership from within the design community is paramount. With newly constructed low-energy use projects emerging around the globe, it is evident that the technology and design tools for change currently exist, with particular strength in the residential sector. Frankly, they existed over 35 years ago, as evidenced in one of many instances - Judy and Michael Corbett's Village

Homes project.

Built in the mid 1970's in Davis, California, the Village Homes sustainable community was founded on principles that sought viable solutions to planning and architecture that would dramatically decrease prevalent energy intensive lifestyles. Subsequent assessment of the Village have suggested that the payoff of the Corbetts' careful planning and design guidelines have resulted in a 30 to 50 percent energy savings as compared to surrounding Davis neighborhoods.⁵⁵

To accomplish such a feat, the Corbetts understood the importance of a systems approach to planning and design. The baseline principles that guided their decision making process focused on the relationships between the planning elements as much as they focused on the elements themselves. Open space, edible landscape vegetation, circulation, open channel drainage, energy use/conservation, water conservation, management, community economics, food production, and traffic calming were all considerations within their 'ground breaking' design. However, the inherent success of these factors emerged as a result of a willingness to

understand how they each related to one another. Ultimately, such systems thinking allowed new planning and design considerations to emerge and allowed for a greater sophistication, thus decreased consumption, than neighboring developments.⁵⁶

Strong correlations between the framework of the Corbett design and the regenerative design principles, proposed by John Tillman Lyle, further strengthen the tendency toward a systems thinking design process. Regenerative design strategies⁵⁷, for many

years now, have championed the study of sustainable energy flows and their inherent relationships within a systems view as being central to realizing good design. Such strategies make available an approach that subverts the dominance of, and reliance upon, existing technology – as such reliance has the deeply rooted flaw of mechanistic efficiency “to the virtual exclusion of other concerns.” Lyle implores designers to venture beyond the mechanistic design paradigm and enter the regenerative⁵⁸:

Regenerative systems by contrast are enmeshed in natural and social processes in ways that make their purposes far more



Figure 13.

⁵³ Orr, 179.

⁵⁴ Scott, Andrew, ed. *Dimensions of Sustainability*. Declaration of Interdependence, by William McDonough. London: E & FN SPON, 1998, 46.

⁵⁵ Francis, Mark. *Village Homes: A Community by Design*. Washington: Island Press, 2003.

⁵⁶ Corbett, Judy and Michael Corbett. *Designing Sustainable Communities: Learning from Village Homes*. Washington, D.C.: Island Press, 2000.

⁵⁷ These strategies are: 1) let nature do the work, 2) consider nature as both model and context, 3) aggregate, not isolate, 4) seek optimum level for multiple functions, 5) match technology to need, 6) use information to replace power, 7) provide multiple pathways, 8) seek common solutions, 9) manage storage as a key to sustainability, 10) shape form to guide flow, 11) shape form to manifest process, and 12) prioritize for sustainability. (see Lyle, John. *Regenerative Design for Sustainable Development*. New York: John Wiley & Sons, Inc., 1994, 37-45.)

⁵⁸ Lyle.

complex. While technology remains the means for augmenting nature, it ideally becomes a factor within the larger social and ecological context rather than the engine driving that complex.

Furthermore, with the need to interrelate technology with society and nature, a broad and disparate body of knowledge enters the process. To further complicate matters, regenerative systems function as integral parts of the communities they serve. This means they necessarily involve those communities in their design and operation.

Lyle admits to arising challenges, and subsequent criticism, regenerative design presents on practical levels of application. Complexity and the challenge of “connecting means with ends” are not foreign difficulties of such a system. Yet the linear natures of our current industrial processes,

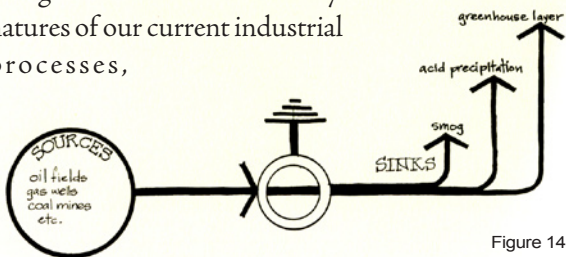


Figure 14.

despite their efficiency to accomplish singular tasks, remain the perpetrators of the converging crisis

we currently face. It is their ‘singular nature’ that makes this so. Conversely, regenerative design, while relatively young in its modern applications, seeks to incorporate reams of information once thought disparate

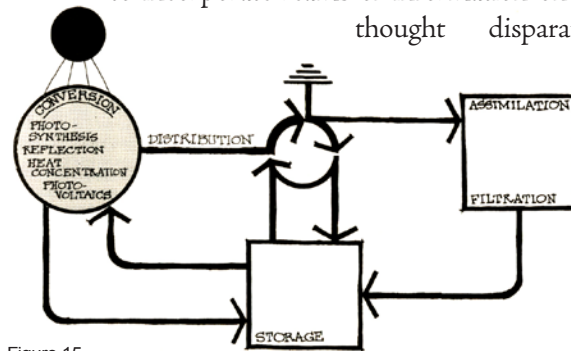


Figure 15.

and unrelated to any design problem at hand. What linear processes may perceive to be superfluous information, regenerative processes may discover as important relationships and crucial points of entry for developing viable design solutions.⁵⁹

More contemporary concepts of sustaining systems that inform solutions for the 63 percent existing building challenge continue Lyle’s strong assertions for his regenerative design strategies. The iconographic Cradle to Cradle concept set forth by McDonough and Michael Braungart remains deeply rooted in the spirit of regenerating systems. *Cradle to Cradle* has proposed that mono-directional industrial systems of production, from textiles to towns, fail to integrate

with the biosphere (and this includes humans) in the crucial ways necessary to maintain its health; such “cradle to grave” processes suffer from a serious lack of human ingenuity and intuition. Instead, Cradle to Cradle design approaches ask us to model our systems and the products after sophisticated natural systems (not linear industrial ones) where “form follows evolution.” Such Cradle to Cradle concepts begin to deeply challenge our presumptions concerning questions of how to (re)Design our existing industrial processes. When viewed through the ‘waste equals food’ lens, what decisions need to change with regard to this monumental design challenge?⁶⁰

The leadership and innovative approaches of both regenerative design and cradle to cradle concepts are of particular use to the (re)Design of existing waste treatment facilities within Bozeman. Their application to this challenge offers a refreshing framework through which design decisions can be made. These approaches begin to ask challenging questions that question how we can be ecologically better, do more with less, and adapt our design behavior. The future is asking more of us, and the Corbetts, Lyles and McDonoughs have answered with effective, yet poetic, systems for change.

⁵⁹ Lyle.

⁶⁰ McDonough, W. and Michael Braungart. *Cradle to Cradle*. New York: North Point Press, 2002.

Energy Performance Systems (EPS): Integration of the technical, social, economic and political

In the spirit of regenerative design and a tendency to 'maintain the whole,' it seems necessary to discuss specific energy performance systems within their greater context to appropriately understand each as they relate to a city's potential for (re)Design and energy reform. To understand these relationships, an integrated systems view is paramount. As discussed above, regenerative design and related concepts rely distinctly on an embrace of complexity and a disdain for oversimplification.

It is expected that, in the integration of the systems below, value is generated not only within each discussion, but in their overlap as well. Exploring the relationships between elements within a given system (and not just the elements themselves) allows the 'hidden realities' of a given system to be seen. Ultimately the revealing of such realities is the true interest of a systems integrated view.

The Technical: Building-based energy performance systems (BEPS)

Prescriptive, 'soft' strategies (LEED, Green Globes, HERS etc.) appear to have become a predominant focus of sustainable design systems. The checklist and point-based compliance approaches to fostering a design response to human and ecological needs has become well-known and respected by many. They have contributed heavily to forcing change by raising public awareness, creating a sustainable building 'language,' and providing methods for implementation. As a result, prescriptive methods have made moderate gains in



Figure 16.

reducing emissions and reliance on fossil fuel energy. Each of these systems has been successful in their own right by providing tactile solutions to designers for the built environment.

It is noteworthy, however, that the prescriptive nature of these systems (which is what makes them so popular and usable), may be the impetus for 'feedback loops' that undermine the potential for more rapid change. By creating checklists as aids, though helpful in streamlining an often complex process, a divergent course is set in the attempt to produce 'green' buildings. A platinum rating, 4 green globes, or 92 HERS points may indicate to all parties involved (particularly the public) that a building has made a concerted, environmentally-conscious effort. However, the true question remains: 'How sustainable is it?' Performance ratings aside, checklist compliance cannot confirm that the actual building has a decreased environmental impact.⁶¹

The problem of not being able to answer this question with hard and fast data⁶² is the double-bind of prescriptive sustainable building systems.⁶³ In an atmosphere of urgency, where we are being asked to immediately reduce building energy consumption by 50 percent, prescriptive strategies may not be doing enough.

What 'soft' strategies lack in the way of delivering evidence of true energy performance, target-based strategies make by the fist full. As stated

⁶¹ Levin, Hal. *Sustainability and the Building Environment*. ASHRAE Satellite Broadcast and Webcast, 2006.

⁶² Perhaps this is the 'holy grail' of prescriptive-based sustainable strategies.

⁶³ Geshwiler, 20.

in the ASHRAE Green Guide, “An important part of green design is verification that the goals defined by the owner and integrated by the design and construction team are actually achieved as intended, from the first day of occupancy.” The focus on following performance goals, from schematics to completion, and ensuring the goals are met is an important distinction between a prescriptive strategy versus a target-based approach. Intensely promoted by those who have experienced it, integrated design (while labor intensive and heavily reliant upon cross-discipline collaboration), is quickly becoming a desirable strategy for the creation of high-performance buildings.⁶⁴

While it is difficult to assign names to the specific uses of the integrative design process (other than building names as their products), there are movements that offer tools for target-based decision making methods.⁶⁵ On a federal level, the Environmental Protection Agency (EPA) has made

available building energy “targets,” associated with building types, on which designers can establish energy performance goals. Such approaches are heartening in the design community’s effort to achieve the lofty goals of the aforementioned 2030

Challenge. This shift is a strong indicator that effective methods of working are currently available for municipal use.

Emerging tools in the realms of integrative design fundamentally subscribe to the ‘brains over brawn’ approach. Software developments in the recent past have

generated enormous opportunities to better inform building and systems design decisions. The U.S. Department of Energy, Building Technologies Program supports a directory of over 300 software programs, many of which are free, for assessing building energy and related factors.⁶⁶ Two categories of particular interest within this list of programs are applications that assist in energy auditing and life-cycle assessments (LCA) – both of which are

crucial tools for exploring municipal building energy solutions. The need for designers to understand, in a holistic manner, the true ecological impacts of the decisions they make, is central in the argument for LCAs.⁶⁷ Simultaneously, energy auditing software is providing designers test-and-compare opportunities by quantifying the ramifications of design changes within a given simulation. The synergies between these two types of applications are the relatively untapped resources, by both designers and municipal governments, on the journey to achieving the goals of the 2030 Challenge.

The tech-based energy systems, ‘hard’ or ‘soft,’ are reliant upon intense design charrettes and the running of complex software programs – a process that requires effective ways of working in cross-disciplinary settings. This highlights the effect human decisions have on a building and its infrastructure’s energy performance. Energy consumption is affected on all levels of human interaction within the built environment – whether it is an architect carefully considering the energy impacts of a structural system, an engineer calculating the size of an air handling system, a landscape planner designing a street layout, or an occupant choosing to clean their daylighting light-shelves. This indicates an important interface between the technological and social Energy Performance Systems – an overlap not to be ignored by designers.



Figure 17.

⁶⁴ Geshwiler.

⁶⁵ Green Building Challenge, C-2000, and Commercial Building's Incentive Program are among a few of them. (see Geshwiler, 21-22.)

⁶⁶ <www.eere.energy.gov>

⁶⁷ These programs, with varying degrees of sophistication, are able to assess design decisions that extend the capabilities of a designer well beyond their original capacity. In a case study of a specific LCA application, Athena™, researchers calculated and compared the life cycle ‘costs’ of wood and concrete buildings. By defining sets of parameters, entering building element factors, along with local weather data and energy sources, the program was able to calculate an array of information. Greenhouse gas emissions, air toxicity, embodied energy, and solid waste calculations are among a few of the data sets produced when the program is run. While accuracy and legitimacy remain in question, as they are heavily reliant on a pre-established, closed code, life cycle inventory (LCI), Athena and similar applications represent a new potential future in methods for building assessment. (see Trusty, W.B. and J.K. Miel. “Building Life Cycle Assessment: Residential Case Study.” <http://www.environmental-expert.com/articles/article1157/ATH_AIA_paper.pdf>)

The Social: Person-based energy performance system (PEPS)

It is imperative that a synergy between target-based building performance programs and target-based social responsibility be established to rethink existing energy-use infrastructures – particularly if it is to achieve the 2030 challenge goal of an immediate reduction in building energy use by 50 percent. Without the fusion of the technical and social systems, the response to the converging crisis will be weakened, delayed, and ultimately, may fail.

Of the most fundamental measures for a building's energy performance is the BTU/square foot/year metric. Such a method for quantifying energy use and establishing targets is effective in the technical approach to forcing change. However, with holistic change becoming necessary for an effective response to the converging crisis, we must relate energy consumption directly to the core of the problem – human use.

In 2000, the average American consumed 326 Million BTU/year of building related energy. In contrast, China (the world's second largest energy consuming nation) has an average of 30 Million BTU/person/year.⁶⁸ Respectively, this is the difference between the energy it takes to fly a loaded Boeing 747 from San Francisco to San Diego

(500 Miles) versus flying that same plane from San Francisco to San Jose (50 Miles). By 2020 the U.S. is projected to remain the greatest consumer of building related energy. China's projected 2020 level of consumption per capita is projected to equal what the U.S. level of consumption was in 2000.

Could U.S. energy consumption be reduced if Americans had a daily conceptual indicator of individual energy use? What would it mean for

an American to see energy use in quantifiable terms? What relationships can emerge between occupant and building? We have begun to see it in our cars. Many vehicles, despite their own shortcomings at making drastic fossil fuel consumption

reductions, now sport fuel efficiency indicators. If people are provided with comprehensive "per person" building energy consumption information, more extensively than that of the monthly gas and electric bill, would social change be fostered?

New studies indicate that energy efficiency can be doubled when a building's occupant is provided with specific energy use feedback.⁶⁹ This assumes an individual is motivated to act as a response to the associated information (through Municipal Based Energy Performance System incentives, competition, an urge to "do the right thing," or a little bit of each). This begs the question: Is the occupant the "niche market" in a municipal energy strategy? Bridging

the gap between the experts (engineers, architects, and building managers) and the average building occupant expands the opportunity for rapid change. It is understood that automation of certain building controls, such as HVAC, louver adjustments, and

lighting controls, can result in increased building efficiency. However, is the greatest energy efficiency accomplished by relegating the occupant as merely cargo within the built environment with all energy systems being automated and mechanized? Or is it,

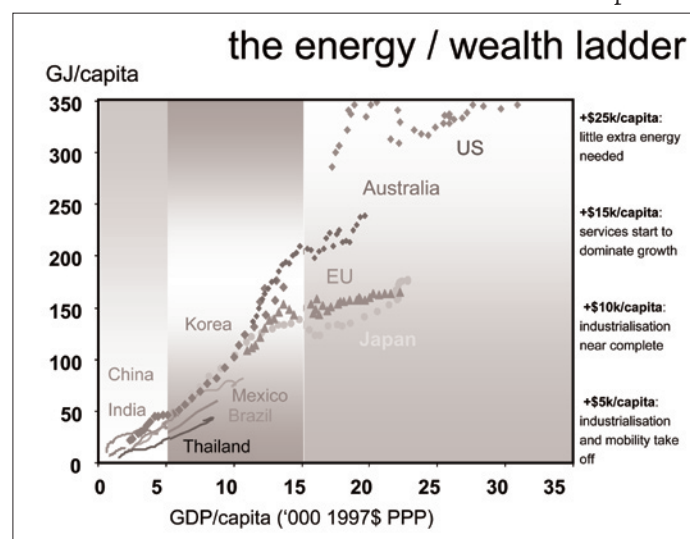


Figure 18.

⁶⁸ <eia.gov>

⁶⁹ Orr, David W. *Design on the Edge: The Making of a High-Performance Building*. Cambridge: The MIT Press, 2006, 185.

as in the example of certain automobiles (and even sailing vessels), an exercise in providing the occupant with pertinent information for guiding the vessel for optimal performance?

If municipalities are to implement a strategy for a rapid decrease in energy use, they must couple Person-based Energy Performance System (PEPS) tools with Building-based Energy Performance System (BEPS) tools in their application to the municipal infrastructure.

The development of methods and tools for collecting and quantifying large amounts of person-based energy use information is crucial to establish such a connection while initiating energy reform. Our current need for such data to make intelligent decisions concerning the careful use of our energy sources depends greatly on the harvesting of such data. The reward for these efforts will be the establishment of a more sophisticated understanding of the best paths to immediate and drastic reductions in greenhouse gas emissions. The need to develop an 'ear to the ground' approach in the effort to assess the city's existing infrastructure has never been greater. (re)Design objectives of such infrastructure must seek such an approach to successfully accomplish effective energy reform.

The Economic: Money-based energy performance system (MEPS)

The economic factor of the Energy Performance Systems is, quite possibly, the most challenging element within the U.S. and cannot be ignored. With capitalism as our current system of economy, like a sieve, it will not allow unmarketable ideas to pass. Whether loaded with idealism or good



Figure 19.

intentions, even the best technologies, when poorly proven or marketed, will fail. However, the opposite can be equally true. Examples are continuing to emerge as evidence that 'going green' can happen when supported with viable economics. Of the best of these illustrations is an extensive study conducted

in California through the collaborative efforts of the Capital E, Future Resources Associates, Task Force members, and the United States Green Building Council.⁷⁰

Titled "The Costs and Financial Benefits of Green Buildings," this study took an extensive and detailed look at green commercial buildings, nationwide, in an effort to explore the monetary benefits of green design and construction. The results were definitive – green building projects pay greater returns than their less sophisticated 'gray' neighbors. While risking an oversimplification of this elaborate study that used over 30 LEED certified buildings as base cases, it is worth noting that the financial benefits of such buildings ranged anywhere from \$48.87/square foot (Certified and Silver) to \$67.31/square foot (Gold and Platinum), on a 20 year return. The construction cost premiums averaged only 2 percent (\$4/square foot). In economic terms, these figures are vivid illustrations regarding the monetary allure of a sustainable building and energy conscious project.⁷¹

With commercial buildings proving value in going green, the overall building sector has yet to make significant, economy-based shifts toward more sustainable uses of energy. The current challenge to make this shift is directly related to cheap energy prices and the delayed effects of climate change. Despite concerns for the impacts fossil fuel energy

⁷⁰ Kats, 84.

⁷¹ Kats, 84.

use may have on future generations, with cheap energy costs abound, there remains no pressing need for change. According to Thomas Friedman, it is not a typical technical challenge to find alternative systems for green energy, or for energy efficiency. Going green, en masse, will only take place when the cost of doing so, and the savings involved, will realistically compete with fossil fuel energy prices. Concurrently, it is a social and ethical phenomenon that prevents people from taking responsibility for climate change – as the true impacts will affect those not yet born.⁷²

In an effort to advance the greening of the residential sector, the National Renewable Energy Laboratory (NREL) has recently published a conference paper on the subject. In August 2006, NREL presented a method to evaluate the most cost-effective approaches on the route to a zero net energy (ZNE) home. The paper acknowledged that this was a site specific study (Sacramento, California), tailored to a warm weather climate. However, it stressed the importance of “beyond-code” energy systems that would “maximize whole-house energy savings by targeting all residential end uses rather than focusing energy-savings strategies on specific building components.” For this to be accomplished, the study utilized Building Energy Optimization (BEOpt) software. The results of the study calculated a 40 percent energy savings could

be achieved through passive and efficiency-based measures without any increased cost in the sum of mortgage and utility costs. Ultimately, the payoff of 40 percent energy savings ‘break even’ with the cost

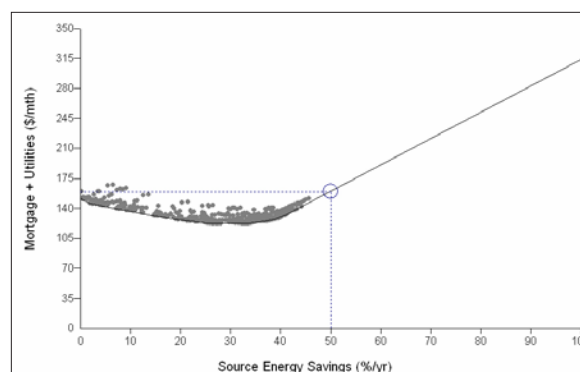


Figure 20.

of measures necessary to implement these changes. To achieve the final 60 percent energy savings on the ZNE path, the study concluded with the application of active systems (photovoltaic panels, in this case), and an accompanying increase in mortgage costs to pay for the system.⁷³

To a point, the NREL study indicates the economic viability for greening one's residence by employing existing technologies. However, the present challenge of sparking shifts to green strategies in the 'common' residence is not one of technical implementation. In order to cause large scale green change within the residential sector we must respond to this difficult question: What is the

incentive for residents to make their homes green when, to achieve up to 40 percent energy savings (and reductions in carbon dioxide emissions), they will, financially, only break even? Simply stated: What will make it worth their trouble, when the only real payback is a reduction in carbon emissions? Once again, this hails the events of the U.S. oil embargoes where social and economic changes occurred in accompaniment with government action.

Greater local government involvement is, quite possibly, the missing link to affect overall energy reform. While most cities have energy codes and programs for compliance, most have not faced the core of the issue by answering how to make dramatic energy-use reductions economically feasible. By failing to do this a disproportionate responsibility is placed on business interests to pull off one of the greatest industrial challenges of recent generations.⁷⁴ Prevalent opinions assert that public greening can occur only with the aggressive support of local government through monetary incentives for change.

The energy use of existing city infrastructure will occur on large scales when city governments provide effective technical expertise to homeowners and business owners - while taking a long, hard look at needed efficiencies for municipal infrastructures. An incentive and service-based branch of local government will greatly support energy reform for

⁷² Friedman, Thomas. "The Power of Green." New York times on the Web 17 April 2007. 17 April 2007. <<http://www.nytimes.com/2007/04/15/magazine/15green.t.html>>

⁷³ Anderson, R., C Christensen, S. Horowitz. "Program Design Analysis using BEOpt Building Energy Optimization Software: Defining a Technology Pathway Leading to New Homes with Zero Peak Cooling Demand." Presented at the August 13-18, 2006 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA: National Renewable Energy Laboratory, NREL/CP-550-39821.

⁷⁴ Friedman.

rapid change. This might be accomplished with the establishment of a municipal service department - with a full scale focus on providing energy auditing, assessment and consulting services to the public. Relationships between private contractors, for implementation, and this municipal service allow interested parties to not only know what they can do to increase their home's energy performance, but how they can do it as well. The costs of paying the contractor to make the necessary design changes could be offset by making them tax deductible while the city's consulting services would be a municipal service. Creative opportunities exist for city governments to establish economic opportunities for both businesses and home owners to increase overall urban energy performance. These opportunities fortify potentially strong relationships between Money-based Energy Performance Systems (MEPS) and Municipal-based Energy Performance Systems (MUNEPS) and are creative opportunities for (re)Design of existing municipal infrastructure.

The Political: Municipal-based energy performance system (MUNEPS)

City governments have in their power the opportunity to define paths of least resistance for the application of energy reduction designs to city

infrastructures. Currently, U.S. city economies rely heavily on 'market forces' to initiate greening strategies. Yet aside from prescriptive energy codes, publicizing recycling programs, and zoning, coding and planning for new construction, seemingly small increments of change are occurring in the effort to implement aggressive energy reform. Instead, disproportionate expectations are leveled on the business and construction sector to produce viable and effective solutions. However, without a synergistic relationship between city government and local business interests, the leap to effective and widespread energy strategies will achieve limited success.⁷⁵

A more appropriate approach may be to consider businesses as 'momentum' and city government as 'direction.' Without municipal direction, it is expected that the markets will 'sort themselves out' by following the path of least resistance - often with undesirable results. From deregulation of utility companies to production of goods with questionable health impacts on their

consumers, many examples make it quite clear; without directionality provided by government (aka: the people), big business interests have generally shown a propensity towards short term profit at the cost of public welfare and/or health. With typical government responses to the above factors being simply to police infractions, the cat-and-mouse games between government and businesses greatly hinders change. Rather, city dwellers, local governments, and businesses alike may be better served when the paths of least resistance are redefined. This can occur only when aggressive new directions are set by city planners and policy makers to adapt new and sustainable energy uses.⁷⁶

Of particular interest in seeking these new directions are an increased focus on infrastructure performance and assessment, followed with enforcement. In the climate of concerns over harmful greenhouse gas emissions and rising energy costs, municipalities require target-based solutions to new problems. Thus the solution to such problems rests on the burden of proof. City

Figure 21.



⁷⁵ Low, N., B. Gleeson, R Green, D. Radović. *The Green City: Sustainable Homes, Sustainable Suburbs*. Sydney: Routledge, 2005, 166-207.

⁷⁶ Low, 166-207.

governments need data and information, converted to usable knowledge, to inform the policies and decision making processes necessary to make effective energy reform. This maintains a strong need for the harvesting of large sets of information, often seemingly unrelated to one another, and the assembly of such data into a framework that will be as informative as it is comprehensible.⁷⁷

Inroads are being made in these efforts by municipal governments. Yet they fall short of establishing a truly holistic understanding of city systems and how they can be changed, adapted, or completely removed in the effort to reduce energy use and/or emissions. Traffic and pedestrian studies, neighborhood assessments and wastewater monitoring are among a few of these inroads. However, cities can further this progress with even greater sophistication and effectiveness. The use of software and technology can inform policy makers by assessing ecological 'footprints,' conducting LCAs, and performing/enforcing regular energy audits - all measured against previously established targets.⁷⁸

In turn, such practices will demand new strategies from local government and new professional opportunities. Observed changes in professions and "trans-boundary professional networks" are indicating this. Overlaps between differing fields of study are resulting in either innovative relationships or even entirely new professions⁷⁹ - degrees in

bioregionalism and programs for sustainable building systems are among a few that come to mind.

Of course, complexity and funding becomes the restraining factors for city governments to initiate holistic strategies for greening their cities. A framework of strategies for working through these issues is in order. An excellent example, paraphrased from the book *The Green City*, of such a framework to be considered when devising municipal green strategies is listed below⁸⁰:

- *Distinctions* – reconciling ecological sustainability with social responsibility and profitability
- *Dependencies* – reconciling the fact that societies are highly dependent on exploitation of the natural world
- *Interests* – reconciling conflicting interests, from those working to protect profitability, to those working to protect the unborn (some are compelled by reasons for ecological sustainability, while others are compelled by other objectives)
- *Material requirements* – reconciling an agreed upon concept of ecological sustainability
- *Goals, targets, indicators* - reconciling targets to indicate progress or regress toward ecological sustainability
- *Political conditions* – reconciling political needs to achieve ecological sustainability

It is worth noting that the most pressing question, unanswered by the above factors, is: Is ecological sustainability acquiescent with social responsibility and profitability? While this thesis dares not attempt to answer this question (as it is at the least a thesis in itself!), it will proceed based on the assumption that ecological sustainability can be reconciled with social and economic forces. Accepting it to be otherwise, would be a premature admission of defeat under the burden of the previously discussed global challenges.

Conclusion: Systems integration for assessment, design and accountability

Inherent in each of the four discussions above is the ensuing challenge to comprehensively (and creatively!) establish the relationships each has with the other in their application to this project's proposal. Expectedly, some systems will have greater applicability when focused on (re)Design challenges of municipal buildings and systems. Nevertheless, this thesis will maintain an appreciation for each system and their interconnected nature.

⁷⁷ Personal communication with Chris Saunders, City of Bozeman Department of Planning and Community Development.

⁷⁸ Low, 183-185.

⁷⁹ Low, 186-187.

⁸⁰ Low, 219-221.



Figure 22.

Do(ing) Something: Precedents

Many examples of sustainable and energy-use reducing projects are currently emerging across the globe. While the critical mass of these projects continues to build, it is appropriate to consider a few, of many, precedents to further equip this discourse. Following are a few 'projects,' of varying degrees of complexity, scale, and focus. Lessons from urban planning in the Brazilian city of Curitiba, an EnergyPlus Action Plan for a downtown section of Seattle, Washington, a case study for affordable zero energy homes in cold climates, and various examples of waste handling systems from around the globe offer varying, yet crucial, strategies for success in tackling the climate and energy related challenges of the 21st century.

Despite immensely varied foci, the common theme between each of these precedents remains to be that of a problem-solving process that finds its successes through integrated and assessment-based solutions. As previously discussed, this is not unlike the act of, in Lyle's regenerative design concept, "seeking common solutions to disparate problems." Each of the following examples has sought, or seeks, energy solutions that challenge existing norms. They suggest that radical change, with regard to city infrastructure, buildings, and their inhabitants, might occur more effectively through massive applications

of incremental change.

The city of Curitiba, Brazil is considered by many to be at the leading edge of the movement toward aggressive urban greening. Such efforts to do so were seeded in the latter half of the 20th century as a booming population expansion, which began more than a century before, raised critical concerns for the future urban health of Curitiba. Along with near rampant demographic and economic growth, Curitiba's stability was being threatened on many sides with problems of city sanitation, solid waste removal, poverty, air quality, water quality, and public transport. In 1965, with few other options, an urban design competition was held. The winning design entry was made available to the City and, in the same year, the municipality established an innovative and aggressive plan to implement solutions to avert the rapidly building urban problems.⁸¹

Today, Curitiba remains to be a fast growing city. Nevertheless, the city has managed to stave off many of the negative impacts of urbanization through a commitment to careful planning and implementation of zoning, public transport systems, reconfiguration of existing buildings, social programs with multiple beneficiaries, and establishment of city-owned green space. Of all the factors that conspired to generate such a successful, energy efficient city, certainly the most effective ones stem from the city government's commitment to

integrative and incremental planning solutions. Best reflected in the specifics of these solutions, a few of these are listed below⁸²:

Rapid transit bus system and road system – Curitiba is best known around the world for its public transport systems. Early in the planning process, the city made a fundamental decision to commit to a mass transit system entirely based on the bus. Curitiba recognized the high costs associated with other forms of mass transit (underground metro or light rail). Instead, the city committed to an integration of all municipal systems to support an efficient transit method. What emerged was a master plan that focused on efficient movement of people through a complex of 'feeder' roads and buses, operating in a hierarchy of passenger volume and intensity. Simultaneously a rezoning of the city allowed Curitiba to concentrate commercial activity along major arterial axes, while creating 'pedestrian only areas' in the city center.

Through a hierarchy of six bus systems, each feeding into another, the clever use of 'feeder tubes' to expedite passenger loading and unloading, and a single user fee, a highly efficient transit system was achieved. The busses are privately owned and operated, while the city government handles fare collections. The bus companies are paid by the city according to the total number of miles traveled.

⁸¹ Rabinovitch, Jonas. "Curitiba: towards sustainable urban development." *Environment and Urbanization*, Vol. 4, No. 2, October 1992.

⁸² Rabinovitch.

With this system, Curitiba has been able to attract two-thirds of its population to use the bus system (even as Curitiba retains the highest car per capita ratio in Brazil), which is partially responsible for an economic 30-year growth rate that is three percent greater than Brazil's national average of 7.1.⁸³ Economic benefits aside, it is predicted that the bus system has reduced fuel consumption within the city by as much as 25 percent.

Extensive Park system and creative maintenance solutions – From 1970 to 1990, 1.5 million trees were planted within the city of Curitiba - as it currently maintains one of the best ratios of green space per inhabitant for cities worldwide. Instead of relying on expensive fossil fuel powered mowers and related equipment for upkeep of these areas, a municipal program was established to have grazing sheep 'maintain' park areas. Income from wool production allowed the program to support itself with excess funds supporting social city programs. The purchase of green space by the city focused on acquisition of land of little value.⁸⁴ In particular, floodplains were purchased in an effort to avoid the health and safety risks associated with flooding – and to avoid barrios from springing up in such areas instead. This was an appealing alternative to the more expensive option of allowing urban growth and expansion in these areas, at the cost of building the necessary levees and berms to resist

threats of flooding (think: New Orleans).

*Lixo Que Não é Lixo*⁸⁵ – One of Curitiba's most brilliantly conceived city services is best represented in the implementation of the "Garbage That is Not Garbage" program. It is as simple as it is elegant. In many of the poorer neighborhoods within Curitiba, 'streets' are too narrow for city sanitation trucks to navigate. Lack of trash removal services was causing an increase of waste build up and associated health problems within the barrios. Instead of relegating the poor as a misfortunate burden, the city sought to turn this problem into a solution. The "Garbage That is Not Garbage" program pays anyone for the trash they collect, by weight. A simple system of weekly circulating trash trucks picks up the garbage and is taken to stations where it is sorted, two thirds of which is then recycled. The cost and energy expenses of this 'soft infrastructure' of trash collection remains to be far less than what would be required to provide a more standard system of trash collection.

Reconfiguring existing buildings – Throughout its rapid expansion and development, Curitiba has maintained a strong support for the reuse of its existing building stock. Fueled by a desire to preserve historic value along with a tendency toward regenerative solutions, the city possesses a thick quiver of buildings whose reuse has prevented the unnecessary event of excessive material and energy use. In Curitiba, existing building transformations

abound. A gunpowder arsenal becomes a theater, an old glue factory converts into an art center, and a foundry is now a popular shopping mall.

If one person can be attributed to Curitiba's success, it would be its three-time mayor and architect, Jamie Lerner. Lerner,

a one-time governor of Paraná, Brazil as well, was largely involved in the design of the Curitiba Master Plan. His commitment to an urban plan that would raise the economic, social, and technical quality of life for Curitiba and its inhabitants was paramount to the city's green development. He is highly recognized



Figure 23.

⁸³ Low, 203.

⁸⁴ Curitiba's botanical garden, even, rests atop a retired landfill!

⁸⁵ <www.curitiba.pr.gov.br>

for his efforts. Worldwide, cities look to Curitiba for scalable solutions that can be gleaned from such success. Of the over-arching conclusions that can be drawn from these examples, five municipal lessons are worth noting⁸⁶:

- *Make deliberate technical, political and economic decisions* – Avoiding detrimental impacts of urbanization requires well timed responses to existing urban trends through “a conscious decision to promote an integration of different elements of urban development.”
- *Challenge technical norms* – Effective solutions to reducing energy use and minimizing waste may result from methods that defy the typical, obvious or complex. The ‘soft infrastructure’ solution to Curitiba’s waste management problem is one such example.
- *An energy efficient city “spends the minimum and spares the maximum”* – A city is best served when all of its integrated systems conspire to be ‘more than the sum of its parts.’ Interconnected urban solutions trump those that are isolated.
- *“Creativity can substitute for financial resources”* – Cities can address one problem by turning it into a resource for another solution.
- *Reliable data systems are vital* – A precise understanding and assessment of city functions, and their impacts, must be gained if city leaders

are to implement effective energy solutions.

While sound urban planning is a partial factor in Curitiba’s success, it was, ultimately, the effort to implement and integrate the ideals of this plan within the city systems that cemented its success. Concurrently, such efforts may best describe the keys to success in the northern hemisphere city of Seattle, a leader in urban greening (by U.S. standards). In November 2006, at the Seattle Greenbuild Conference and Exposition, Jayson Antonoff conducted a presentation titled “EnergyPlus Action Plan for the Pioneer/Stadium District.” Antonoff presented an approach for assessment and a framework of strategies for the city of Seattle in an effort to tackle energy use issues within the existing urban infrastructure. Looking at “neighborhood-scale strategies,” creators of the EnergyPlus Action Plan hope to achieve stringent, target-based emission reduction goals set by the city

government of Seattle – with particular attention being given to the existing building challenge.⁸⁷

The rationales for focusing the Seattle Action Plan on the Pioneer/Stadium district are based primarily on its urban setting, community willingness, and mix of uses. However, continued economic competitiveness, nationwide and worldwide, is a core factor as well. Like Curitiba, the city of Seattle considers urban greening as an opportunity to accomplish energy efficiency while creating a climate for economic gain and stability as well. The Seattle Action Plan calls attention to the fact that the U.S.

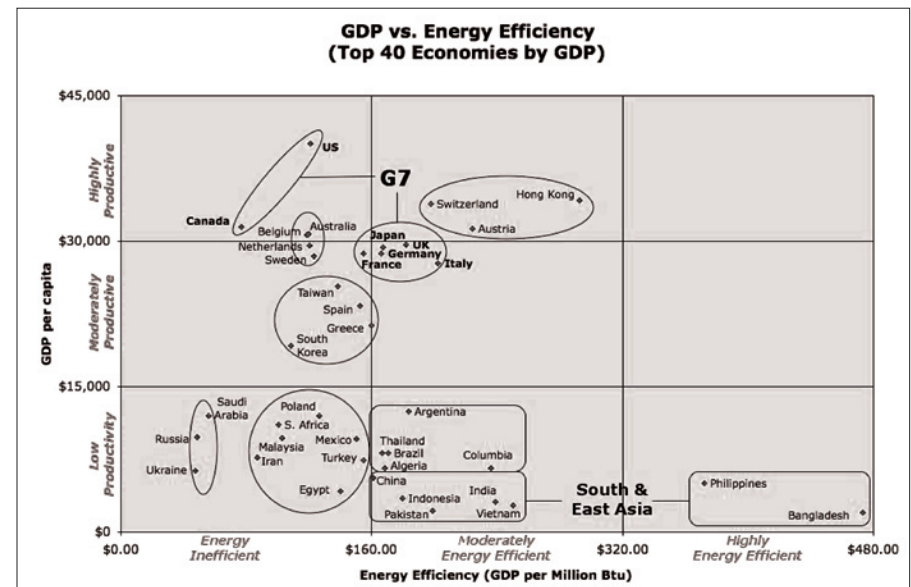


Figure 24.

⁸⁶ These are paraphrased (unless quotation marks indicate otherwise) conclusions of Rabinovitch's paper.

⁸⁷ Antonoff, Jayson. "EnergyPlus Action Plan for the Pioneer Square/Stadium District." Seattle: Presentation at Greenbuild International Conference & Expo, November 15, 2006. Site visited April 25, 2007. < <http://www.i-sustain.com/docs/GreenBuildBig.pdf> >

holds a GDP/Capita over GDP/BTU ratio that is grossly out of scale. The city makes its case on the fact that, within the U.S., great economic strides can be made with drastic increases in energy efficiency. It is banking on the idea that ‘using less to do more’ will win the hearts and minds of entrepreneurs, thus inducing the much needed infusion of capital to ignite an effective greening of the city.⁸⁸

The three primary EnergyPlus Action Plan methodologies, respectively, are to reduce energy consumption, address electrical and thermal energy needs through district heating and cooling systems, and use on-site or near-site renewable energy sources.⁸⁹ In order to implement these methods, a careful assessment of energy use intensities of

Annual Energy Consumption by Bldg Type						
	Retail	Office	Warehouse	Residential / Lodging	Other / Unknown	Total
Typical Energy Intensity per EIA (kWh/sf)	20.7	24.7	7.7	24.4	20.1	
Total Area (1,000 sf)	511	4,060	681	1,070	991	7,312
Estimated Total Annual Energy Use per EIA averages (MWh)	10,600	100,000	5,240	26,100	19,900	161,840
Actual Annual Energy Use per Aggregated Meter Readings (MWh)	25,100	63,100	8,270	11,200	14,800	122,000

Figure 25.

regional buildings (type and area), and connecting infrastructure is conducted. With precise knowledge gained through this phase of data collection, the city is then capable of setting aggressive, yet attainable,

goals upon which over-arching energy reform can be implemented. At this point the city is equipped to seek energy-use and emission reductions on the three levels of consumption, distribution and generation – achieved through the application of technical, social, economic and political mechanisms.

Identification and implementation of the necessary strategies for aggressive energy reform is presently taking shape as evidenced in drafts of Seattle’s Livable South Downtown Master Plan. The plan, focused on strengthening and vitalizing communities in the Pioneer/Stadium District, identified twelve sustainability recommendations.⁹⁰ Of these twelve, five directly or indirectly address municipal energy-use concerns and are subsequently included in the EnergyPlus Action Plan. A list of these five recommendations is as follows⁹¹:

- *Recommendation 1* – Consider LEED Silver as a requirement for all new buildings or Built Green 4-Star or better for multi-family dwellings.
- *Recommendation 5* – Create and implement a

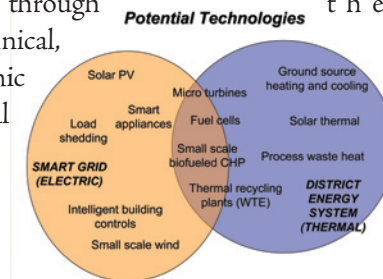


Figure 26.

new “Sustainable Infrastructure Policy” for all City Departments active in South Downtown.

- *Recommendation 6* – Evaluate a range of thermal and electrical strategies and efficiencies that could be appropriate in South Downtown.
- *Recommendation 11* – Develop an economic development analysis that explores the potential for a green business area that could incubate, co-locate, and encourage new and emerging sustainable businesses.
- *Recommendation 12* – Identify special sustainability demonstration zones to initiate implementation and experimentation of these policies.

Interestingly, differences do exist between Curitiba’s urban energy solutions and Seattle’s attempts at a comprehensive energy plan. These occur, predominantly, on the economic levels. Curitiba’s problem solving systems have tended to allocate municipal funds toward the purchase of park lands, city transport systems and the soft infrastructure of city services. This city has been aggressive, with a ‘hands-on’ approach, in efforts to establish sustainable municipal systems. On the other side of the equator, Seattle appears to be intent, and ultimately reliant, upon luring private investors and commercial interests into the fray. Of course, a direct comparison between these two cities

⁸⁸ Antonoff.

⁸⁹ Incidentally, a recent personal communication with Bozeman Design Review Board member, ????? ?????, focused on such a strategy. The discussion revealed that a geothermal heat system could be installed in the shallow groundwater beneath city roads as they are being constructed. Supporting arguments centered on the fact that such an installation could be made with few additional dollars, as excavation is already being performed for road construction. Heat acquired from the geothermal loop could then be provided to surrounding homes and businesses, with operations being conducted by municipal government or a private energy company. Such systems reflect the three EnergyPlus Action Plan methodologies of reducing energy consumption, addressing energy needs through district systems, and using local non-renewable energy sources.

⁹⁰ See <www.seattle.gov>.

⁹¹ Antonoff.

remains skewed, with many other complex factors involved, not the least of which are fundamental political differences. As Seattle progresses forward with attempts at urban greening, the contrasting methods between these two great cities are worth noting and will warrant future reflection.

Despite this difference, both cities share threads of commonality in many other areas. Each city has displayed a remarkable propensity at seeking tools to understand the economic, social, and ecological impacts of the urban condition and how they feed into integrative solutions. It is possible, even probable, that no 'blanket' solution exists for all cities and those elements of climate, culture, politics and the will of the people play far greater roles in defining energy strategies for greening cities. Nevertheless, methods of assessment, careful data analysis, and an understanding of how each response will reduce carbon dioxide emissions are significant hinge points for future city planning. The efforts being taken by the city of Seattle and those already taken by Curitiba speak to the coming age of the need to accurately assess energy use and greenhouse gas impacts of design decisions early in the planning and design process.

Even on much smaller scales, as a NREL case study indicates, great focus remains on assessment and energy performance within the built environment. Near Denver, Colorado, a project was

recently undertaken to navigate the complex options on the road to building affordable zero energy homes in cold climates. Through collaboration between NREL researchers, Habitat for Humanity volunteers and local real estate developers, a 1200



Figure 27.

square foot, three-bedroom house (that promises to be a zero net energy user) was built. The use of applied strategies was based on decision-making that bridged wide ranging factors. These factors included: 1) establishing a working definition of zero net energy use,⁹² 2) the ability to replicate the design and build process of affordable zero energy homes, 3) making decisions that take advantage of cheap (volunteer) labor, 4) balancing decision making between energy efficiency and solar energy production by calculating the full cost of materials, 5) avoiding special or atypical construction techniques and building operations, 6) using 'market

proven' technology and, 7) maintaining a focus on simplicity.⁹³

This NREL study was effectively conducted in three consecutive phases. Conceptually, these phases traversed from more passive, construction related considerations to the highly mechanized, advanced technology-based systems. In practical terms, this led researchers to first establish a building envelope system that would minimize heat losses. Second, standard air handling and domestic hot water systems were designed to support requirements for minimal energy use. Finally, solar hot water and photovoltaic panels were applied to supplement the remaining energy needs of the home. Following this process allowed designers to hedge the tendency toward premature applications of technology with less complex and/or costly solutions.⁹⁴

Computer simulation and use of "heuristic" software applications played an integral role in establishing best case scenarios for realizing a zero energy home. Balanced with calculated human decisions regarding financial viability of materials and building systems, the computer assessments were critical in establishing best case scenarios for energy efficiency and, in the case of the photovoltaic system, production. It may appear that the 'magic box effect' of computer use tends to relegate the design process to an unpredictable series of zeroes and ones. However, it is important to recognize

⁹² Zero net energy, in this case, is defined as zero net use of energy *annually*. By remaining tied to the grid, the zero energy home (ZEH) is able to balance its energy-use over the length of a year. All energy used by the home, not just electricity, must be balanced by the ZEH over the course of a year. Consequently, this means the photovoltaic system will have to generate all power for annual electricity uses, as well as returning to the grid an annual electric equivalent for the natural gas energy used over the same period.

⁹³ Norton, P. and C. Christensen. "A Cold-Climate Case Study for Affordable Zero Energy Homes." Presented at the July 9-13, 2006 Solar 2006 Conference, Denver, CO: National Renewable Energy Laboratory, NREL/CP-550-39678.

⁹⁴ Norton, P.

that the researchers applied these applications in the similar careful and studied ways with which a draftsman strikes a creative pen to vellum. As the saying goes, 'garbage in, garbage out.' Yet, with careful application, and intuitive, mindful human operation, such software represents a veritable goldmine for the greening of the built environment.⁹⁵

While the finer points of the project conclusions are not warranted for discussion, general strategies and their results are worth further explanation. Ultimately, researchers established their strategies on building elements that were easy to implement and build, while simple to maintain. What emerged was a super-insulated envelope design, utilizing staggered stud, walls to prevent "thermal shorting." Window selections were conditional to solar aspect, with lower U-values assigned to the east, west and north sides of the home. As well, window apertures were carefully computed, with increased glazing on the southern elevation. Eave dimensions were calculated based on seasonal solar angles, providing increased window shading in the summer and maximum solar exposure in the winter. Raised heel roof trusses were specified to maximize the insulative properties of the attic space.⁹⁶

With a super-insulated, highly efficient envelope design established, NREL researchers were able to then focus on air handling and hot water systems. The design strayed from designing

building systems that were overly integrated – in the event that one system fails, unassociated systems could continue, unaffected by the other's decreased performance. Nevertheless, with such an efficient building envelope, sizing the systems became an exercise in minimalism as load demands were computed to be remarkably low. Great consideration and calculation of a multitude of options was given to this problem. Eventually, a system was chosen that combines point source heating ventilation (gas furnace) in living areas along with small electric resistance baseboards in the bedrooms. This simple arrangement both allowed for versatility, as each

space is its own zone, and great efficiency. Finally, hot water needs were met through an isolated system that utilized 200 gallons of water storage - heated by fixed plate solar collectors (with an area of 96 square feet) and backed up by a tankless water heater.⁹⁷

To solidify the intent of achieving zero net energy use, researchers were eventually required to meet remaining electricity needs, and offset natural gas use, through the application of a photovoltaic system. Building America benchmark standards were used to predict consumer electricity demands and then combined with building system electricity needs to calculate total demand for the residence. A thorough completion of electric load calculations allowed researchers to conclude that a 4kW

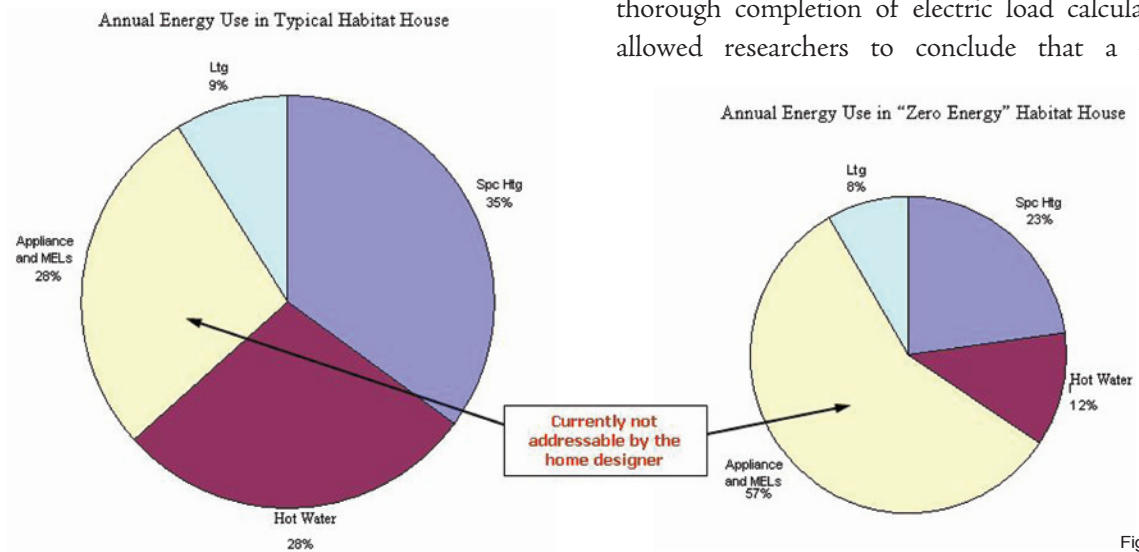


Figure 28.

⁹⁵ Norton, P.

⁹⁶ Norton, P.

⁹⁷ Norton, P.

photovoltaic system would be appropriate.⁹⁸

As this NREL study is ongoing, there remains no data to assess actual performance and financial viability. A conference paper in early 2008 is forthcoming and will submit initial conclusions and supporting information. However, particular assumptions might be made regarding these findings. One postulation suggests that, initial financial savings can be made in the early stages of design. Super-insulated homes with carefully designed building systems and envelopes may make efficiency implementation financially viable. However, as more complex and less mainstream technologies (photovoltaic and solar hot water systems) are applied, overall costs will inevitably creep up and, eventually, negate financial viability. In this case, factors that may balance this inequity may be through increasing energy rates and decreasing technology costs.

Overall, the NREL study indicates a positive and much needed step in the right direction. It begins to address an easy to ignore, yet vital question: how will the greening of mainstream, residential infrastructures be accomplished? With only partial amounts of data obtained, it is difficult to address how challenging it will be to answer this question. One can only assume that it will not be easy! Nevertheless, ducking this question is not an option – or even possible. Momentum continues

to build, awareness is being raised and, most importantly, leadership is being taken. Time is not on our side, but then again - is it ever?

Curitiba's poetic ingenuity and urban problem-solving, Seattle's feverous commitment to assessment and response, and NREL's commitment



Figure 29.

to affordability of zero net energy homes are encouraging precedents, each in their own right. Together they form a chorus of increasing voices attempting to find greater ecological harmonies than our current infrastructure systems provide.

Generally speaking, these 'reality-based' paradigms for conceptualizing, designing and implementing high-performance energy systems are parallel intents. Establishing the certainty of energy reform and reducing emissions of greenhouse gases occurs on a continuum of municipal strategies that range from integrated city-wide approaches to individual home solutions. Each, in their own right, is a crucial path to major carbon reductions.

⁹⁸ Norton, P.



Figure 30.

Changing the Stream

Finally, a discussion of energy reduction strategies would not be complete without assessing the far reaching impacts of the American waste stream. The following short-list of facts characterizes this 'stream': In 2006, the US produced 251 million tons of Municipal Solid Waste (MSW), equaling 4.6 pounds of waste per person per day. 32.5% of this amount was recycled.

12.5% was incinerated. 55% was landfilled. Of the total MSW collected in 2006, 33.9% was paper and 12.9% were yard trimmings. Plastics, wood, metals, textiles and glass made approximately equal contributions to 25.7% of the total 251 million - with food scraps at a whopping 12.4%!

Despite promising advances with recycling programs, 8,660 curbside recycling programs existed within the US in 2006 – down from 8,875 in 2002. Sadly, although the number of landfills has decreased regularly since 1988, the size of existing and current landfills has increased.⁹⁹

Considering the statistics listed above,



Figure 31.

a common myth might be dispelled. Despite the widespread perception that waste is nothing more than waste, waste is not, in fact, waste. Waste is a commodity, waste is a business, waste is a livelihood - a reality; and it is in great, great abundance. Zooming the camera lens further and further out, away from the baby doll heads and twice used toothbrushes, the swirling wastewater tanks and off-gassing digesters, the diapers and demolished buildings, beyond the piles of plastic, paper and swirling seagulls, one can begin to visualize a nation dotted with one waste 'facility' after another. In its abundance, waste has become a resource. Yet we remain to treat it as a problem to be dealt

with, a by-product and an afterthought.

Incidentally, the inherent value and embodied energy of solid and liquid waste should be a vital, albeit under-appreciated, consideration of municipal governments within the US. While the waste stream has many controlling factors and terminals, it is important to discern that 55% percent of the 'stream' ends at landfills that dot the

nation. Simultaneously, billions of gallons of treated wastewater effluent are released by municipal wastewater systems each year. Yet, all waste has an inherent and embodied energy¹⁰⁰ that remains largely under-utilized in common waste management practices.

While efforts to reduce the overall quantity of waste entering the stream exist, this remains to be one strategy of what is a two pronged attack in adapting both behaviors and methods with regard to reducing and managing the waste that enters the stream. It is the difference between affecting overall human behaviors versus changing large scale methods of waste management: changing behaviors vs. changing methods. Each is a valid point of entry toward forcing change. However, in an effort to make rapid and immediate reductions in carbon emissions, a close examination of the inherent energy production properties of the waste produced within the urban centers of the US is required. What follows is a discourse of intriguing and inventive alternate methods for converting waste resources into an energy supply. Subsequently, these precedents introduce important points to inform the thesis project proposal in the following sections.

In King County, of the state of Washington, a forward thinking and innovative approach to wastewater treatment has begun to aggressively

⁹⁹ See <<http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm>>.

¹⁰⁰ For example, waste to energy facilities in Denmark report that 1 ton of waste can produce 2 Mwh of heat for district heating while, at the same time (Waste to Energy in Denmark. RenoSam and Rambøll 2006 see <<http://viewer.zmags.com/showmag.php?mid=wsdps>>). Wastewater cogeneration can produce roughly 1 MW of electricity on a 30 MGD (million gallons per day) rate of flow (personal communication with Greg M. Bush of King County Wastewater Division, September 14, 2007).

challenge the status quo of wastewater treatment practices. Typically, across the United States, wastewater treatment has focused primarily, if not solely, on processing effluent waste to achieve a level of water quality that allows for eventual discharge into natural ecosystems of leach fields, oceans, and rivers. Such linear systems seldom, if ever make efficient use of the biogases emitted from the effluent (methane). Instead, they are limited to burning off these combustible gases to prevent their contribution to greenhouse gas emissions. Simultaneously, these systems depend on vast quantities of electricity to operate and are often the most intensive consumer of electricity in a given region making them a 100 percent 'open-loop' system. At the King County South Wastewater Treatment Plant in Renton, Washington, designers, engineers and administrators



Figure 32.

are taking innovative steps to close this loop.¹⁰¹

In simplistic terms, the South Wastewater Treatment Plant utilizes wastewater digester gas as a renewable energy source to produce electricity and heat. Through a series of steps, effluent is first processed through preliminary wastewater treatment, where liquids and solids are separated in sedimentation tanks. The primary sludge is then processed in the solids handling stage, passing into the digester tank. Biogases are then siphoned off and sent through a cleaning process (a 'scrubber') and readied to fuel the 1 megawatt fuel cell power plant. Current estimates indicate that the power plant produces up to 3.5 megawatts of electricity through such processes – a substantial portion of the total 5.5 megawatts of electricity consumed.¹⁰²

While the design of the South Plant excels by producing clean energy from fuel cells, it goes a step further to 'wring' out all useful energy from the process. This is made possible through the cogenerative process of capturing heat (a byproduct of fuel cell electricity production) and using it to preheat the

fuel entering the fuel cells. Using such methods, cogeneration (also called combined heat and power) allows flexible options for how this heat may be used. In the case of the South Plant both buildings and certain sewage treatment processes utilize this fuel cell byproduct. Such a commitment to high efficiency processes allows the plant to achieve up to a 70% efficiency of fuel input.¹⁰³

Just as the South Wastewater Treatment Plant seeks alternate methods to the processing of liquid waste, cogenerative methods for handling solid waste are being explored in other parts of the world. Of particular interest are the innovative, clean burning, and carefully designed waste-to-energy (WTE) plants of Europe, though most widespread in Denmark. Due to stringent government controls to greatly limit landfill waste, the solid waste sector in Denmark has developed methods for handling waste that challenge common western practices. While the catchphrase 'reduce, reuse, recycle' may be religiously *said* in the United States, it is religiously *practiced* in Denmark. Such commitment has generated an energy infrastructure of 29 waste-to-energy facilities currently on-line within the borders of Denmark.¹⁰⁴

The basic operation of a typical WTE plant involves the collection, sorting, then conversion, or gasification, of input waste. The gas is then used to operate turbines, whose primary function

¹⁰¹ See <<http://dnr.metrokc.gov/wtd/southplant/#Process>>.

¹⁰² See <<http://dnr.metrokc.gov/wtd/southplant/#Process>>.

¹⁰³ See <<http://dnr.metrokc.gov/WTD/fuelcell/index.htm>> As a point of reference, power plants (either coal or gas fired) typically peak at a maximum efficiency of 30-40%.

¹⁰⁴ Waste to Energy in Denmark. RenoSam and Rambøll 2006. See <<http://viewer.zmags.com/showmag.php?mid=wsdps>>.

is to produce electricity and, secondarily, heat which is a natural byproduct of the process. The electricity is then sold into the electric grid while heat is captured and used for district heating in surrounding urban areas, with both commercial and residential buildings. The preliminary sorting allows all recyclable materials to be removed prior to incineration and maintains a minimal loss of



Figure 33.

the embodied energies of these materials. Post-incineration, bottom ash is sorted for collection of ferrous metals to be recycled (comprising approx. 20% of all ash) while the remaining fly ash is made available for construction materials (a replacement for portland cement).¹⁰⁵

Emissions from the above process remain a top priority for their European operators and customers alike. The incineration process *does* result in greenhouse gas emissions, despite claims by the WTE industry that state otherwise. However, looking beyond the simplistic explanations for what may or may not be harmful to the environment, it is worth recognizing that these plants are designed to become local solutions to local problems. These plants are the synthesis of a commitment to first reduce waste production, then to reuse what must be consumed and then, finally, to recycle the waste. Waste that passes through each of these phases is only then incinerated. In these efforts to 'filter' the waste, the WTE plants have building and system designs that reinforce these steps of filtration. Simultaneously, the site strategies of these plants support these goals by being placed close to the populated areas they serve with waste removal, electricity production and district heating. This centralization and localization allows municipalities and private owners alike to keep transportation costs and transmission losses to



Figure 34.
a minimum.¹⁰⁶

In Denmark, ownership of the WTE plants is a mix of public and private enterprises, and varies from plant to plant. While the costs associated with WTE plants remain relatively low due to high efficiency and low operating costs, the larger portion of expenses goes to the waste collection and sorting process. Finally, to balance the costs of collection, all plants maintain a gate fee. The ability of these plants to maintain profitability is a highly considerable factor. Municipalities within the United States are experiencing rapidly increasing costs of construction for maintaining deteriorating existing institutional infrastructure. As a result, public works projects that are both efficient and profitable are highly desirable, and should draw the

¹⁰⁵ Waste to Energy in Denmark. RenoSam and Rambøll 2006.

¹⁰⁶ Waste to Energy in Denmark. RenoSam and Rambøll 2006.

interest of city leaders nationwide.¹⁰⁷

The careful attention to detail and design of industrial infrastructure is difficult to ignore when viewing Denmark's solid waste system. The question might arise, why has the same level of careful design, planning and consideration not been applied in the United States? Whether the answer to this question can be nailed down to a single element, or if there are a series of reasons, the fact remains: the makers of US waste handling infrastructures (and even processes) have failed to grasp the import of good design. The impact of these failures has resulted in significant, potentially irreparable, impacts on both local communities and the global climate.

With new innovations emerging in many areas of how waste is handled, processed, and ultimately disposed of, opportunities abound. The precedents above are two of many pathways being laid in the effort to rethink our existing institutional processes and promise to inspire new modes of thinking about design for such systems. At the same time, educational opportunities should not be forgotten in these designs. The benefits of weaving educational components into the facilities that handle our waste may be directly proportional to how quickly the waste stream can be reduced and its content modified. Learning from the precedents above, there is great opportunity to impact both the waste stream and energy consumption. These

precedents begin to establish clear examples for the frame of mind required to face the grave challenges that remain ahead of us. In the effort to progress forward into the fuzzily charted landscape of Bozeman's waste stream a (re)Design battle cry is in order¹⁰⁸:

And I believe, too, that the world is rich in possibilities. I do not think that we are fated to poison ourselves or cause the heat death of the earth. I think that we can rise above division, hard-heartedness, greed, illusion, and ill will. And we are capable, in short, of becoming citizens in the larger community of life and that doing so would ennoble humankind.

That's my story, and I'm sticking to it!

David W. Orr

¹⁰⁷ Yardley, William. "Building Costs Deal Blow to Local Budgets." New York times on the Web. 26 Jan. 2008. 29 Jan. 2008. <http://www.nytimes.com/2008/01/26/us/26build.html?_r=1&th&emc=th&oref=slogin>

¹⁰⁸ Orr, 217.





Figure 35.

(re)Design: Project Proposal

Bozeman Waste Syndication Center (WSC)

The stage is 'set' for Bozeman to take advantage of the multitude of innovative opportunities by altering the course and terminal points of its local waste stream. The municipality of Bozeman, not unlike the cities of Curitiba or Seattle, possesses an outstanding opportunity to impact its future ecological and economic health by embracing atypical urban strategies for change. As previously discussed, significant opportunities to respond to the converging crisis reside within the existing and future municipal infrastructures – specifically within the potential to interweave the City of Bozeman Solid Waste Division (SWD) and the Bozeman Wastewater Treatment Plant (WWTP). As a result, the City of Bozeman will greatly benefit from the design and implementation of waste management systems that centralize and localize waste management practices while hybridizing to become a local, legitimate, and dependable energy supplier.

According to the aforementioned methods, precedents and technologies, this thesis proposes to design and render a *syndicated waste system* by hybridizing wastewater and solid waste-to-energy

facilities. Following are descriptions of programming, site conditions, zoning, demographics, technology and resources that will support the development and final production of this thesis project. Final presentation of the project described above and associated information will be in the form of drawings, diagrams, renderings and any other forms of visual representation necessary to animate the process and results of the project. The goals of the design will seek to illustrate a process and design capable of replication with other existing infrastructures similar in scope. The proposed design project will seek to (re)Design the city of Bozeman's solid waste and wastewater infrastructures in an effort to reduce the city's use of carbon dioxide emitting energies by half. Of particular interest within this thesis are 1) the qualitative assessment of existing waste management infrastructure and, 2) the subsequent application of innovative technology, methods and tools for the reconfiguration of these systems and, 3) specific architectural opportunities that will impact the functionality and usability of Bozeman's waste systems as they serve the greater community.

The uniqueness of a capitalist economy within the U.S. demands a response to the converging crisis that greatly differs from that of systems less tolerant of economic competitiveness and diversity. Countries, such as Denmark, have fashioned responses to the converging crisis that have left

many other countries (including the U.S.) in the proverbial dust – with over 15 percent of its energy needs coming from nonrenewable sources and a greatly reduced emissions per capita as compared to other developed countries. Much of this, however, is predicated on "command-and-control" systems of government that allow political mobility at the perceived cost of personal freedoms.¹⁰⁹ With greater control in government hands, response time is reduced. Meanwhile, Americans greatly enjoy the freedoms a democratic society affords them, at the cost of a reduced response time to the converging crisis. Where Danes are told to change, Americans must be convinced.

It is desired that this project become an armature for municipal governments who seek viable solutions to seemingly impossible mandates of energy-use reform policies. However, this proposal seeks to contribute useful design conclusions, regarding the challenge of redesigning the existing waste management infrastructure and energy systems, to the policy making discourse. Although it is expected that this project *might* be useful to inform future development planning, the primary focus of this project is that of city waste systems, and not on the policy making and planning process. It is expected that a wide range of strategies from within this framework will be employed in the process.

While this thesis proposes that the greatest

¹⁰⁹ O'Brien, P. and J. Høj. "Encouraging Environmentally Sustainable Growth in Denmark", OECD Economics Department Working Papers, No. 277, OECD Publishing, 2001, 6. <<http://oberon.sourceoecd.org/vl=3532547/cl=18/nw=1/rpsv/cgi-bin/wppdf?file=5lgsjhvj806f.pdf>>

energy savings and opportunity for change exist, within the city of Bozeman, in wastewater and solid waste divisions (and the relationship between the two), it does not consider it to be a foregone conclusion. As well, a systems approach to assessing the municipal complexities of energy supply and consumption *as a whole* will not allow it to be broken into parts without a fundamental breakdown of the assessment. Crucial and divergent discoveries throughout the course of this project are expected; as well they should be in the act of assembling previously unknown information. Ultimately, a systems view on a municipal level, while required to assess the 'big picture,' holds value in the illumination of relationships. Discovering the connectivity and nature of interrelations between the components of the city systems, with regard to its energy use, may result in remarkably different conclusions (than previously thought) concerning the points of entry for action.

The Current Components

Despite this thesis proposal's call for the redesign of Bozeman's current waste handling infrastructures, it is important to understand how these components currently serve the city and how they may serve to inform this thesis proposal. What follows are brief summaries of the key players' within

the City of Bozeman's waste handling systems.

City of Bozeman Wastewater Treatment Plant – Originally built in 1970, the Bozeman WWTP uses a wastewater treatment process called conventional activated sludge. The facility has been expanded five times since its original construction. Its current design flow is 5.8 million gallons per day (MGD).



Figure 36.

Average annual flows during 2001 to 2005 were 5 MGD while peaking, in the spring, as high as 13 MGD. (This is one of the contributing factors for why the plant consistently exceeds discharge permit requirements.) The city currently employs 14 people for operations and maintenance of the facility. The City currently has plans to expand the plant, roughly doubling its current size at a cost of 55 million dollars. These changes will result in a plant that is sized for an estimated population (by 2025) of 92,500, with a design flow of 13.9 MGD. It is expected that additional farmland will be needed for sludge disposal with the new expansion.¹¹⁰

Bozeman Solid Waste Division – The Solid Waste Division manages all aspects of the solid waste

produced within the city of Bozeman. This involves management of hazardous household waste, electronic and appliance handling,



Figure 37.

composting of organic and yard waste, and recycling (curbside and drop-off sites). To date, solid waste that is picked up by the Division's 12 trucks is hauled to the City's Convenience Site, located on Story Mill Road. Here, the trucks deposit collected refuse (non-recyclables see below) into the City landfill. However, due to this landfill's decreasing capacity, the city will begin diverting all non-organic solid waste to Logan, Montana starting in June 2008. This will result in an additional 52 mile round trip for an estimated total of 11 truck trips per day. The estimated cost to the City for this change is 0.5 million dollars.¹¹¹

Bozeman Recycling Service – The City of Bozeman Solid Waste Division works in partnership with the Headwaters Recycling Cooperative Project to run and manage the city's recycling systems.¹¹² Currently within Bozeman, a single pick-up truck collects recycling materials and delivers them to a recycling broker in Four Corners (Full Circle Recycling

¹¹⁰ Bozeman Wastewater Facilities Plan: City of Bozeman, Montana, 2007.

¹¹¹ Personal communication with Steve Johnson, Superintendant of City of Bozeman Solid Waste Division, Bozeman, Montana, January 30, 2008.

¹¹² See <http://www.bozeman.net/waste/recycling_compost.aspx>.



Figure 38.

for each material's typical destination and baling dimensions¹¹⁴;

Inc.).¹¹³ Here, the material is baled and prepared for shipment to either a final destination or to another broker.

See the chart below

Commission's choice to deny approval of the WTS center. First, a lack of capital to properly fund the project is assumed. Secondly, negative public opinion (read: NIMBY) created a difficult and insurmountable barrier for the city to approve the facility. (This, of course, raises the import of the impact of both careful design and careful rendering with respect to 'winning the public over.')

*Bozeman Waste Transfer Station 2005 (WTS) (unbuilt)*¹¹⁵ – In 2005, a proposal for a waste transfer station was considered by City Council Members. In anticipation of the closing of the Bozeman Convenience Site/Landfill in 2008, a transfer station seemed a strategic response for efficiently handling and delivering solid wastes and recycling materials alike. The resulting WTS design was equipped to efficiently transfer from truck to truck through the use of a tipping floor. As well, the facility was to be equipped with administrative offices, employee break rooms, a maintenance building, a truck scale, a truck wash and a gate house. Ultimately, construction of the WTS was not approved by the City Commission. Two reasons are conjured for the

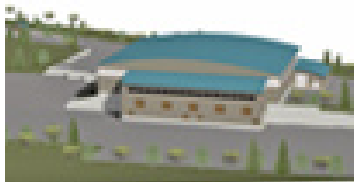


Figure 39.

¹¹³ Recent approvals by the Bozeman City Council have initiated the first steps in establishing a curbside recycling program. It is predicted that 1 truck may serve 1600 accounts within the city.

¹¹⁴ Personal communication with Dave Leverett, owner of Full Circle Recycling, Four Corners, Montana, January 30, 2008.

¹¹⁵ Personal communication with Doug Morely of Springer Group Architects, Bozeman, Montana, January 25, 2008.

Programming

WSC Component	Space/ Component	Description	Number	Sq. FT/ea.	Sq. FT/total #	Acres
Main Bldg.						
	Entry	for reception, interpretive center, public image and relations...etc.	1	1500	1500	
	Administrative Offices	for offices of WSC administrators	10	160	1600	
	Control Room	for complete controlling and monitoring of all WSC functions	1	1400	1400	
	Restrooms	for worker and visitor restrooms	3	200	600	
	Locker/Changing Rooms	changing room and/or locker rooms for facility employees	1	1200	1200	
	Breakrooms	break rooms for facility employees with kitchen and eating/leisure area	2	750	1500	
	Labs	for testing of waste intake, processing and output	4	1200	4800	
	Server room	to house server/computer controls	1	300	300	
	Classroom/conference rooms	for visitor and employee education	3	400	1200	
	Mechanical Room	for central building	1		900	
	Interior Circulation	for interior circulation of WSC occupants	1		1692	
		Subtotals			16692	0.4
General						
	Restroom	additional restrooms	3	200	600	
	Maintenance	for storage, shop, offices for maintenance workers	1	10000	10000	
	Truck Garage	for maintenance of truck fleet	1	3000	3000	
	Gatehouse/Truck Scale	to house employee for receiving and dispatching vehicular traffic	1	400	400	
	Exterior Circulation (footpath & landscaping)	for exterior circulation of WSC occupants and associated landscaping	1	80000	80000	
	Parking	for visitor, worker and semi-truck parking	1	4000	4000	
	Exterior Circulation (vehicular)	for all vehicular circulation	1	100000	100000	
	Truck Wash (exterior.)	for washing down of trucks	1	1000	1000	
		Subtotals			199000	4.6
Wastewater						
	Pretreatment (exterior)	for removal and settling of trash and debris from influent	1	2000	2000	
	Pretreatment (interior)	to house pumps and filters for settling of trash and debris from influent	1	6000	6000	
	Primary Clarifiers (exterior)	for skimming off of grease and separation of solids and liquids	5	4012	20060	
	Gravity Thickening (exterior)	for further thickening of sludge in preparation for transfer to anaerobic digester	2	3500	7000	
	Gravity Thickening (interior)	to house pumps for both primary clarifiers and gravity thickening tank	1	4200	4200	
	Aeration Basin (exterior)	for tanks used to aerate effluent liquids	1	30000	30000	

WSC Component	Space/ Component	Description	Number	Sq.FT/ea.	Sq.FT/total # Acres
	Aeration Building (interior)	to house both aeration and circulation pumps	1	15000	15000
	Anaerobic Digesters (exterior)	to process sludge (solids) and siphon off methane	2	5000	10000
	Digester Control Building (interior)	to house systems to siphon off methane; to house the boiler and heat exchanger as	1	3500	3500
	Sludge Dewatering (exterior)	holding tank for sludge	1	8000	8000
	Sludge Storage (exterior)	storage pond for sludge	1	27853	27853
	Secondary Clarifiers (exterior)	for final settlement and skimming of liquids before discharging to chlorine chamber	7	38000	266000
	Chlorine Contact Chamber (exterior)	for infusement of chlorine into effluent before discharge into the East Gallatin River	1	9000	9000
	Chlorine Contact Chamber (interior)	to house chlorine tanks and circulation pumps	1	3000	3000
		Subtotals		411613	9.4
Recycling					
	Hazardous waste drop	for hazardous household and industrial waste products collection	1	2000	2000
	Appliance and Electronics drop	for collection of appliances and electronics	1	2000	2000
	General recycling drop	for collection point of aluminum, paper, cardboard, plastic, glass, tin, steel...etc.	1	8000	8000
	Organic waste and compost drop	for receiving of all mulch and organic materials	1	8000	8000
	recycled material baling	for machinery to bale recycled material in preparation for shipment	1	2500	2500
		Subtotals		22500	0.5
Waste to					
	Waste storage (exterior)	for long term waste storage (not household waste)	1	20000	20000
	Bunker	for holding of waste to be immediately processed	1	25000	25000
	Furnace/Combustion Chamber	to incinerated waste (producing ash, heat and gas)	1	6000	6000
	Boiler	for steam generation	1	5000	5000
	Bottom ash storage	for settlement of ash that is produced in the furnace	1	1000	1000
	Bottom ash separation	for removal of ash from storage bin and removal of ferrous metals	1	500	500
	Flue gas scrubber/air pollution control system	for cleaning of gasses emitted from the combustion chamber	1	1000	1000
	Flue stack	for final cleaning of emitted gasses from combustion chamber	1	400	400
		Subtotals		58900	1.4
		Total		708705	16.3
				Sq.FT.	Acres

Site

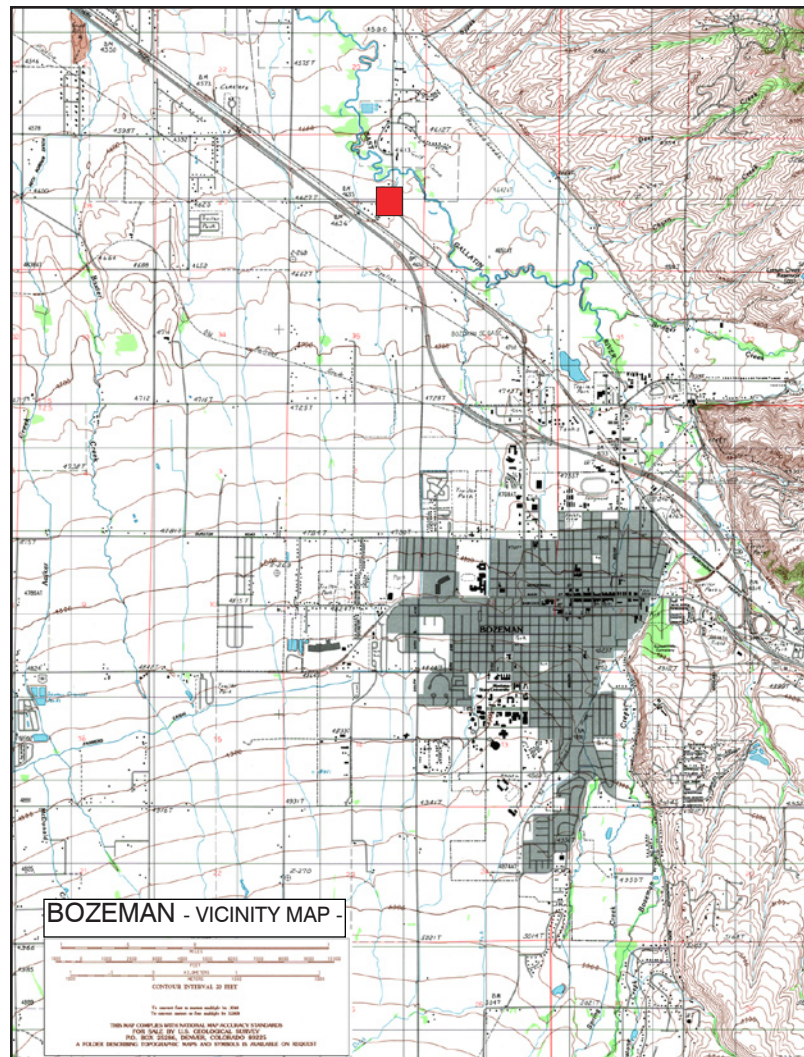


Figure 40.



Figure 41.

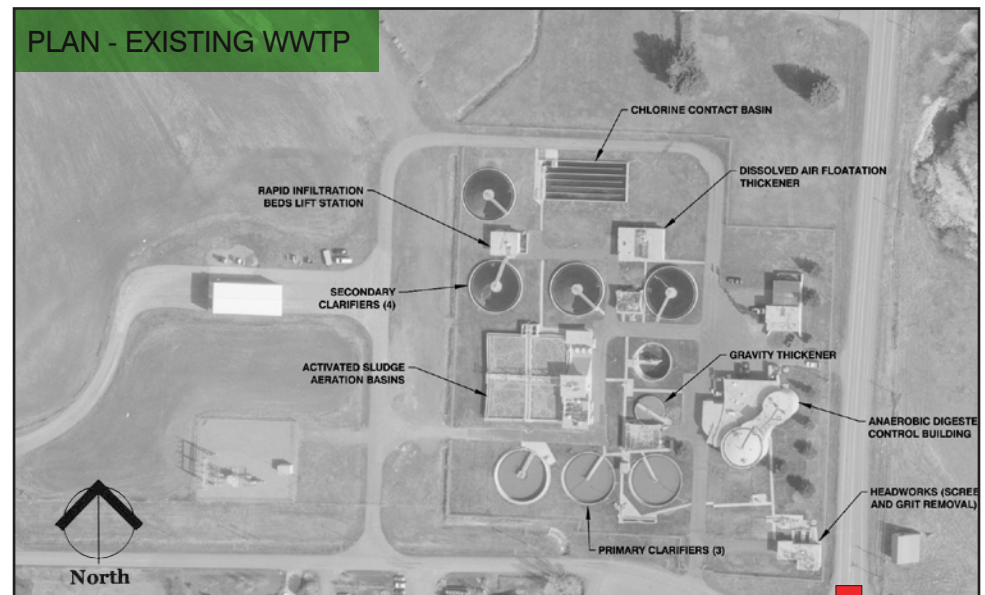


Figure 42.



GREATER BOZEMAN POPULATION, HOUSING, EMPLOYMENT, AND TRANSPORTATION

The 2005 US Census Bureau estimates the current Bozeman population to be 33,535. Long-time residents of the City will confirm that this population has grown remarkably in the past 15 years. From 1990 to 2000, Bozeman's population increased by almost 40 percent. Current trends predict the City to continue this growth, with an expected population totaling 46,600 in 2020.¹¹⁶

By 2020 it is estimated that 20,260 houses will be needed to support Bozeman's burgeoning population. In 2000, the number of dwelling units was 12,026. Of this total, 40 percent was single-family homes. Available data suggests that, over time, household density is decreasing. In 2001 the average household size in Bozeman was 2.3 persons, down from 2.5 a decade before. Decreasing density within Bozeman may be partially affected by an increasing median age and, thus, decreasing numbers of large family homes. The median age of City residents in 2000 was 30.4 years.¹¹⁷

Employment and income statistics for Bozeman indicate a moderately wide range of opportunity. Based on number of employees in 1998, total employment within Bozeman was 21,786. 2020 projections suggest that this number will be 35,721. A noticeable trend within the city-county interface

is Bozeman's proportional decrease of employment numbers in relation to county employment. In 1980, Bozeman supported 59 percent of all jobs within Gallatin County. This same figure in 1998 was down to 45 percent and suggests a diffusion of Bozeman as a centralized employment 'hub.'¹¹⁸

The five largest employers within the City of Bozeman are, respectively, Montana State University, Bozeman Deaconess Hospital, Bozeman School District #7, Gallatin County, and the City of Bozeman. The 3 largest employment sectors, comprising 74 percent of all sectors, within the greater Bozeman area are Services (38.4%), Retail Trade (26.5%), and Construction (8.8%).

The City of Bozeman currently supports 180 miles of streets within its city limits. Bozeman residents are, for the most part, fundamentally linked to the automobile as a primary source of

transportation. Over 60,000 automobile trips traveling in or out of City limits, per day, were recorded in 1998. Annual miles traveled in this same year totaled 1.12 million. This figure is predicted to increase to 1.85 million by 2020. As a result of an auto-intensive lifestyle, Bozeman residents consume 20 percent of their household discretionary income on transportation costs.¹¹⁹



Figure 44.

¹¹⁶ Bozeman 2020 Community Plan: City of Bozeman, Montana, adopted October 22, 2001.

¹¹⁷ Bozeman 2020 Community Plan.

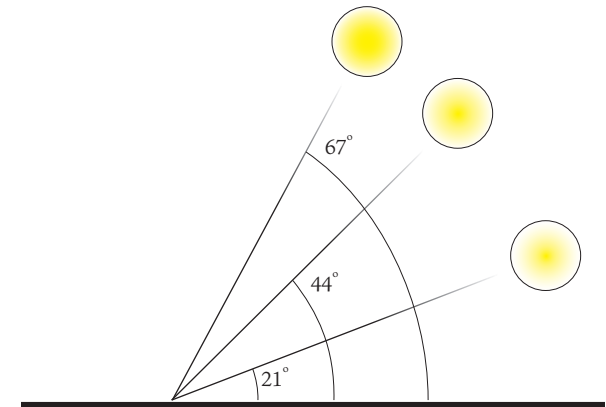
¹¹⁸ Bozeman 2020 Community Plan.

¹¹⁹ Bozeman 2020 Community Plan.

CLIMATE, WEATHER, SOLAR AND UTILITY RATES

As evidenced below, the Bozeman climate is greatly defined by extremes. While the summers have temperatures that range around 80°F, they are known to quickly and unexpectedly change. Incidentally, during the winter, the inverse of this can be true, although temps typically hover around the 30° F mark. Winds are mild, annually averaging 6 mph. The Bozeman area experiences an above average (U.S.) number of heating degree days (base 65). Montana state utility (electric and natural gas) rates are remarkably low as compared to U.S. Averages.¹²⁰

- Bozeman lat./long. – N45.41° W111.02°
- Solar Altitude at solar noon (46° N)¹²¹
 - June 21 – 67°
 - Mar. 21 & Sept. 21 – 44°
 - Dec. 21 – 21°
- Utility Rates (residential)¹²²
 - Electric rate - \$0.061929/kWh
 - Gas rate (residential) - \$5.704/Dkt



♦ Monthly Temperature (degrees F) and Precipitation averages¹²³:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	31.4	35.4	42.4	53.7	63.1	71.5	81.1	80.2	69.1	57.5	42.1	33.7	55.1
Average Min. Temperature (F)	11.9	15.2	21.3	30.5	38.5	45.1	51	49.5	41.1	32.9	22.2	14.6	31.1
Average Total Precipitation (in.)	0.88	0.73	1.33	1.82	2.86	2.9	1.36	1.24	1.73	1.5	1.09	0.86	18.3
Average Total Snow-Fall (in.)	12.7	10.1	16	12.4	4.1	0.5	0	0.1	0.8	5.4	11	11.6	84.8
Average Snow Depth (in.)	5	5	3	1	0	0	0	0	0	0	2	3	2

♦ Heating Degree Days – (degrees F, base 65)¹²⁴:

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Base 65	1343	1121	1028	687	443	223	60	76	307	614	987	1266	8156

♦ Monthly wind speed averages - (mph)¹¹⁸:

	Winter	Spring	Summer	Fall	Annual
MPH	7.4	8.3	7.4	7.4	7.8

¹²⁰ See <www.eia.doe.gov>

¹²¹ Western Regional Climate Center (WRCC). <www.wrcc.dri.edu>

¹²² These are current rates as of April 1, 2007, NorthWestern Energy. <<http://www.northwesternenergy.com/showitem.aspx?M=1943&I=466>>

¹²³ WRCC.

¹²⁴ Stein, Benjamin, and John Reynolds. Mechanical and Electrical Equipment for Buildings, Ninth Edition. New York: John Wiley and Sons, Inc., 2000, 1112.

DATA COLLECTION

As this project will require the assembly and animation of vast amounts of information, in both quantitative and qualitative forms, an indiscriminate (even opportunistic) approach to locating such information is necessary. This process of data extraction will require an accompanying organizing mechanism to extract important threads of knowledge from an otherwise overwhelming volume of facts, figures, statistics and human opinions. This mechanism, in its own right, will be a valuable product of the thesis project as it directly and indirectly 'feeds' the establishment of concepts for (re)Design. The varying source types and targeted needs for information harvest, accompanied with brief descriptions, are listed below.

Print – Printed information will be sought if digital options for accessing the same information have been exhausted. However, in some cases, the ease of use and availability of printed information makes its use desirable. As well, printed information tends to offer greater reliability and accuracy – though sometimes at the cost of being less current than its younger cousin, the internet. Printed documents of particular interest within this thesis are Bozeman city planning documents, City of Bozeman aerial maps and plans, facility plans, transportation studies, energy sources that discuss

in depth tools and methods for energy systems.

The internet – Certainly, The World Wide Web is awash with its share of superfluous, repeated and inaccurate information. Yet it also offers both rapid 'panoramic' views of information on building energy issues, along with valuable leads into current methods and modes of thought regarding energy systems on varying scales of complexity. Information expected to be most useful throughout this thesis project will be found in web locations such as Northwestern Energy, bozeman.net, mt.gov, U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy (EERE) and Building Technologies Program, Building America, Energy Information Administration (EIA), U.S. Green Building Council (USGBC), National Renewable Energy Laboratory (NREL), and Rocky Mountain Institute (RMI).

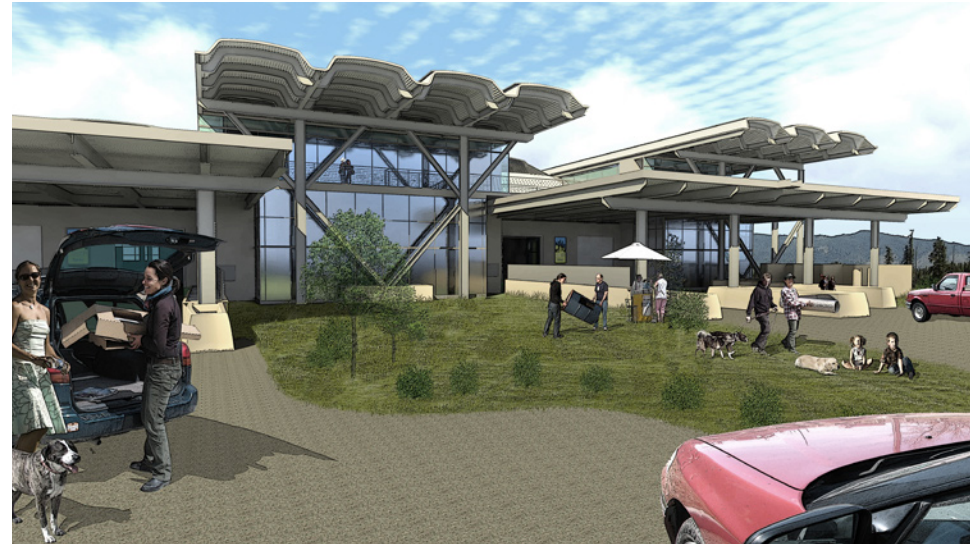
Software – While software may not be considered a direct source of information, it is deemed necessary for inclusion in this list based on its functional ability to produce useful information. As well, many programs, as discussed in the BEPS section, already have data encoded into them. This is most evident in the case of life-cycle information (LCI) inputs. Programs considered useful applications for ensuring this project's overall viability and success are Energy 10, Ecotect, AGI32 and eQUEST.

Interviews and surveys – A particularly critical element within this thesis project will be the procurement, assessment and categorical assembly of human opinion in relation to municipal infrastructure and system issues. This is of great importance as there are virtually few other resources that can replicate the poignancy of recorded human opinion and reflection. Interviews will be used to gather related information from city planners, contractors, systems designers, architects and any other fields deemed necessary for such pertinent information.

Observation – Amidst the more 'tangible' areas of data collection the necessity remains for basic human intuition and 'gut-level' critical observation. While there is no formal organizing system for this, basic human observation is expected – if not required. Examples of such may occur through sketchbook drawings and diagramming, recording of personal reflections and continual dialoguing with any willing persons.

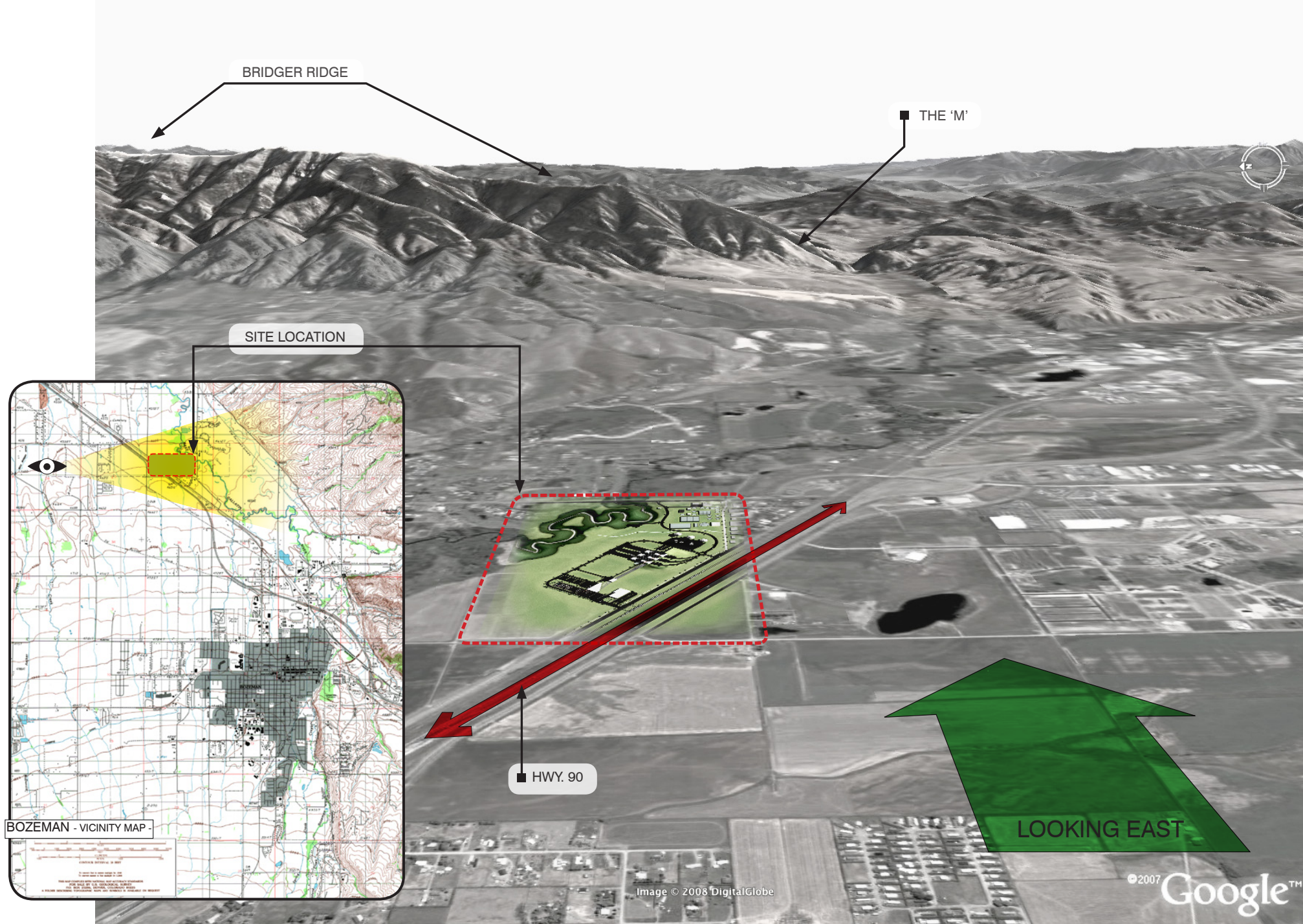
DESIGN PROPOSAL: BOZEMAN WASTE SYNDICATION CENTER

SITE & SYSTEM, SECTION & SYSTEM, PLAN & PERSPECTIVE



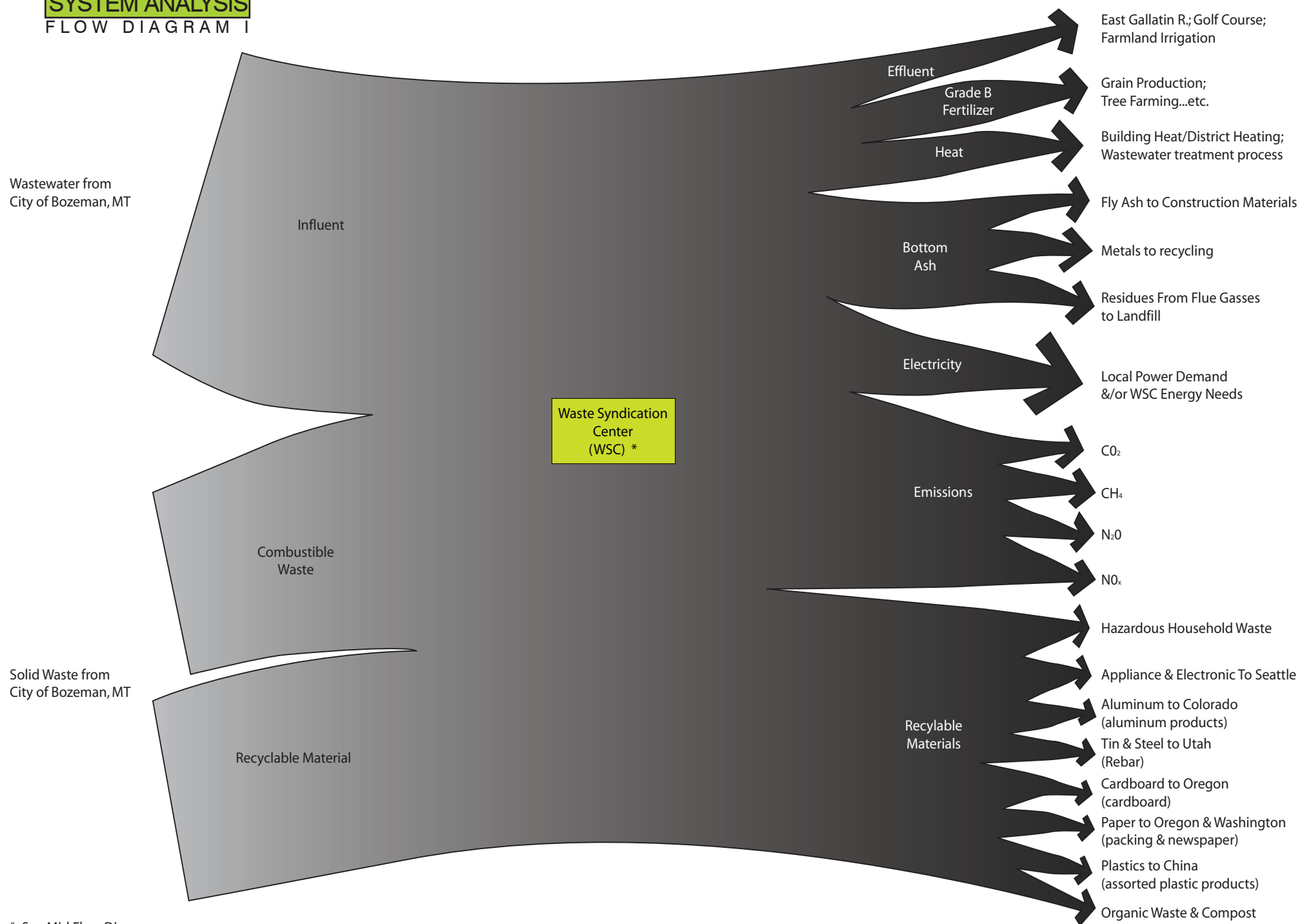
SITE AND SYSTEMS

SYSTEM ANALYSIS, SITE STRATEGY, MASTER PLANNING



SYSTEM ANALYSIS

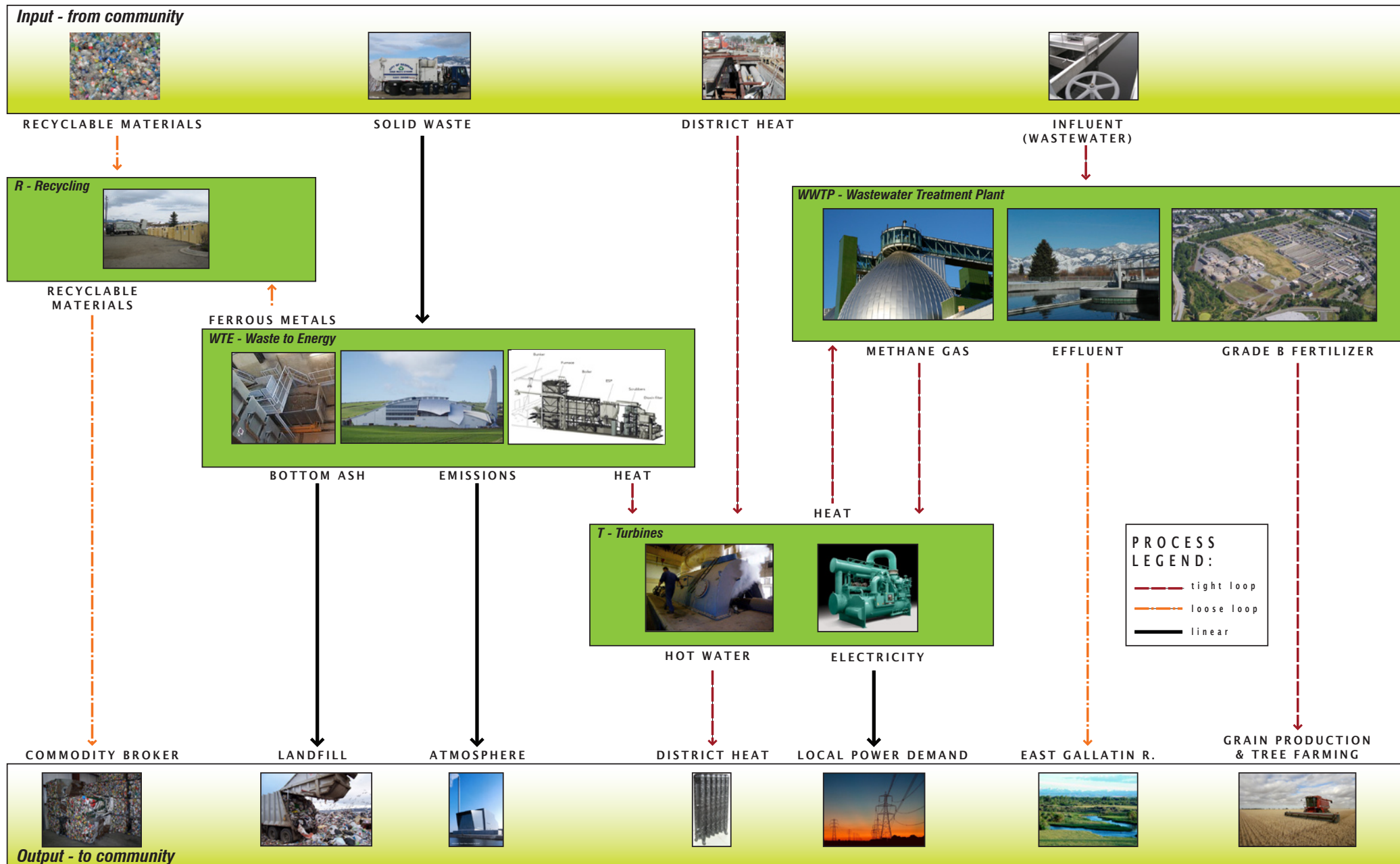
FLOW DIAGRAM I



* See Mid Flow Diagram

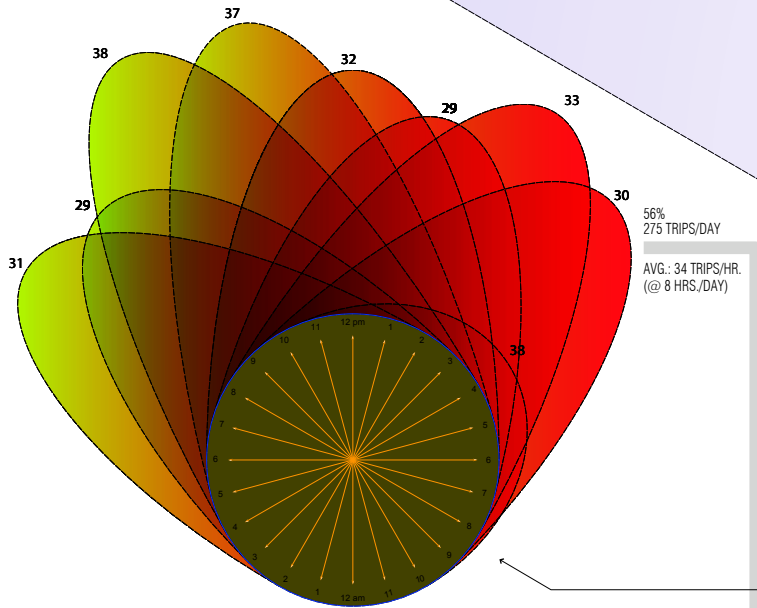
SYSTEM ANALYSIS

FLOW DIAGRAM II



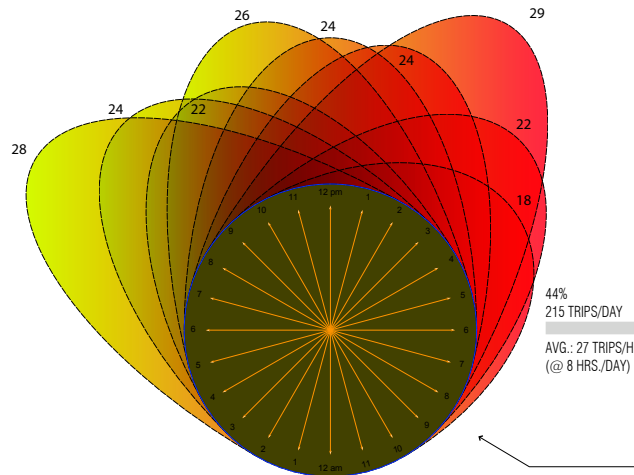
SYSTEM ANALYSIS

TRAFFIC FLOW

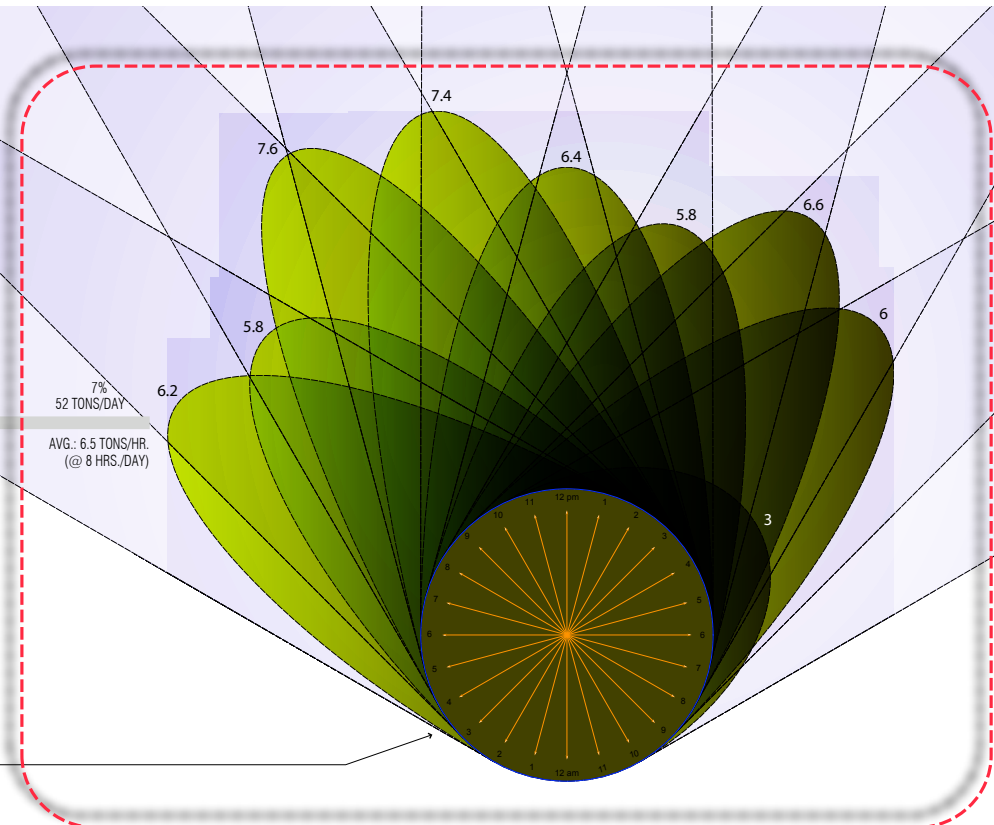


Predicted 2022 Peak
Customer Traffic
Distribution (# of visits)

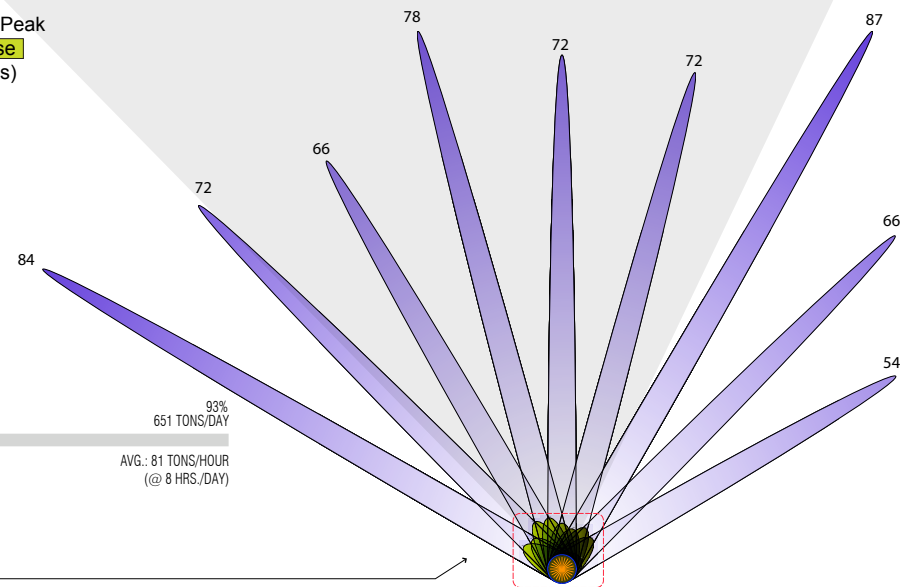
MAX. PEAK TOTALS:
703 TONS/DAY
88 TONS/HR.
(@ 8 HRS./DAY)
490 TRIPS/DAY
61 TRIPS/HR.
(@ 8 HRS./DAY)



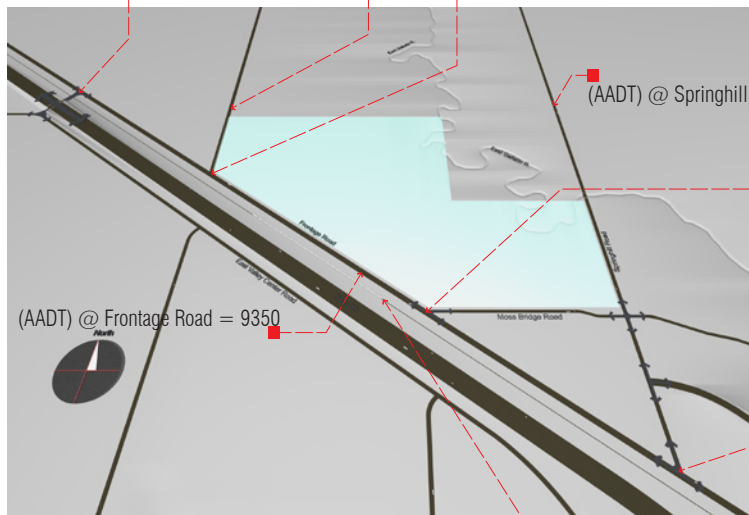
COMMERCIAL
(AVG.: 3 TONS/TRIP)



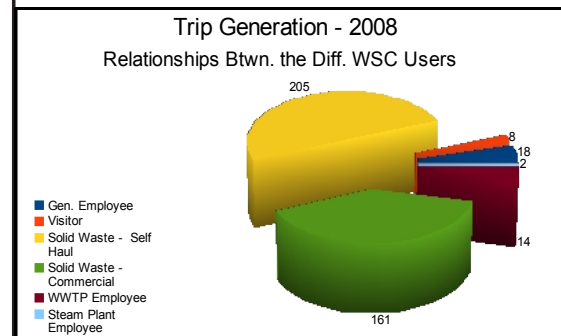
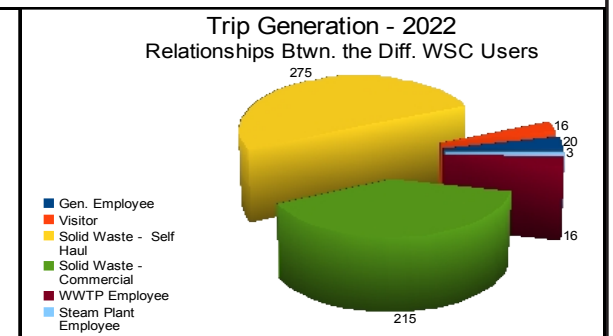
Predicted 2022 Peak
Customer Refuse
Distribution (tons)



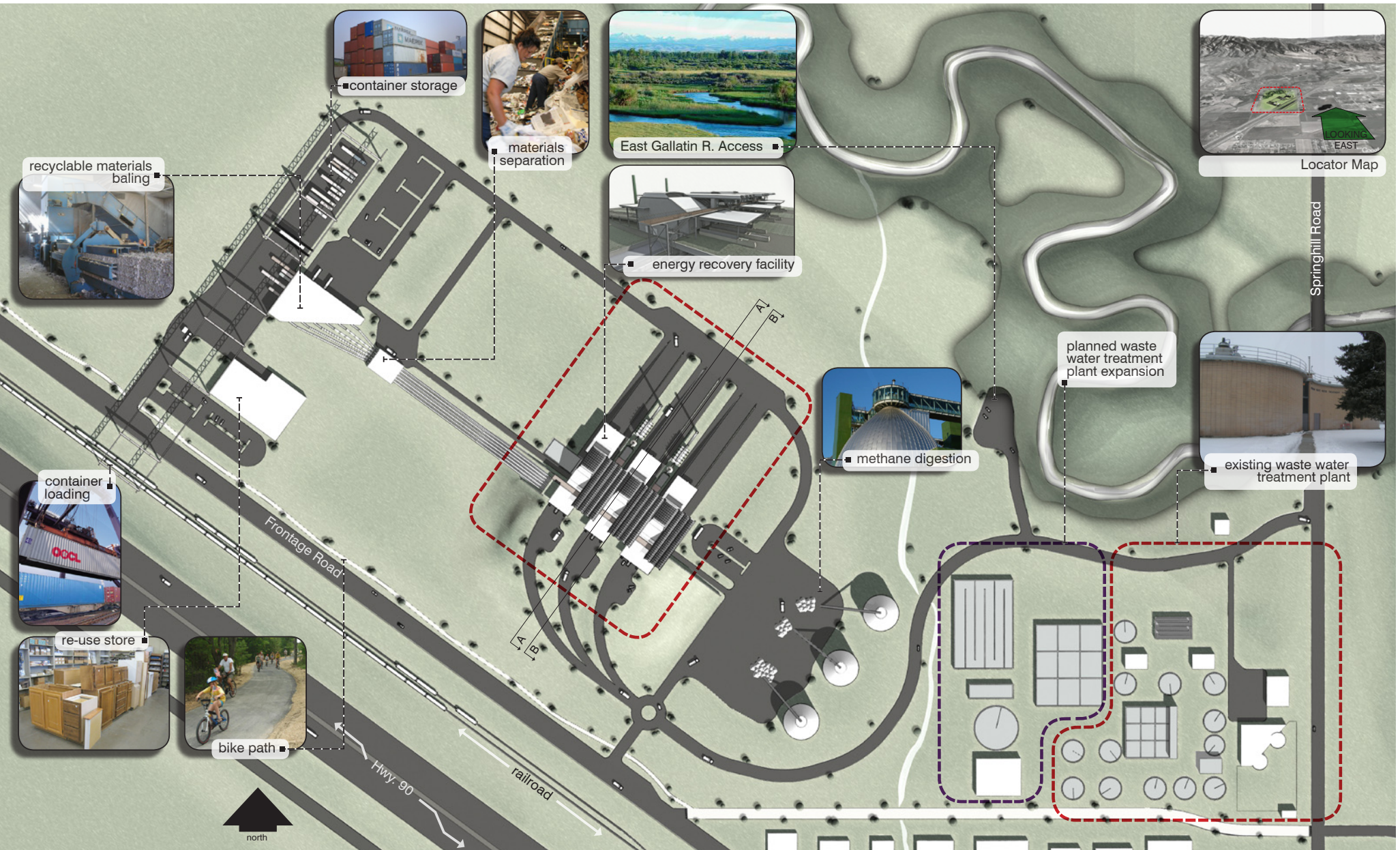
SYSTEM ANALYSIS TRAFFIC STUDY



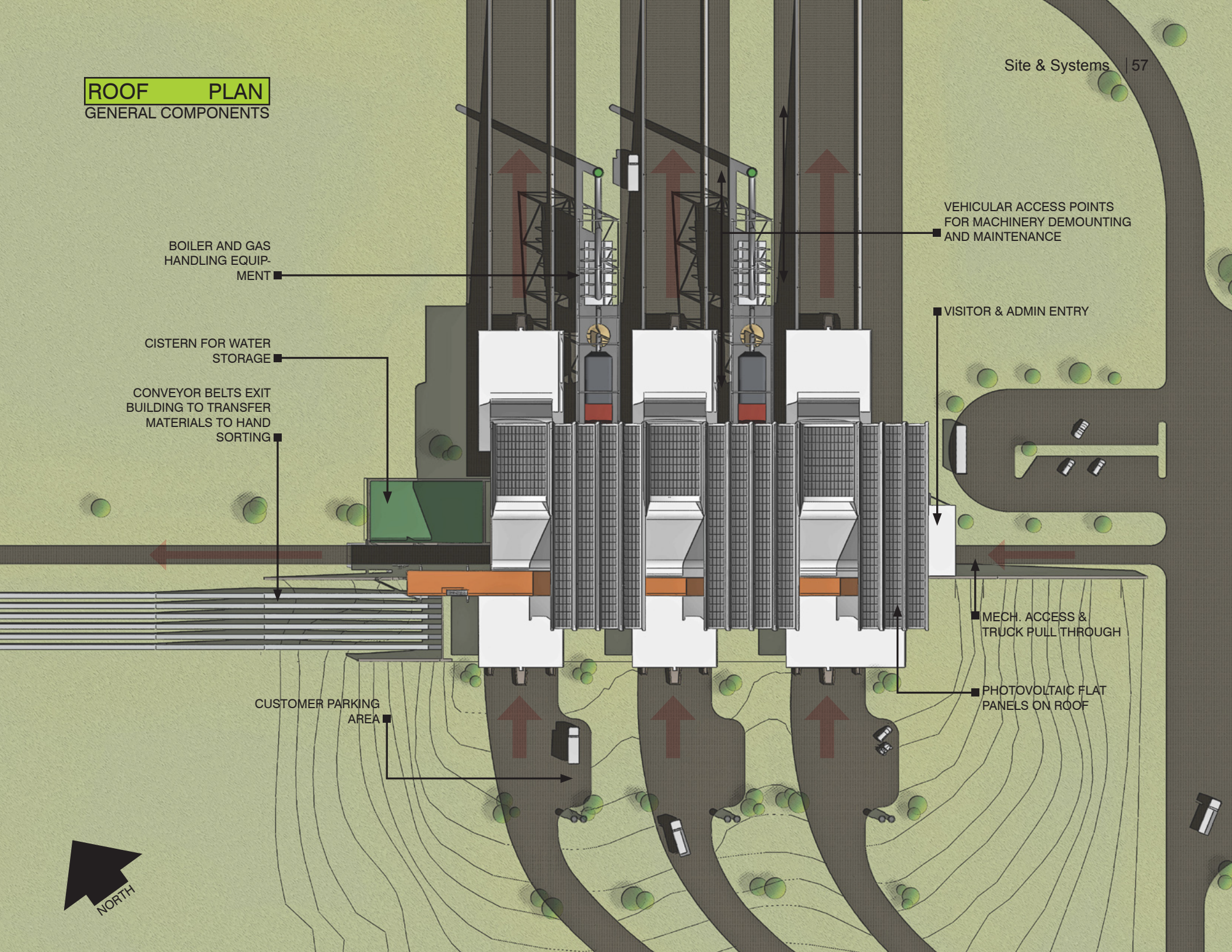
WSC Component	Trip Type	Vehicle Type	# of vehicle visits per day in 2008	# of vehicle visits per day in 2022	Avg. Length of Stay (min.)	Description
General	Gen. Employee	passenger vehicles; light duty truck...etc.	18	20	480	full and part-time employees
	Visitor	passenger vehicles; passenger vans; medium & large busses	8	16	90	Someone visiting the WSC to pay a bill; school groups and others for a tour...etc.
WTE & Recycling	Solid Waste - Self Haul	passenger vehicles; light duty truck...etc.	205	275	20	private users to drop off solid waste & recycling
	Solid Waste - Commercial	business vehicles; collection trucks; drop box trucks	161	215	10	commercial users to drop off solid waste & recycling
WWTP	WWTP Employee	passenger vehicles; light duty truck...etc.	14	16	480	full and part-time employees
Steam Plant	Steam Plant Employee	passenger vehicles; light duty truck...etc.	2	3		full and part-time employees
Totals			408	545		



SITE PLAN GENERAL COMPONENTS



ROOF PLAN
GENERAL COMPONENTS



SITE STRATEGY

EXPANDABILITY / MODULARITY
ADAPTABILITY / ACCESSIBILITY

■ SITING OF BALING, STORAGE, AND SHIPPING FACILITY PERMITS LINEAR ACCESS TO LOADING MATERIALS & FREIGHT ON TRAINS AT DOUBLE SIDED TRACK

■ RE-USE & RECLAIMED MATERIALS STORE IS LOCATED CLOSE TO FRONTAGE ROAD FOR EASY PUBLIC ACCESS AND CUSTOMER USE AT WASTE FACILITY EXIT

■ BUILDING DESIGN & LAYOUT PRIORITIZES MATERIALS DISPOSAL BY ALLOWING USERS TO CIRCULATE RESPECTIVELY:
1) RE-USE STATION
2) RECYCLE DUMP HALL
3) WASTE DUMP HALL

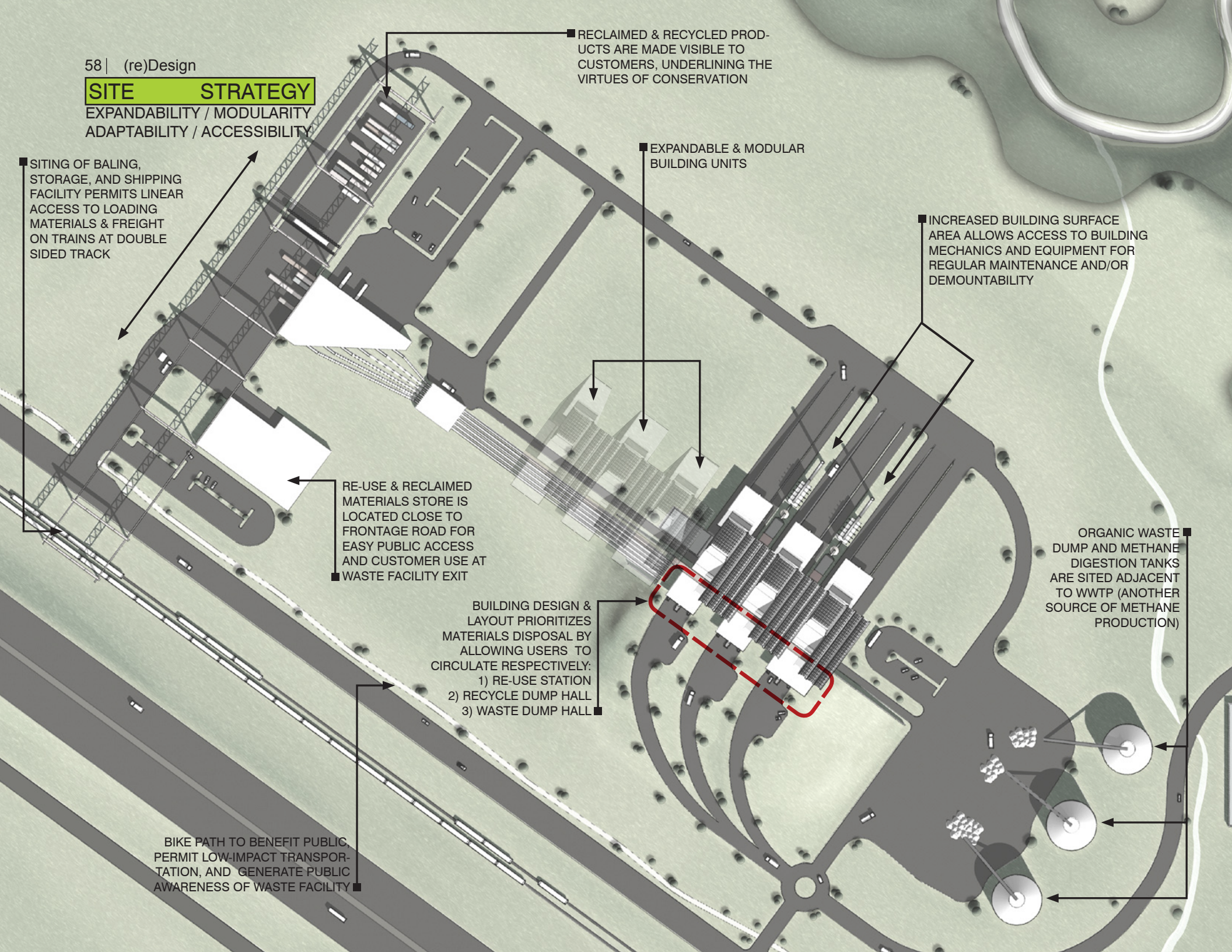
■ BIKE PATH TO BENEFIT PUBLIC, PERMIT LOW-IMPACT TRANSPORTATION, AND GENERATE PUBLIC AWARENESS OF WASTE FACILITY

■ RECLAIMED & RECYCLED PRODUCTS ARE MADE VISIBLE TO CUSTOMERS, UNDERLINING THE VIRTUES OF CONSERVATION

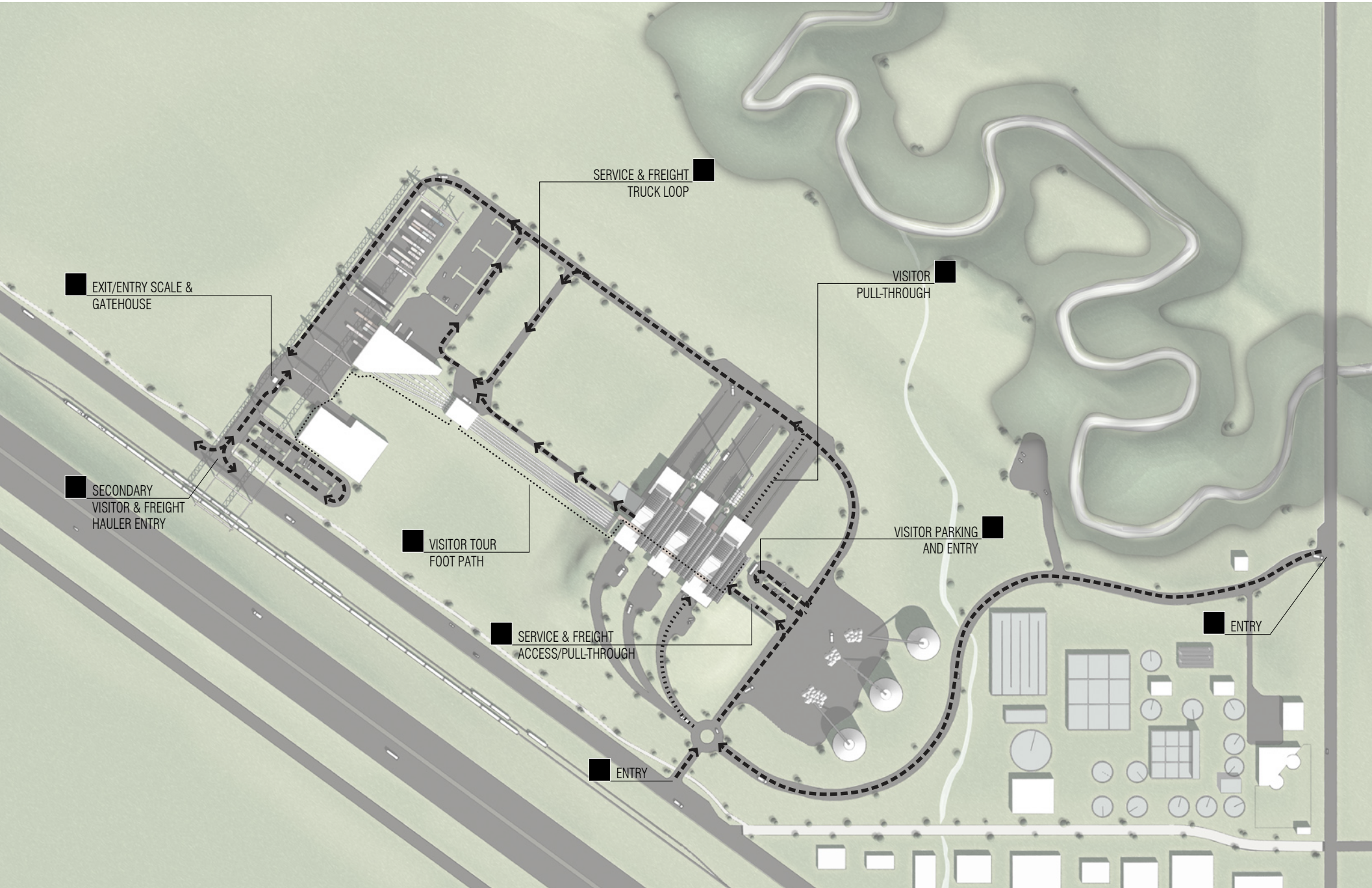
■ EXPANDABLE & MODULAR BUILDING UNITS

■ INCREASED BUILDING SURFACE AREA ALLOWS ACCESS TO BUILDING MECHANICS AND EQUIPMENT FOR REGULAR MAINTENANCE AND/OR DEMOUNTABILITY

■ ORGANIC WASTE DUMP AND METHANE DIGESTION TANKS ARE SITED ADJACENT TO WWTP (ANOTHER SOURCE OF METHANE PRODUCTION)



CIRCULATION
GENERAL



CIRCULATION

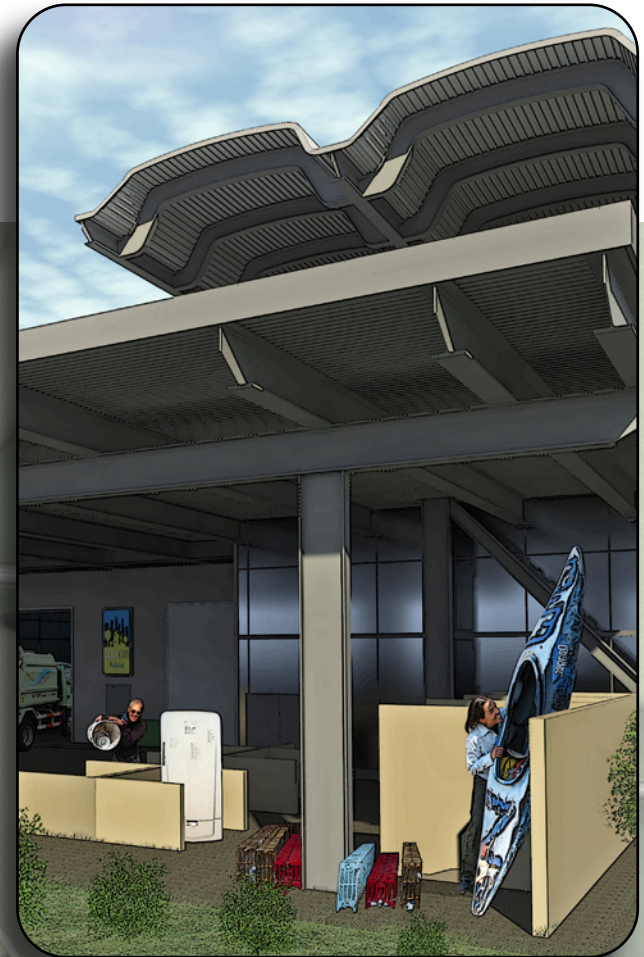
SELF-HAUL VEHICLES



6 EXIT SCALE & GATEHOUSE



4 COMBUSTIBLE
WASTE DUMP HALL



2 RE-USE D/O & P/U,
WHITE GOODS &
HAZ. WASTE

8 EXIT

5 VEHICLE
WASH STATION

3 ENTRY SCALE & RECYCLE DUMP HALL

7 RE-USE MATERIALS
STORE & PUBLIC PARKING



1 ENTRY

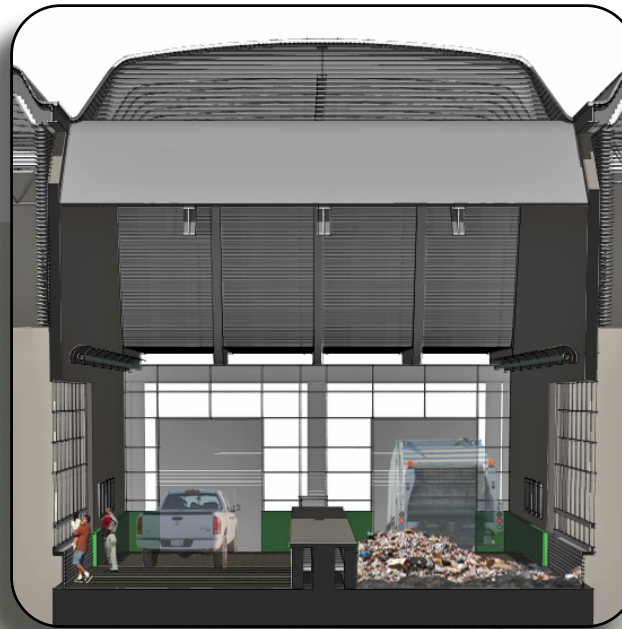
2 ORGANIC
WASTE DUMP

1 ENTRY

CIRCULATION COMMERCIAL VEHICLES



4 VEHICLE
WASH STATION



Site & Systems | 61



6 EXIT

5 EXIT SCALE &
GATEHOUSE

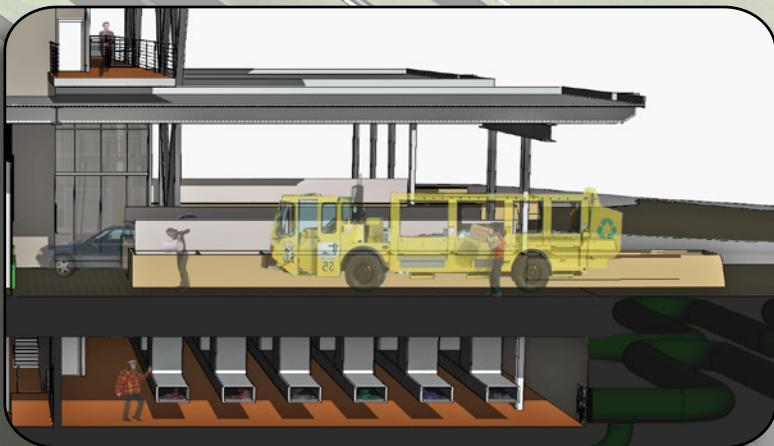
2 ENTRY SCALE & RECYCLE DUMP HALL

COMBUSTIBLE
WASTE DUMP 3

ORGANIC
WASTE DUMP 2

1 ENTRY

1 ENTRY





62 | (re)Design

SYSTEM DESIGN RECYCLING

LOAD MATERIALS FOR
TRANSPORT

5



MATERIALS BALING

4



3 SORTING/HAND
SORTING



2 OFFLOADING



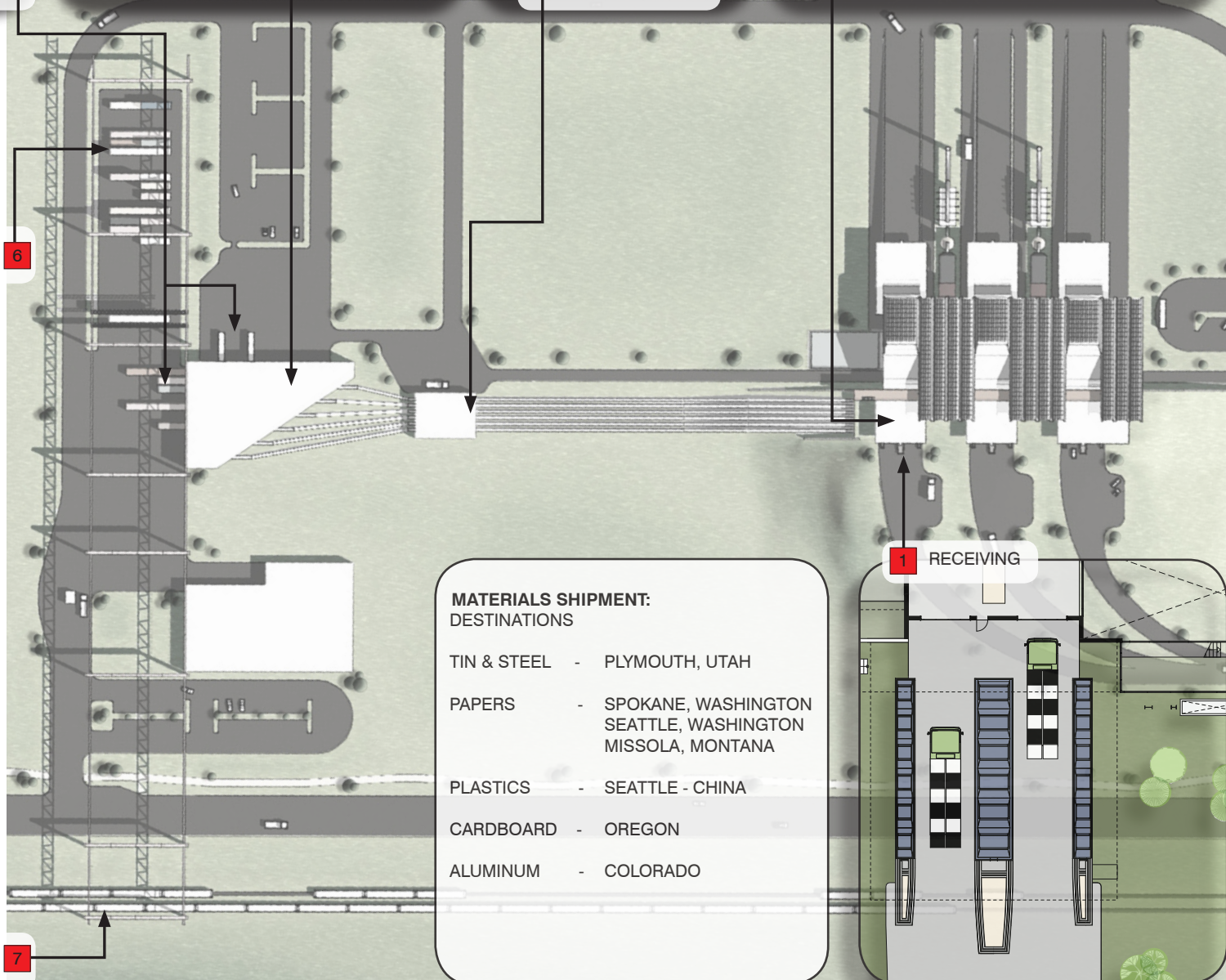
SHORT-TERM CONTAINER
STORAGE

6



CONTAINERS LOADED
FOR SHIPMENT

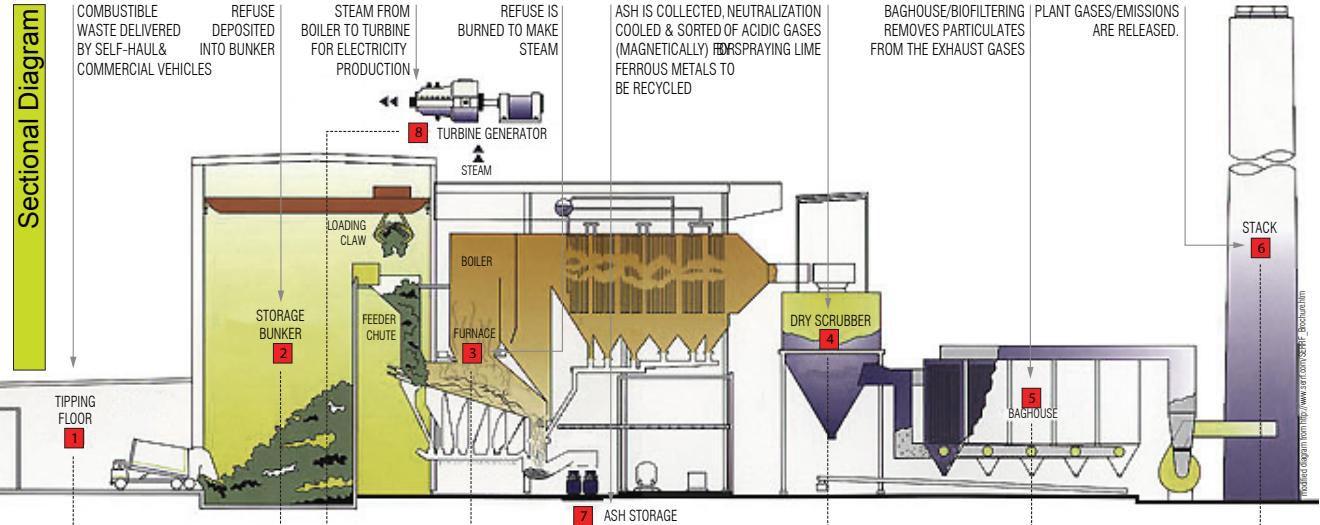
7



MATERIALS SHIPMENT: DESTINATIONS

TIN & STEEL	-	PLYMOUTH, UTAH
PAPERS	-	SPOKANE, WASHINGTON SEATTLE, WASHINGTON MISSOLA, MONTANA
PLASTICS	-	SEATTLE - CHINA
CARDBOARD	-	OREGON
ALUMINUM	-	COLORADO

SYSTEM DESIGN COMBUSTIBLE WASTE



WTE Sizing Comparison

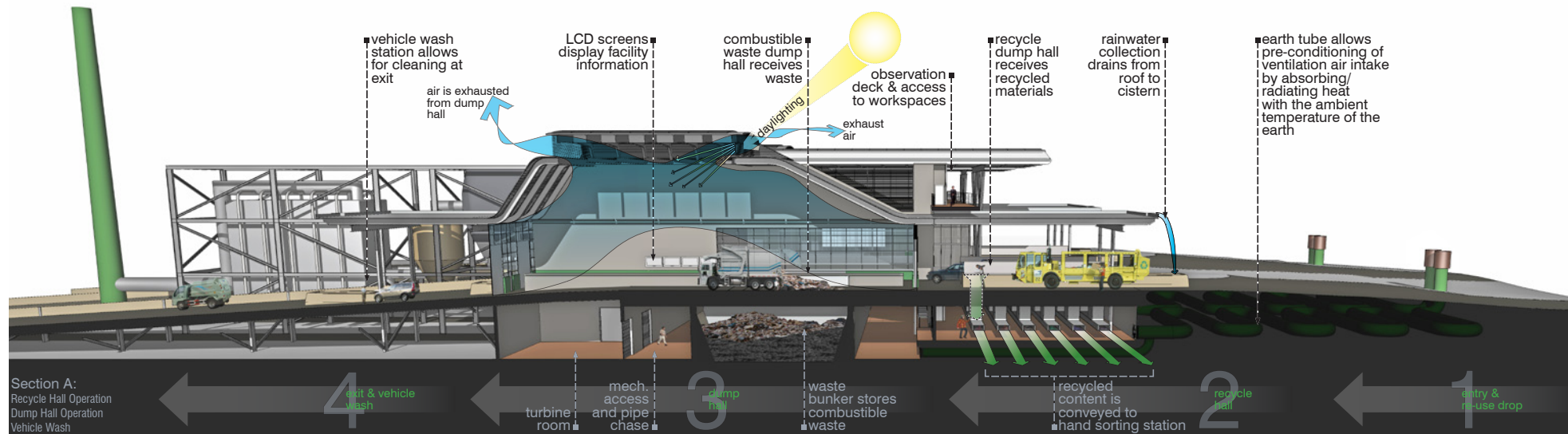
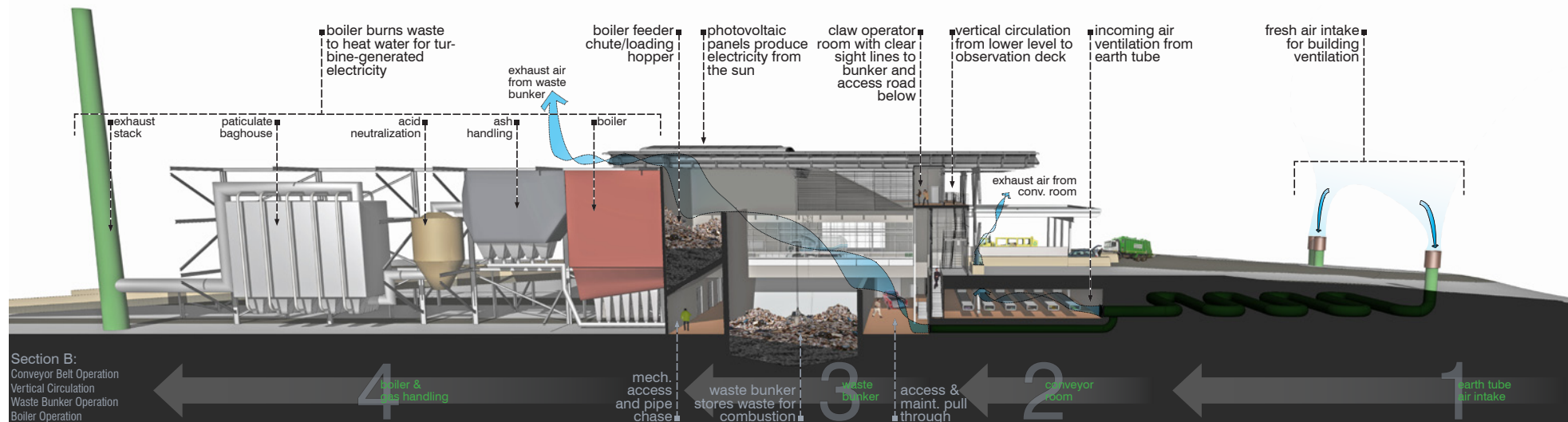
		BASE: Southeast Resource Recovery Facility	Bozeman WSC (2007)*	Bozeman WSC (2022)*
PROCESSING CAPACITY	Waste Processing Capacity (tons/year)	368,000	47,804	65,348
	Waste Processing (tons/day)	1,290	168	229
	Waste Processing Capacity (tons/hour)	3.53	0.46	0.63
	Post Burn Recycled Materials (tons/month)	825	107.17	146.5
BUNKER CALCS.	Bunker capacity (tons)	3,870	503	687
	Bunker capacity (lbs.)	7,740,000	1,005,443	1,374,439
	Bunker capacity (cu. yrd.) - @ 250 lbs./cu.yard	30,960	4,022	5,498
	Bunker capacity (cu. ft.)	835,920	108,588	148,439
	Bunker dimensions (ft.)	260'L x 80'W x 40'D	150'L x 25'W x 30'D	200'L x 25'W x 30'D
GENERAL FOOTPRINT (sq.ft.)	Tipping Floor	17,300	2,247	3,072
	Bunker	21,900	3,750	5,000
	Furnace	14,250	1,851	2,530
	Dry Scrubber	10,800	1,403	1,918
	Baghouse	11,458	1,488	2,035
	Stack	8,000	1,039	1,421
	Ash Storage	11,350	1,474	2,015
	Turbine Generator	13,750	1,786	2,442
	Administration Building	5,800	753	1,030
	Total	114,608	15,793	21,463
POWER PRODUCTION	Electricity Production (MW)	36	4.68	6.39
	# of Homes Powered by Plant Production	35,000	4,547	6,215
	Conversion Factor*	1	0.13	1.37
*Unit Conversion Factor for Bozeman WSC numbers are derived by taking the percentage difference in Waste Capacity between the two facilities.				

Southeast Resource Recovery Facility - Long Beach, CA.



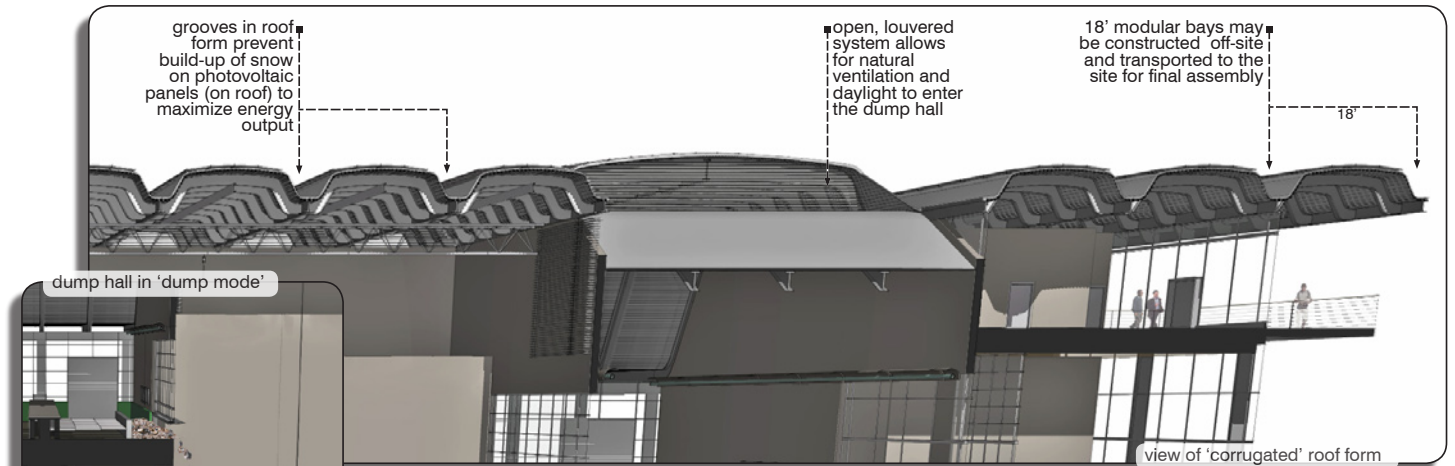
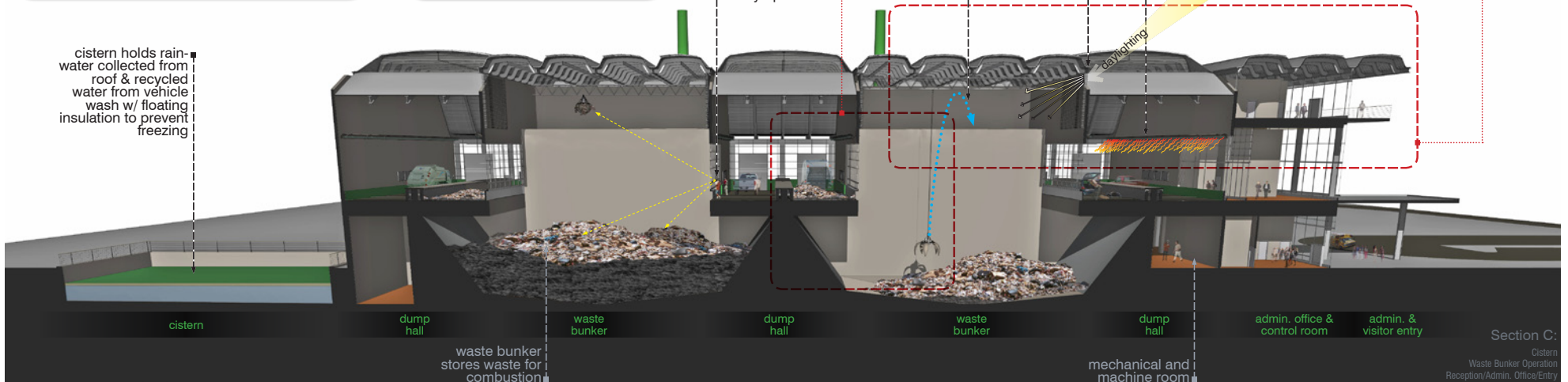
SECTION AND SYSTEMS

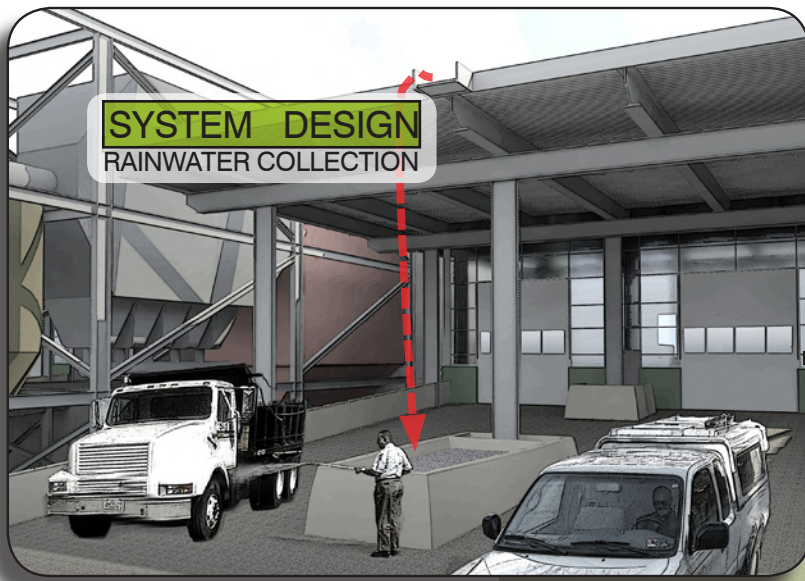
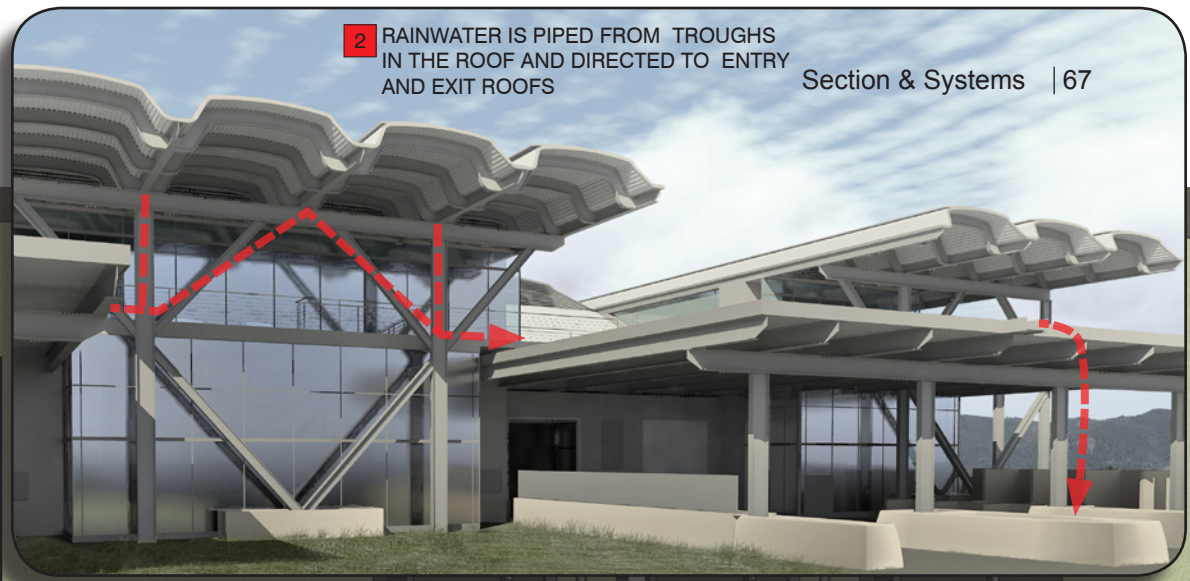
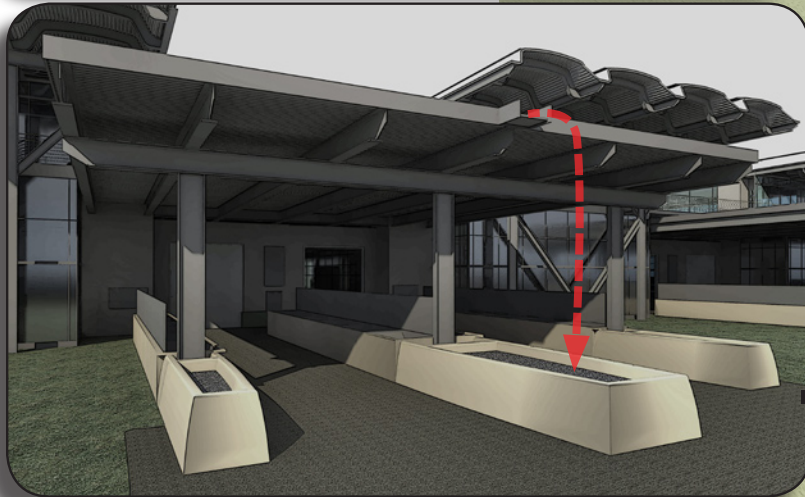
SYSTEM AND BUILDING DESIGN/OPERATION



SECTIONS & SYSTEMS

WASTE BUNKER, DUMP HALL
CISTERN, ADMIN. OFFICE

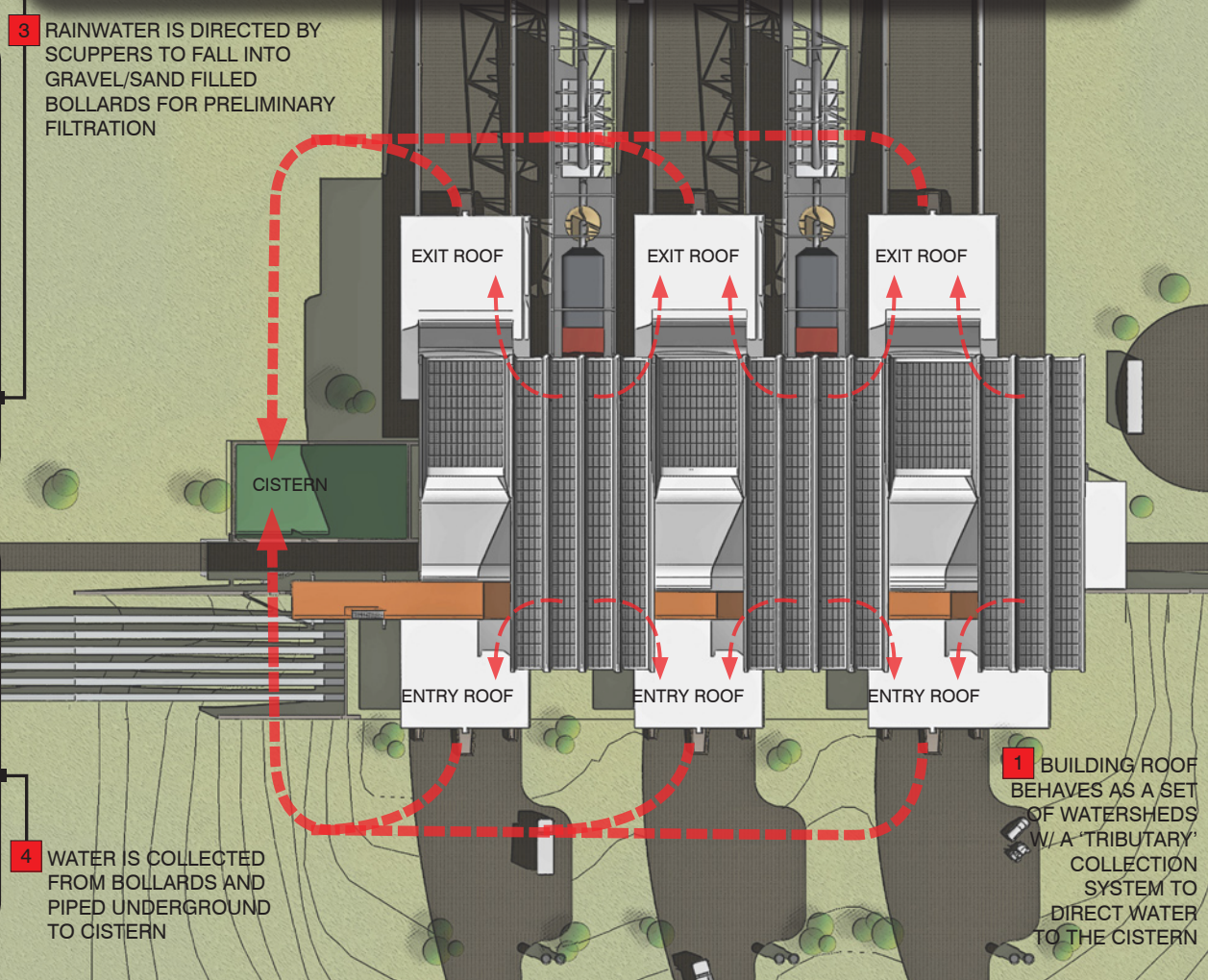




3 RAINWATER IS DIRECTED BY SCUPPERS TO FALL INTO GRAVEL/SAND FILLED BOLLARDS FOR PRELIMINARY FILTRATION

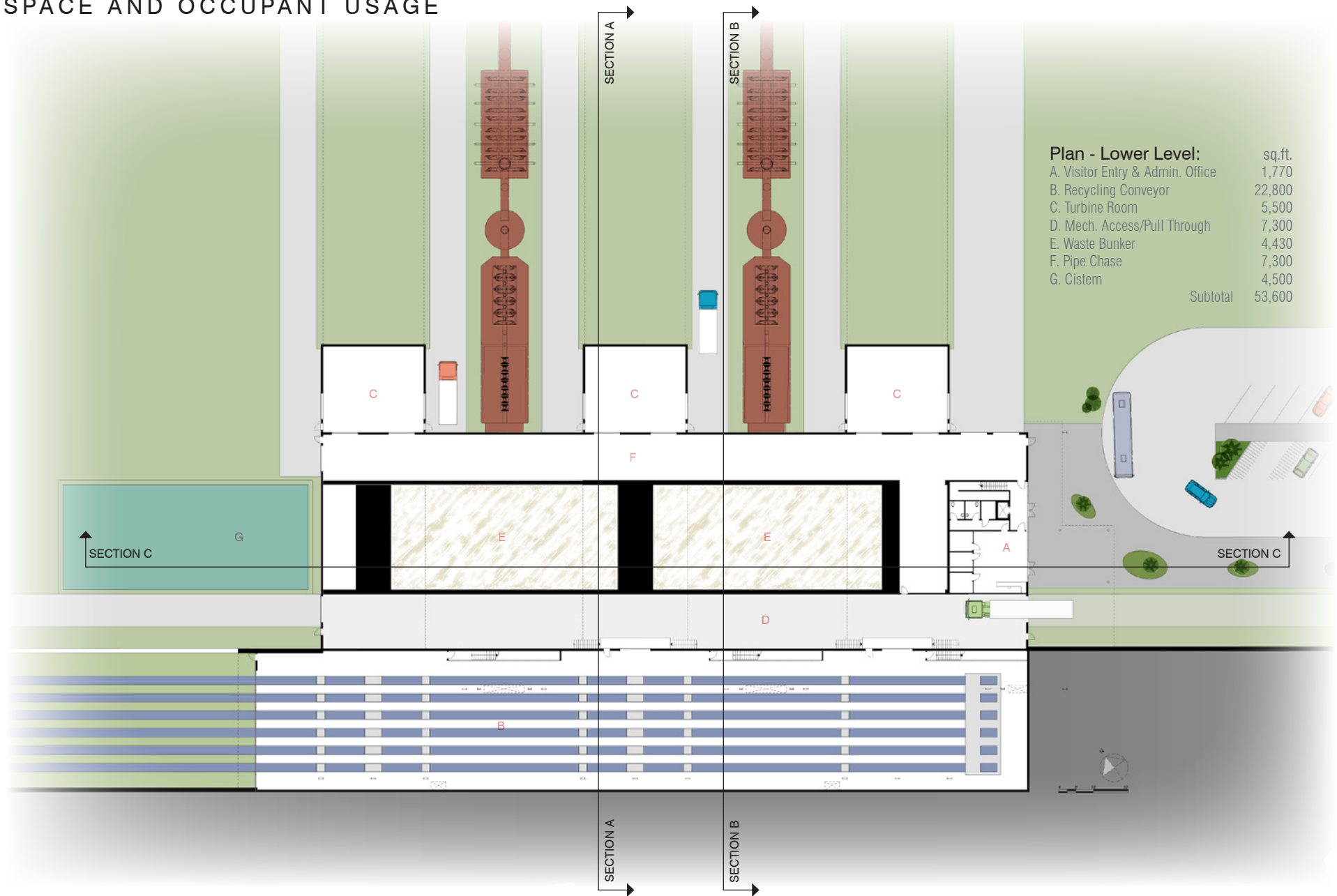


4 WATER IS COLLECTED FROM BOLLARDS AND PIPED UNDERGROUND TO CISTERN



PLAN AND PERSPECTIVE

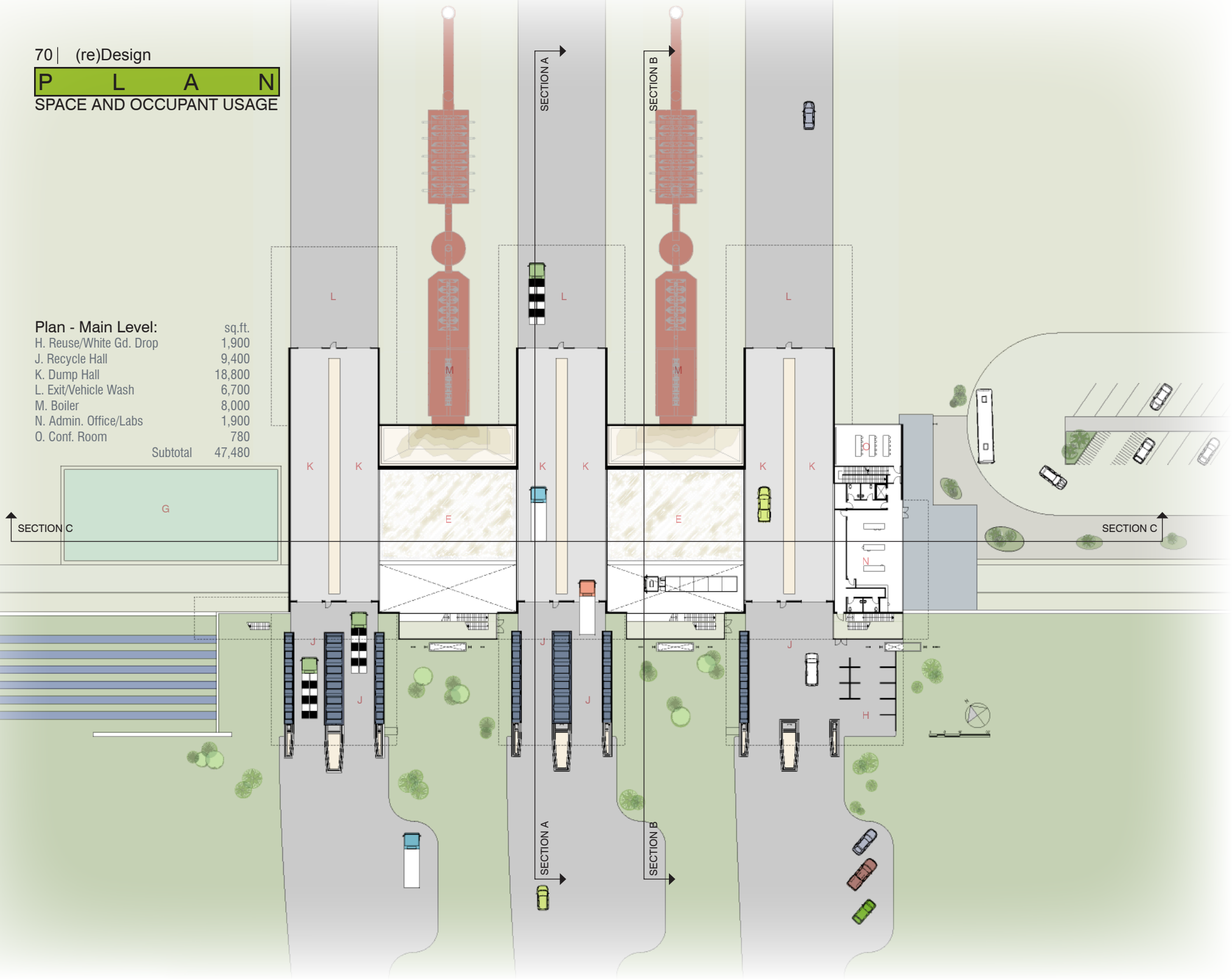
SPACE AND OCCUPANT USAGE



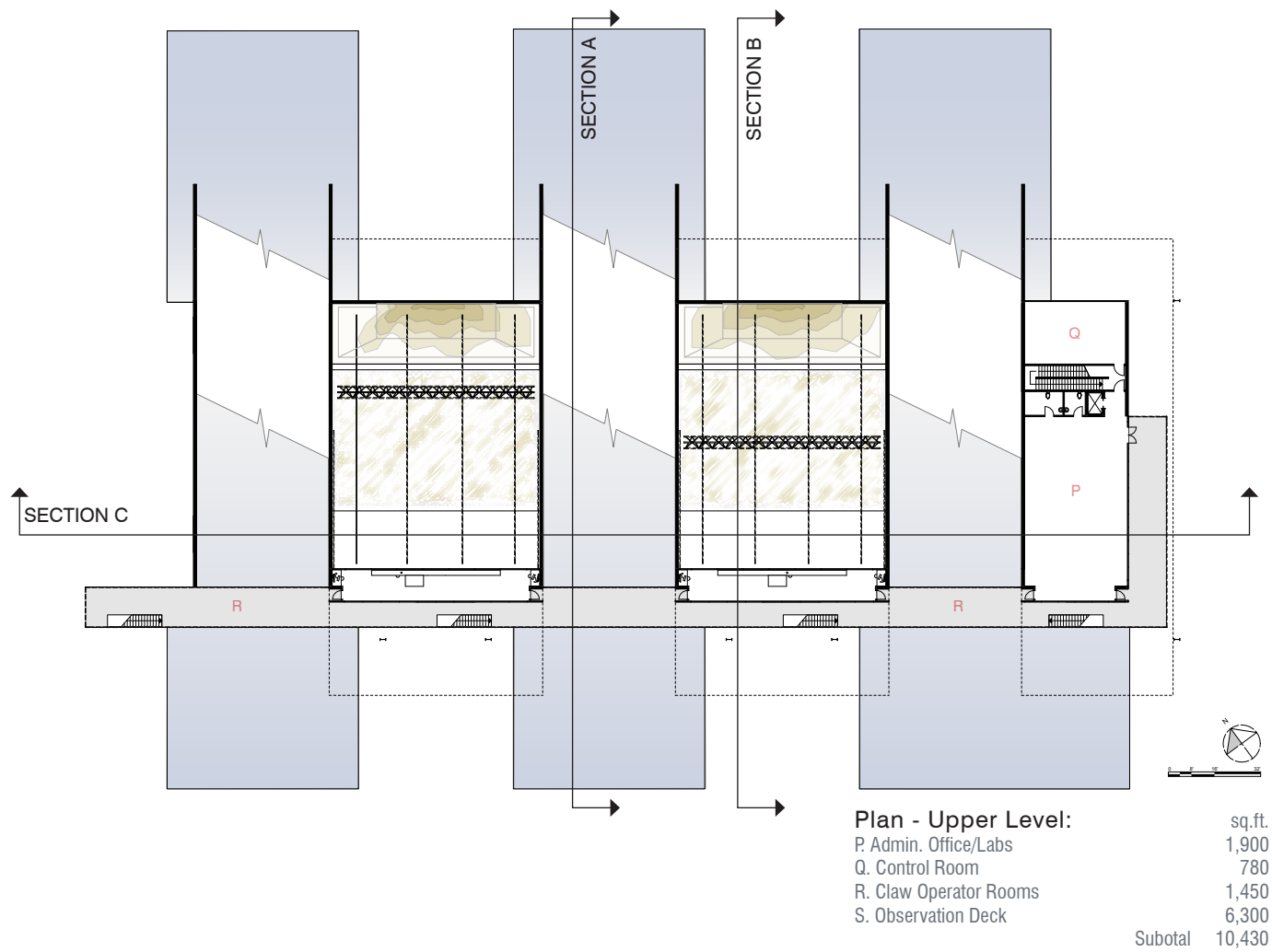
P L A N
SPACE AND OCCUPANT USAGE

Plan - Main Level:

H. Reuse/White Gd. Drop	sq.ft.	1,900
J. Recycle Hall	9,400	
K. Dump Hall	18,800	
L. Exit/Vehicle Wash	6,700	
M. Boiler	8,000	
N. Admin. Office/Labs	1,900	
O. Conf. Room	780	
Subtotal	47,480	



P L A N
SPACE AND OCCUPANT USAGE

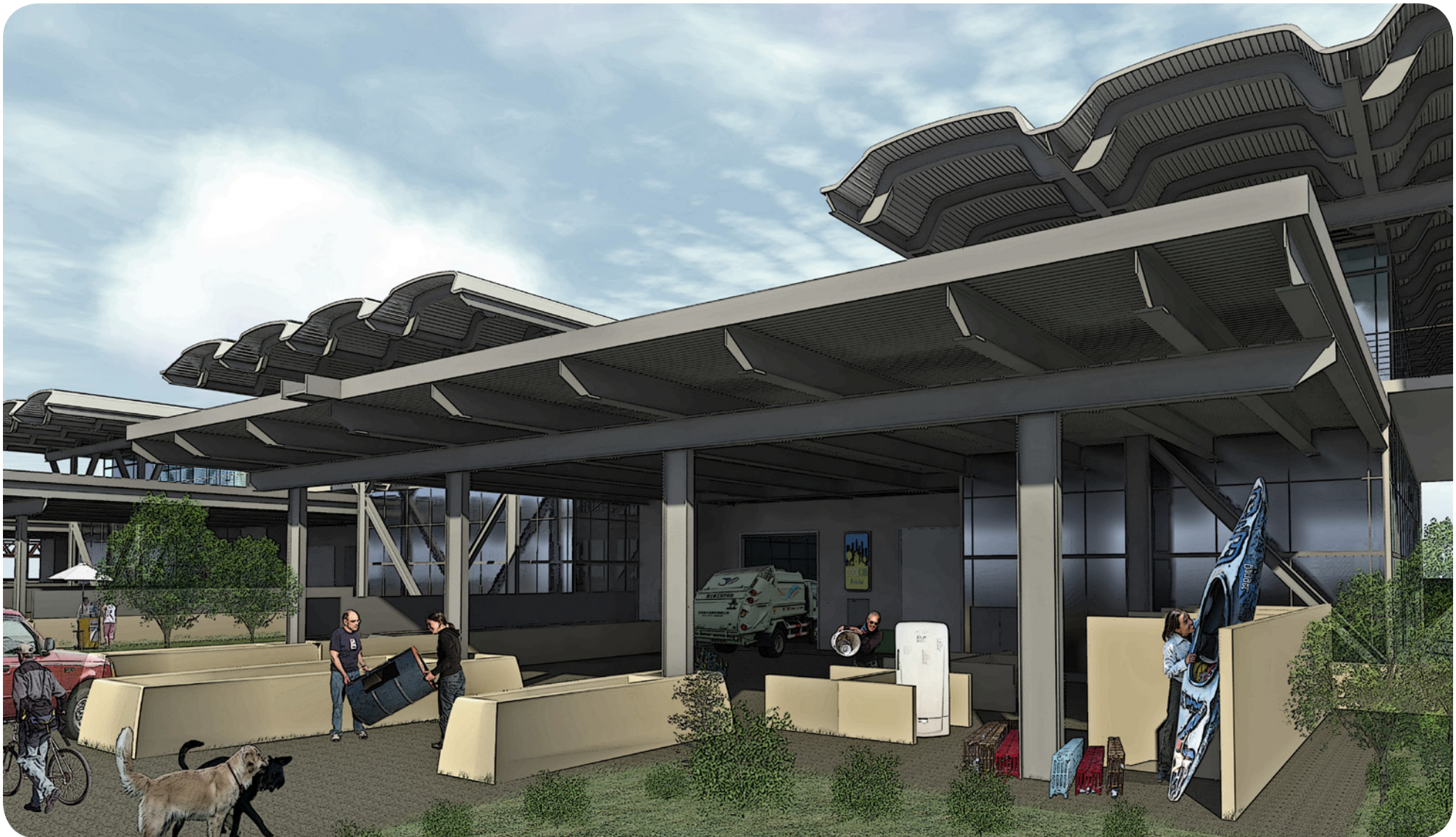


PERSPECTIVE

BIRD'S EYE VIEW:
LOOKING EAST



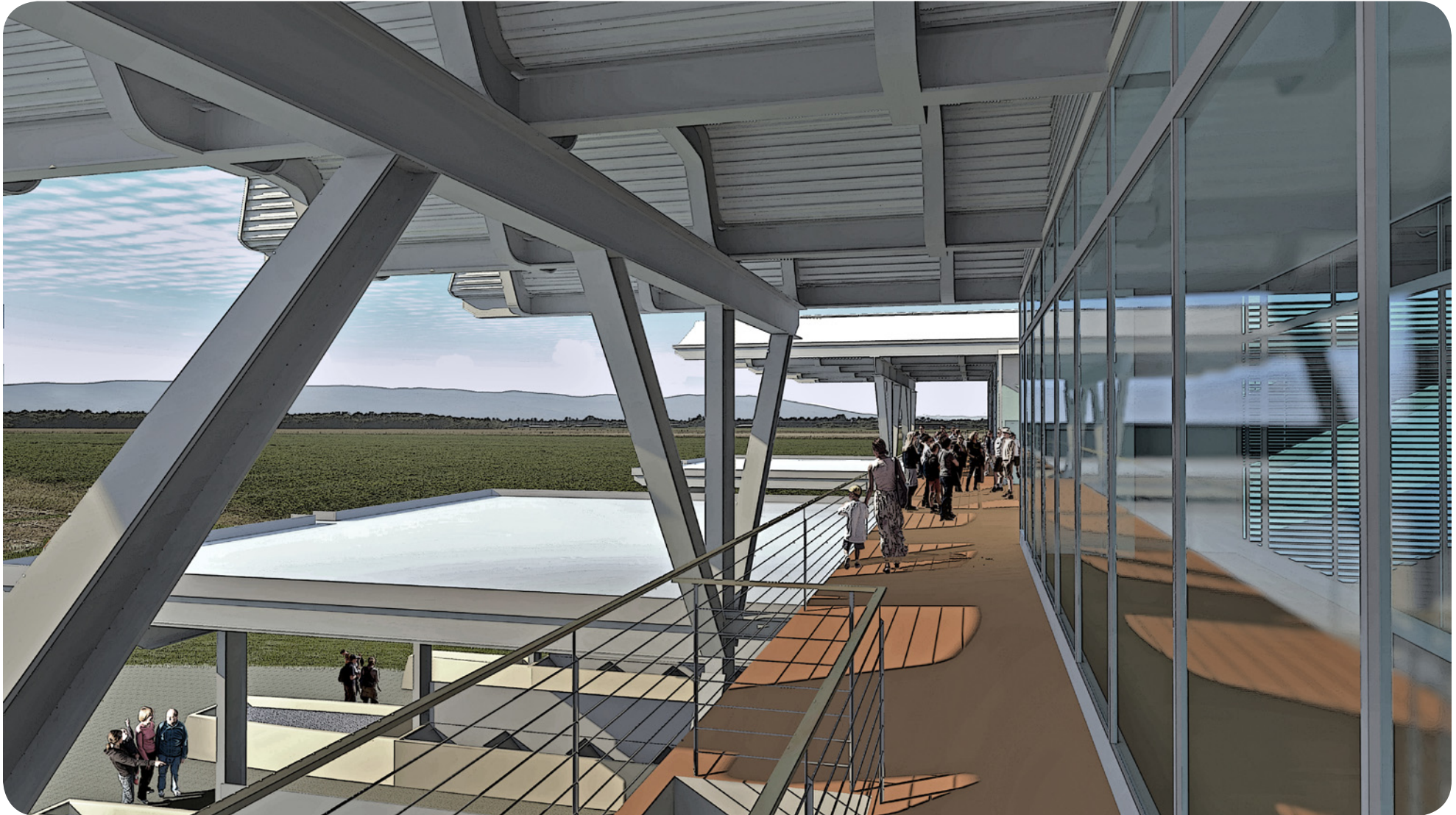
PERSPECTIVE
RE-USE STATION:
LOOKING NORTH



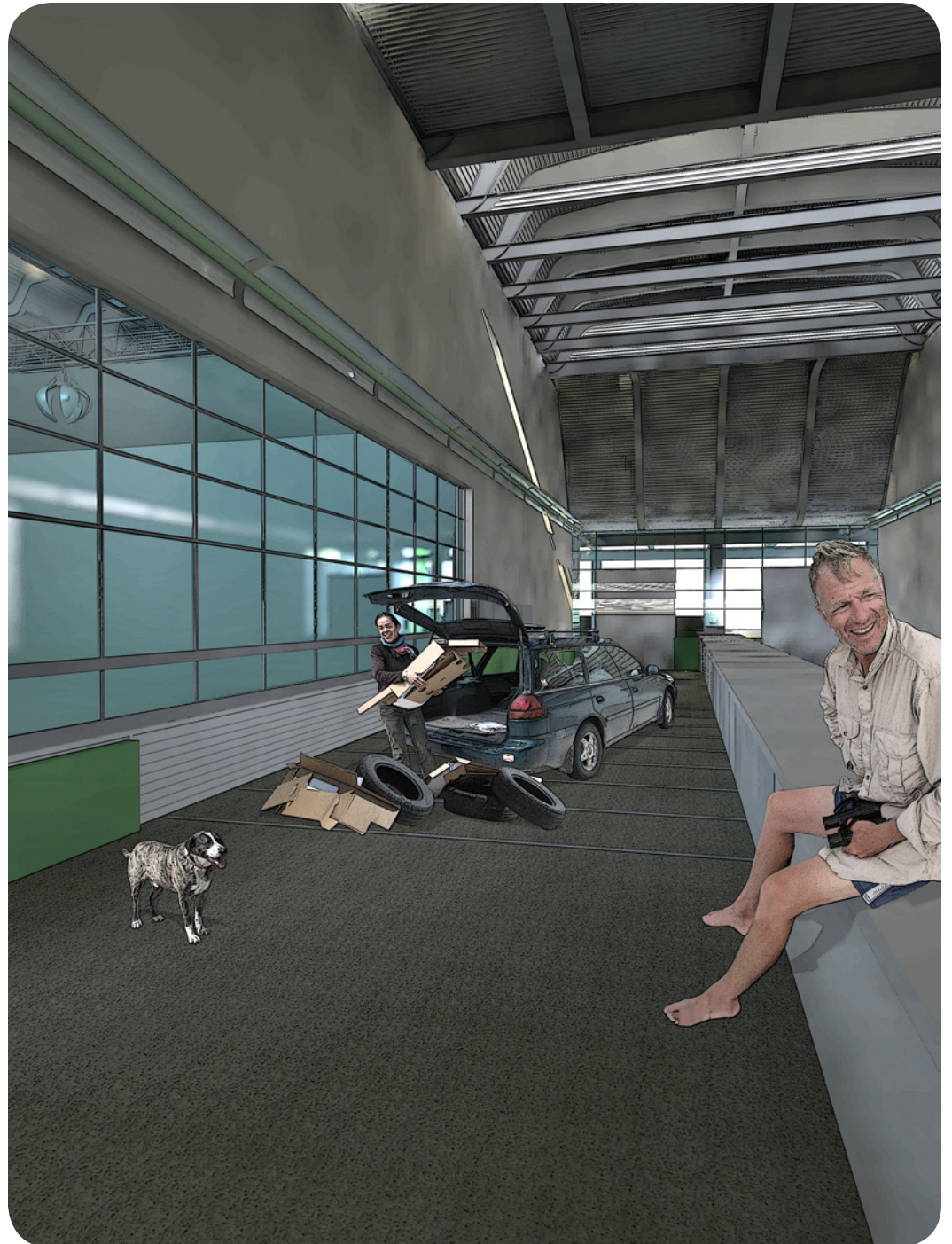
PERSPECTIVE
VEHICLE WASH STATION:
LOOKING SOUTH



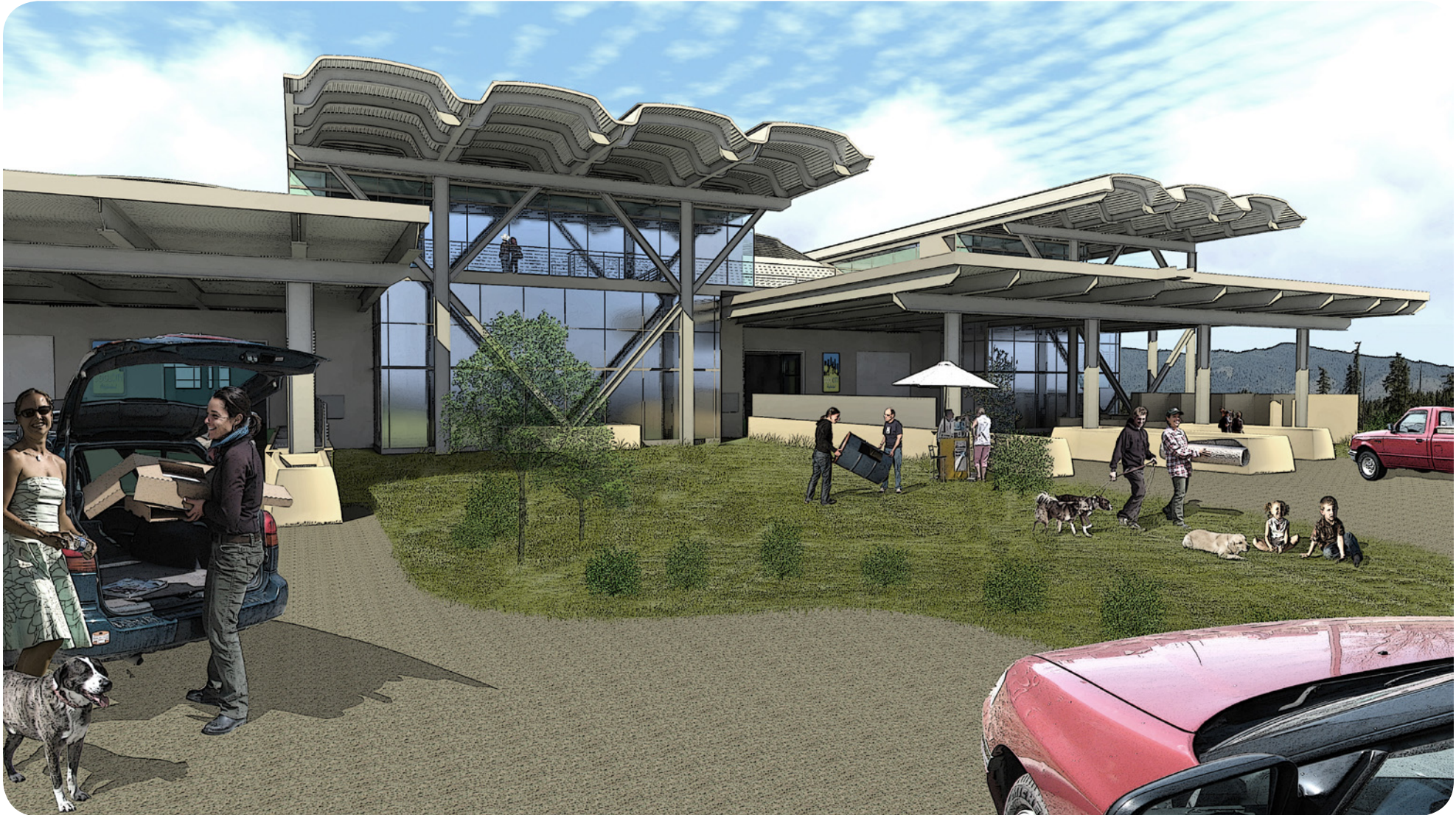
PERSPECTIVE
OBSERVATION DECK:
LOOKING WEST



PERSPECTIVE
WASTE DUMP HALL:
LOOKING NORTH



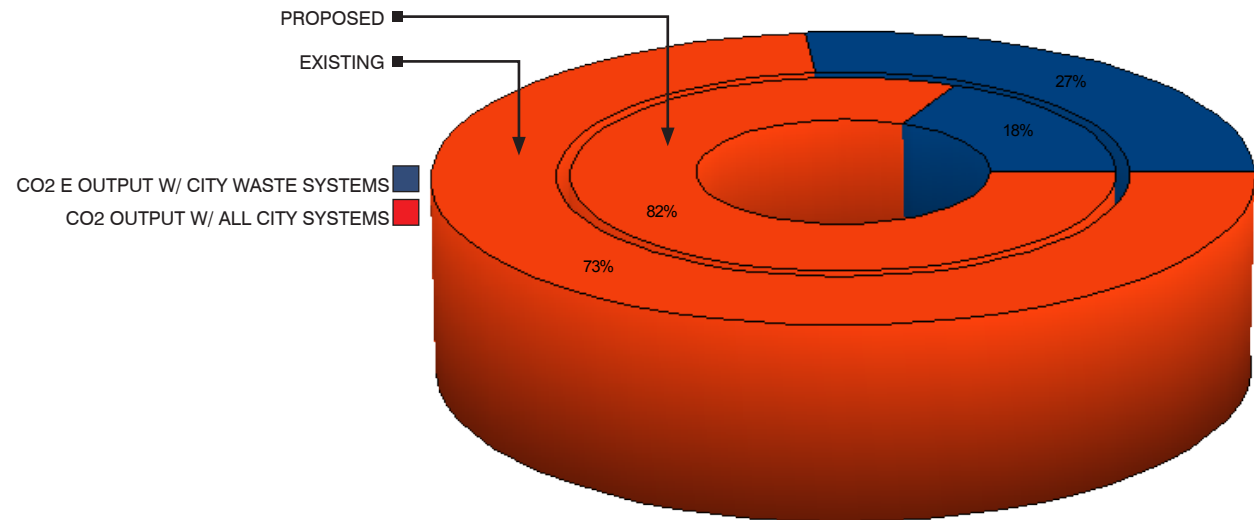
PERSPECTIVE
RECYCLE HALL ENTRY:
LOOKING NORTHWEST



ASSESSMENT

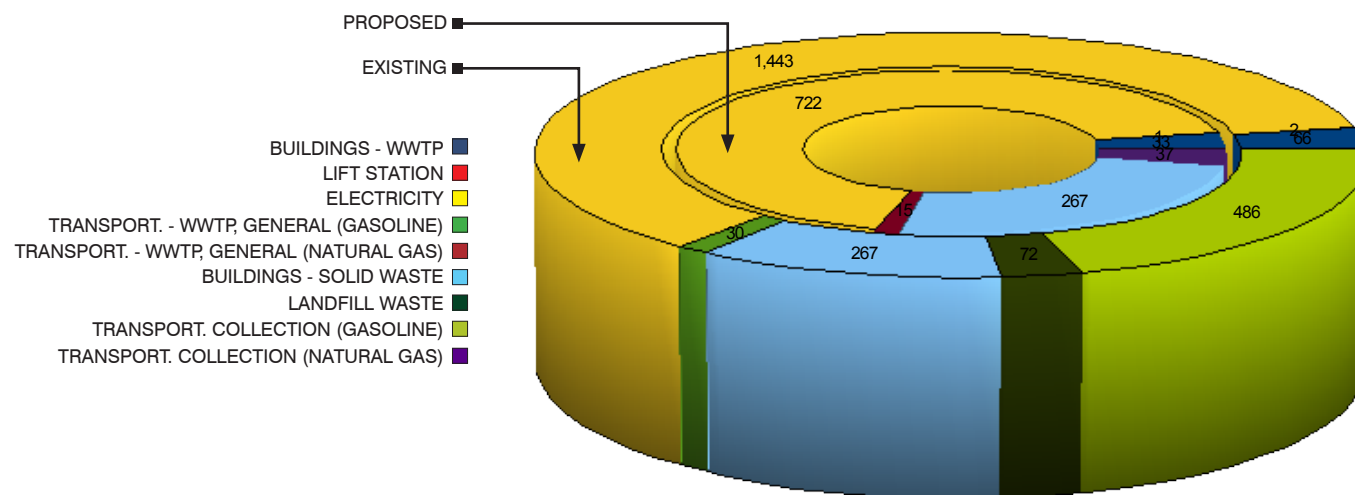
CARBON OUTPUT

Waste System Component Comparison
City Waste Components vs. All City Components



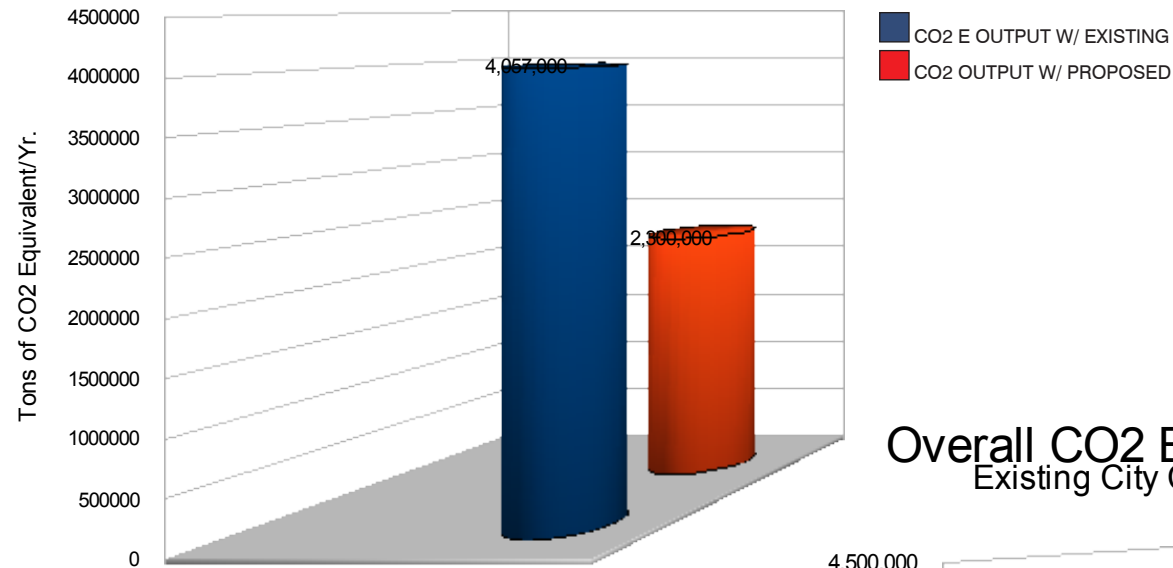
CO2 Emission Comparison

Existing City Waste Systems vs. Proposed Waste Syndication Center

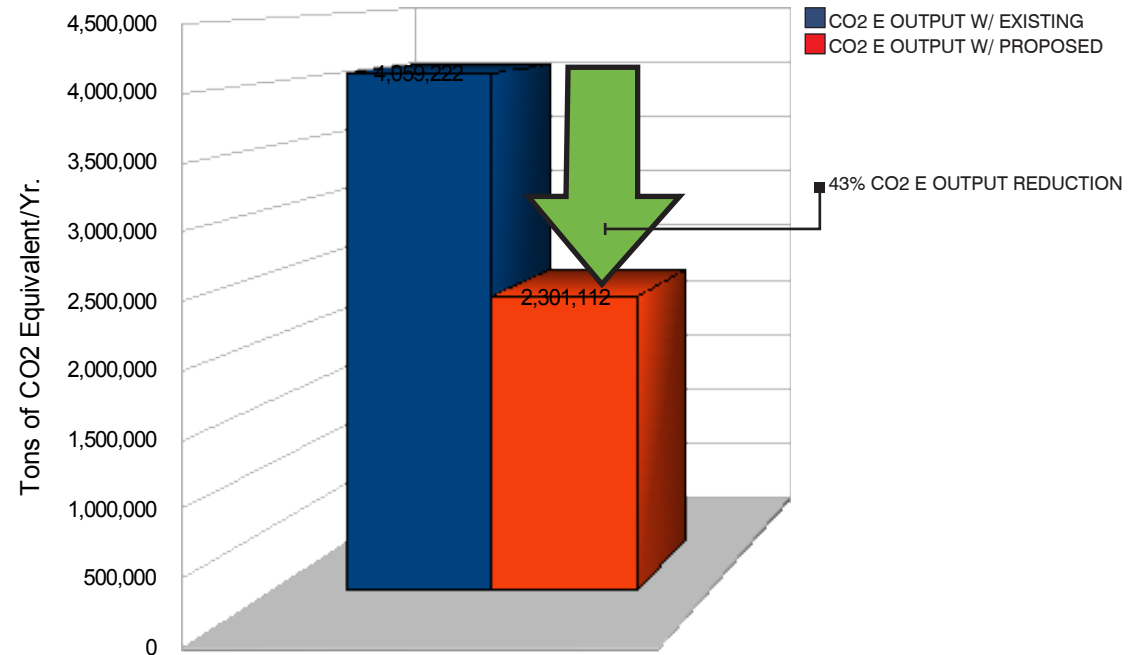


ASSESSMENT
CARBON OUTPUT

Power Production vs. Power Production Equivalent District Heating & Electricity Production

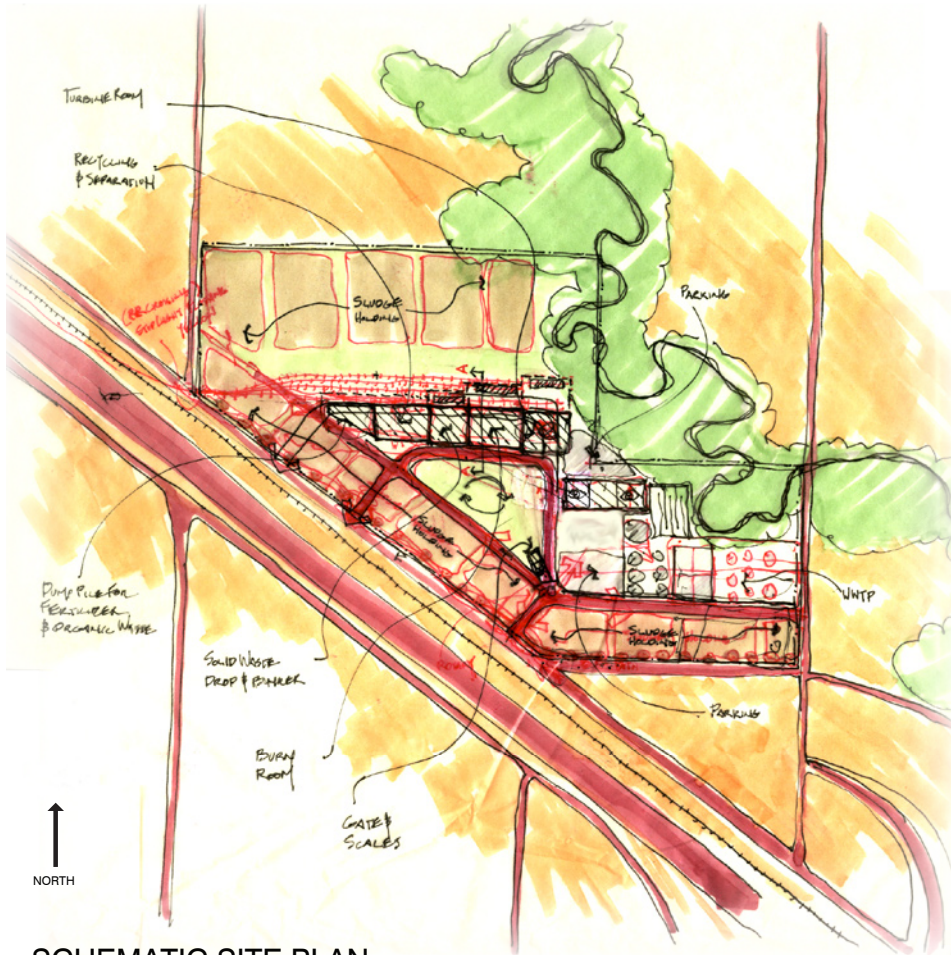


Overall CO2 Emissions Comparison Existing City Components vs. Proposed

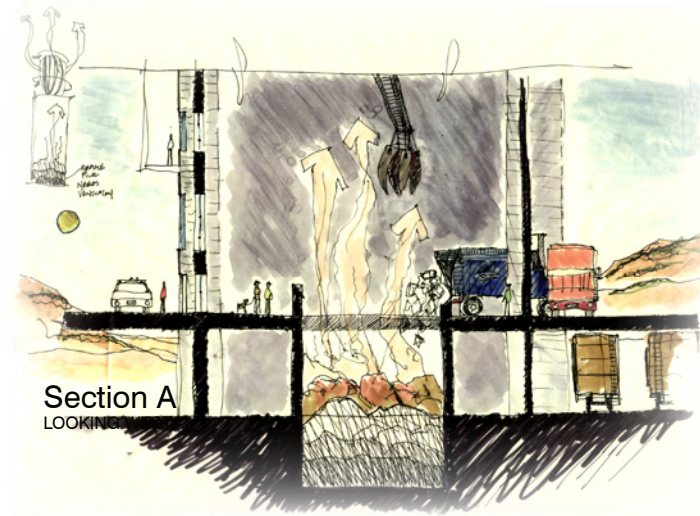
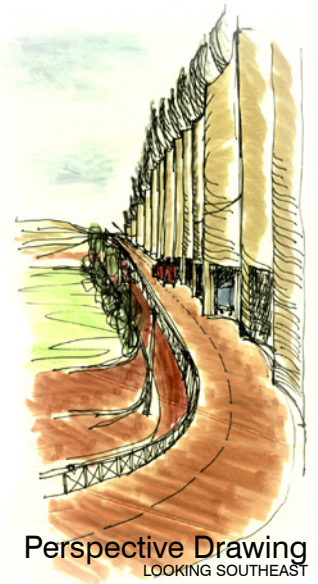
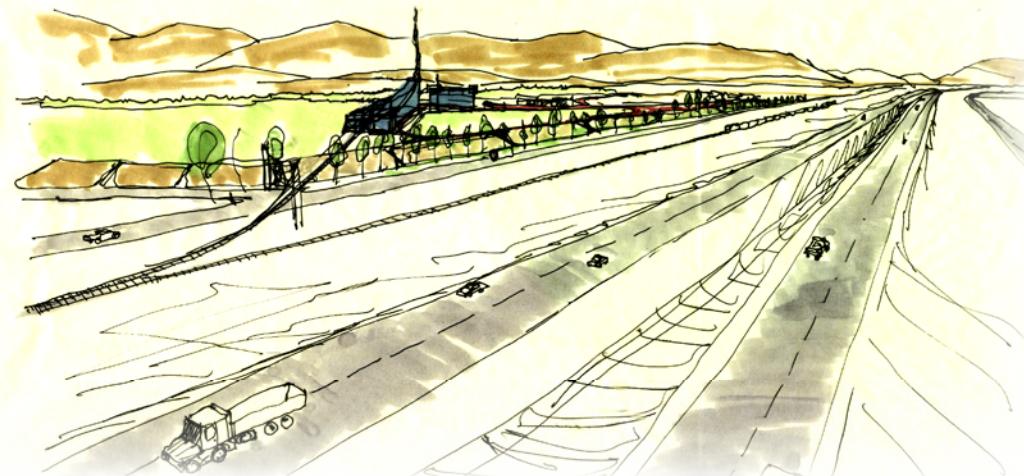


PROCESS

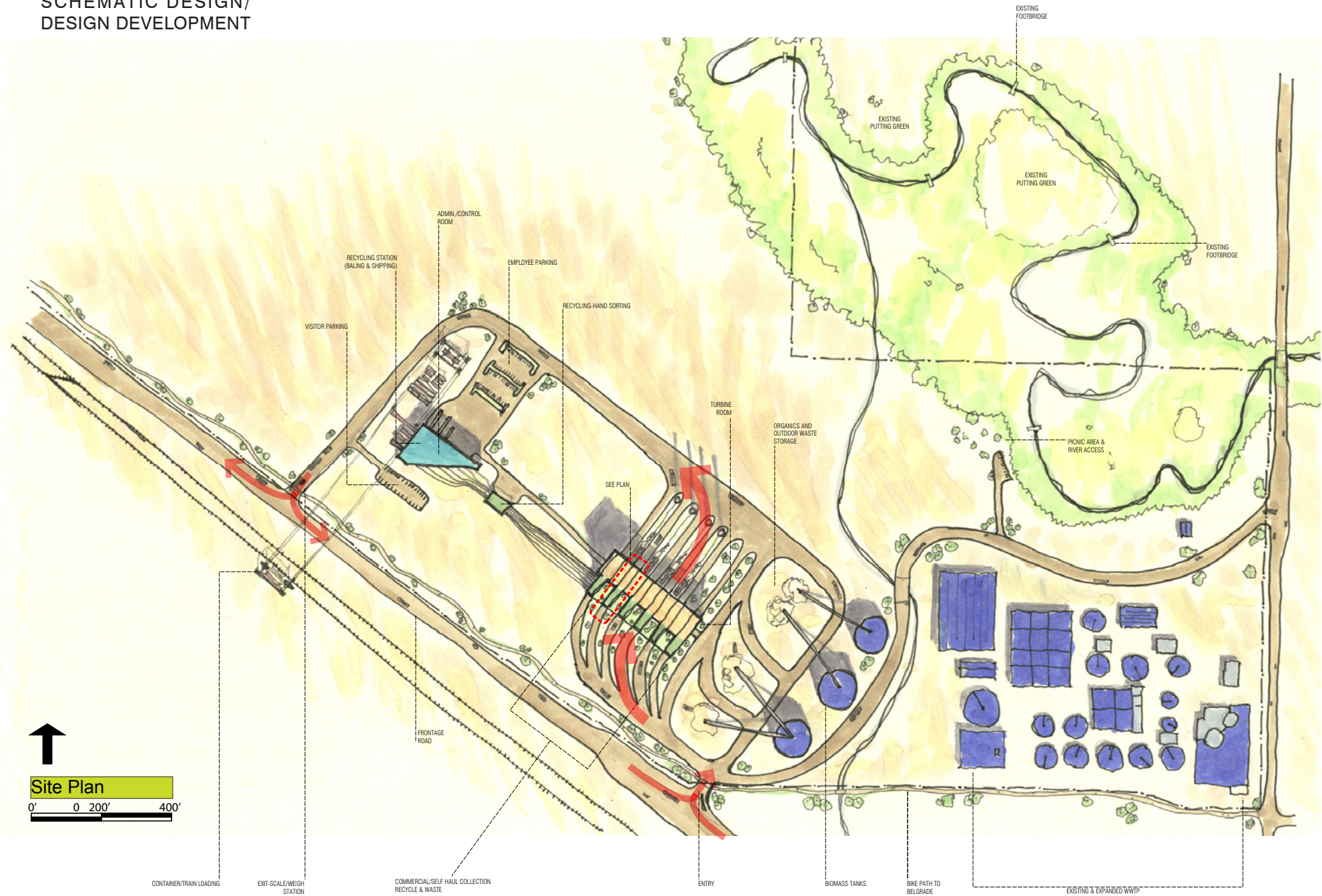
SCHEMATIC DESIGN/DESIGN DEVELOPMENT



SCHEMATIC SITE PLAN
N.T.S.

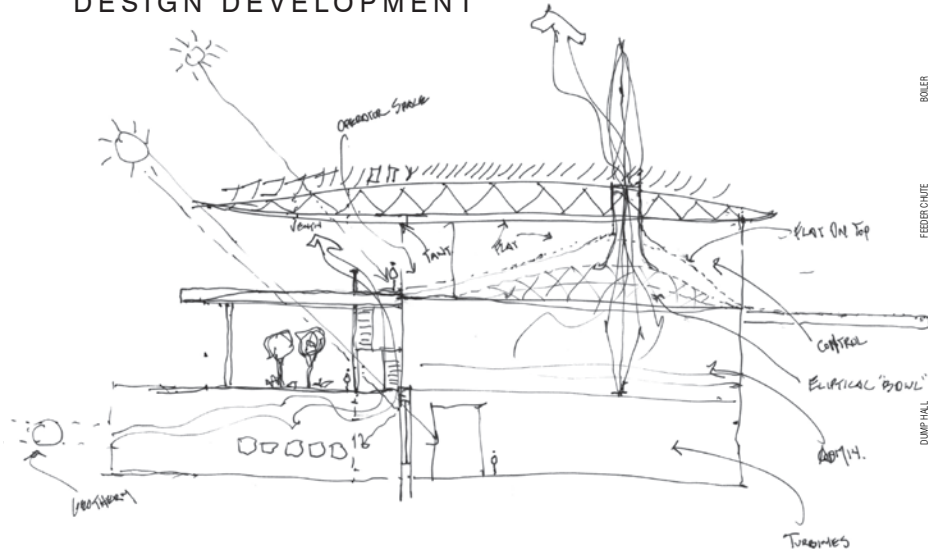
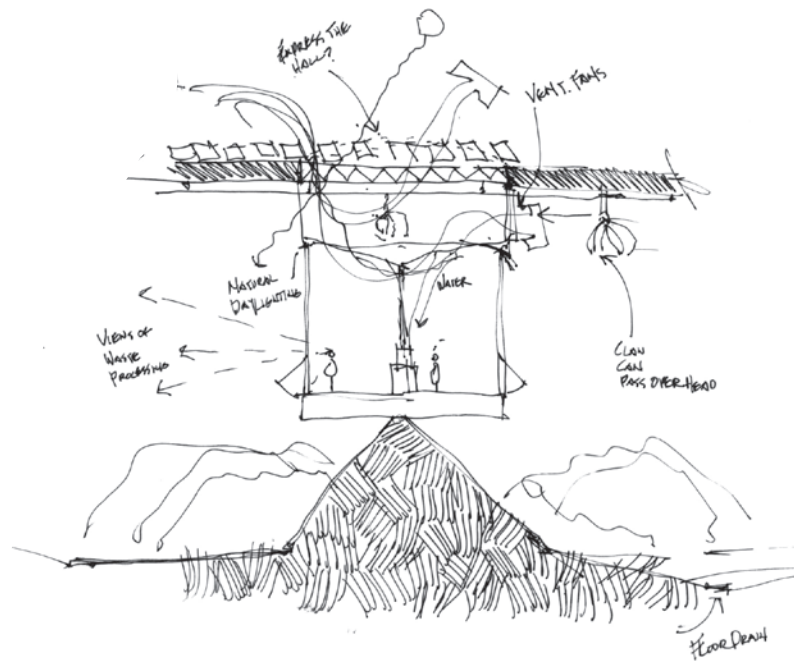
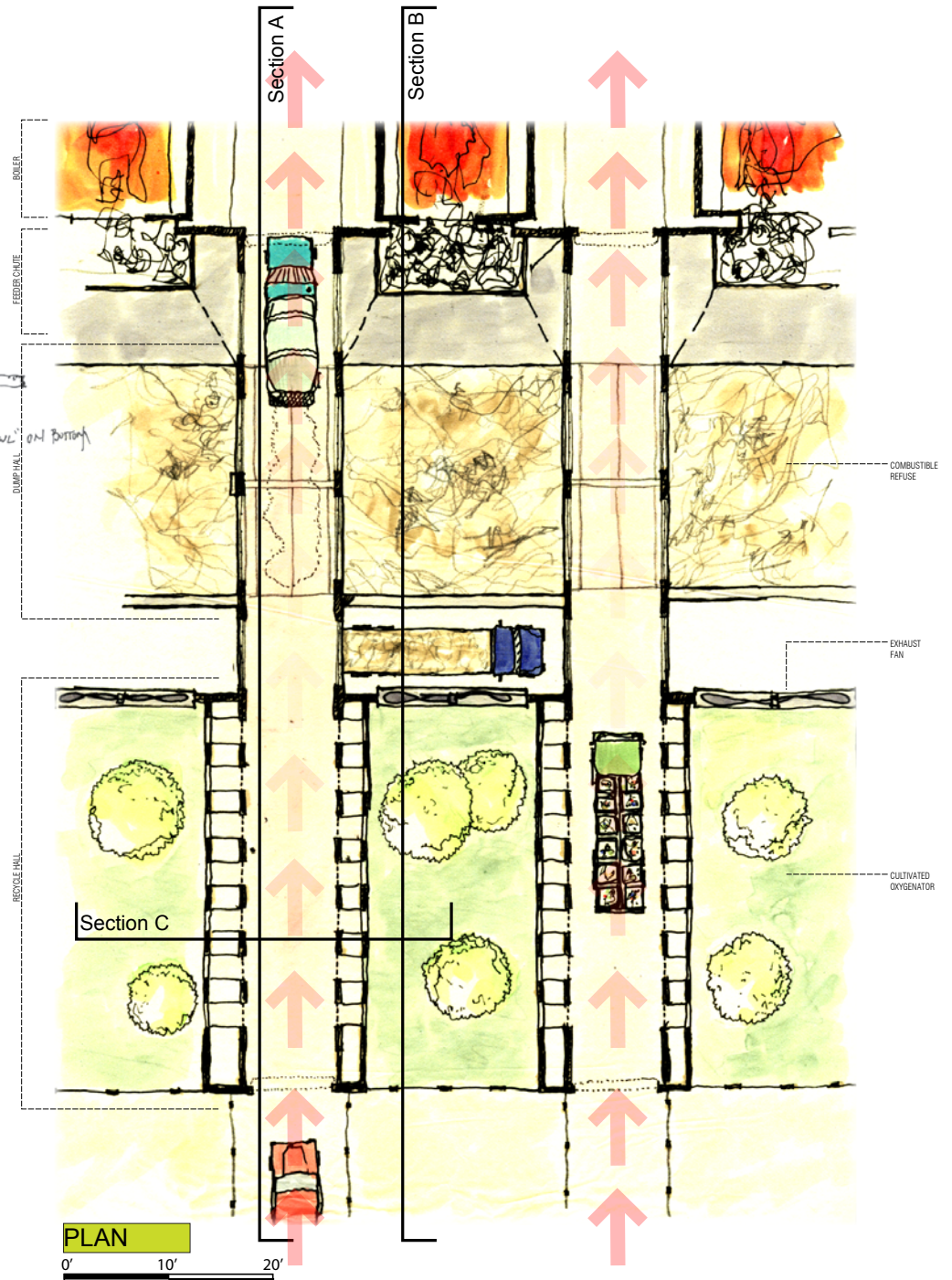


PROCESS - SITE
SCHEMATIC DESIGN/
DESIGN DEVELOPMENT

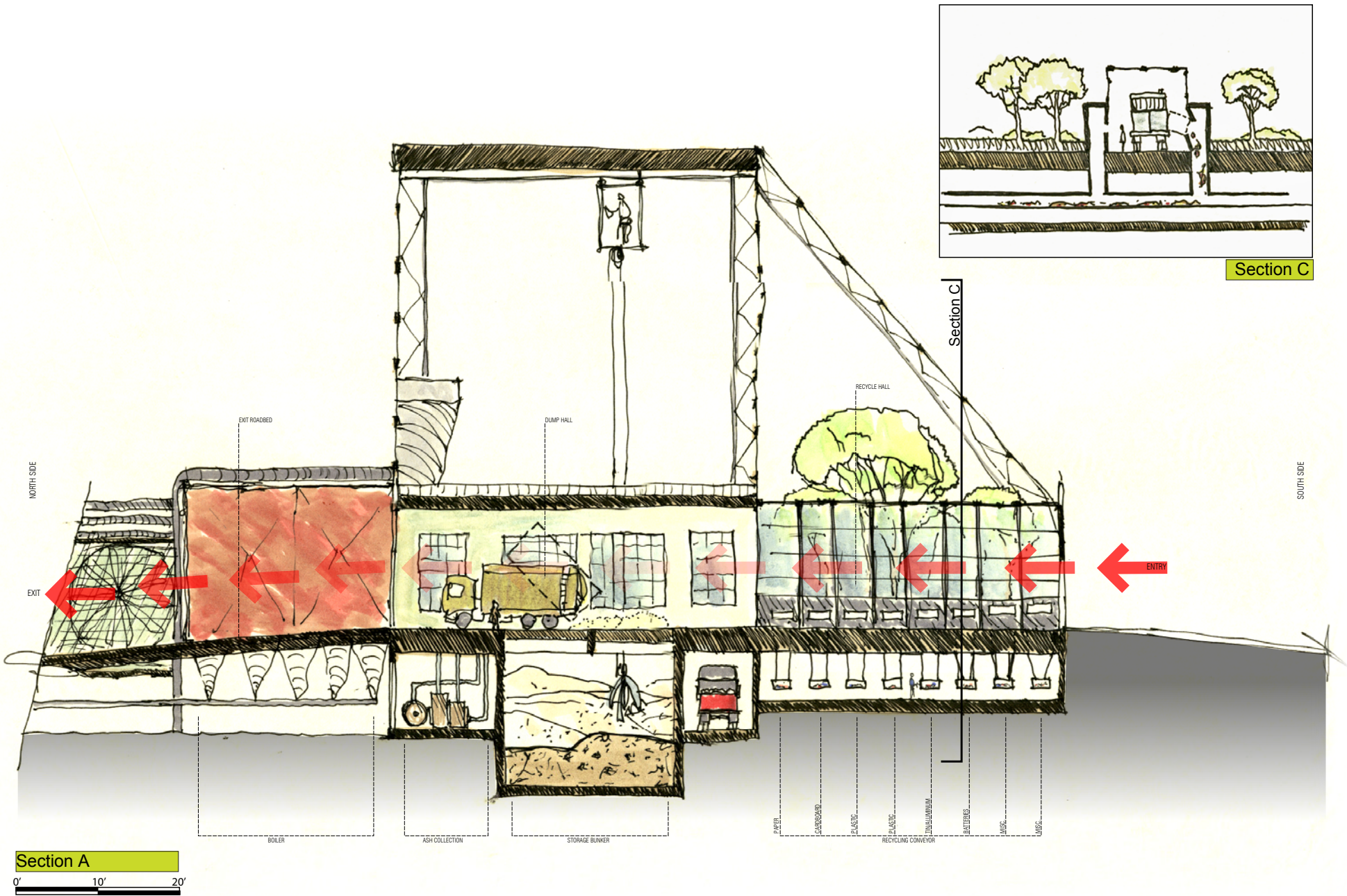


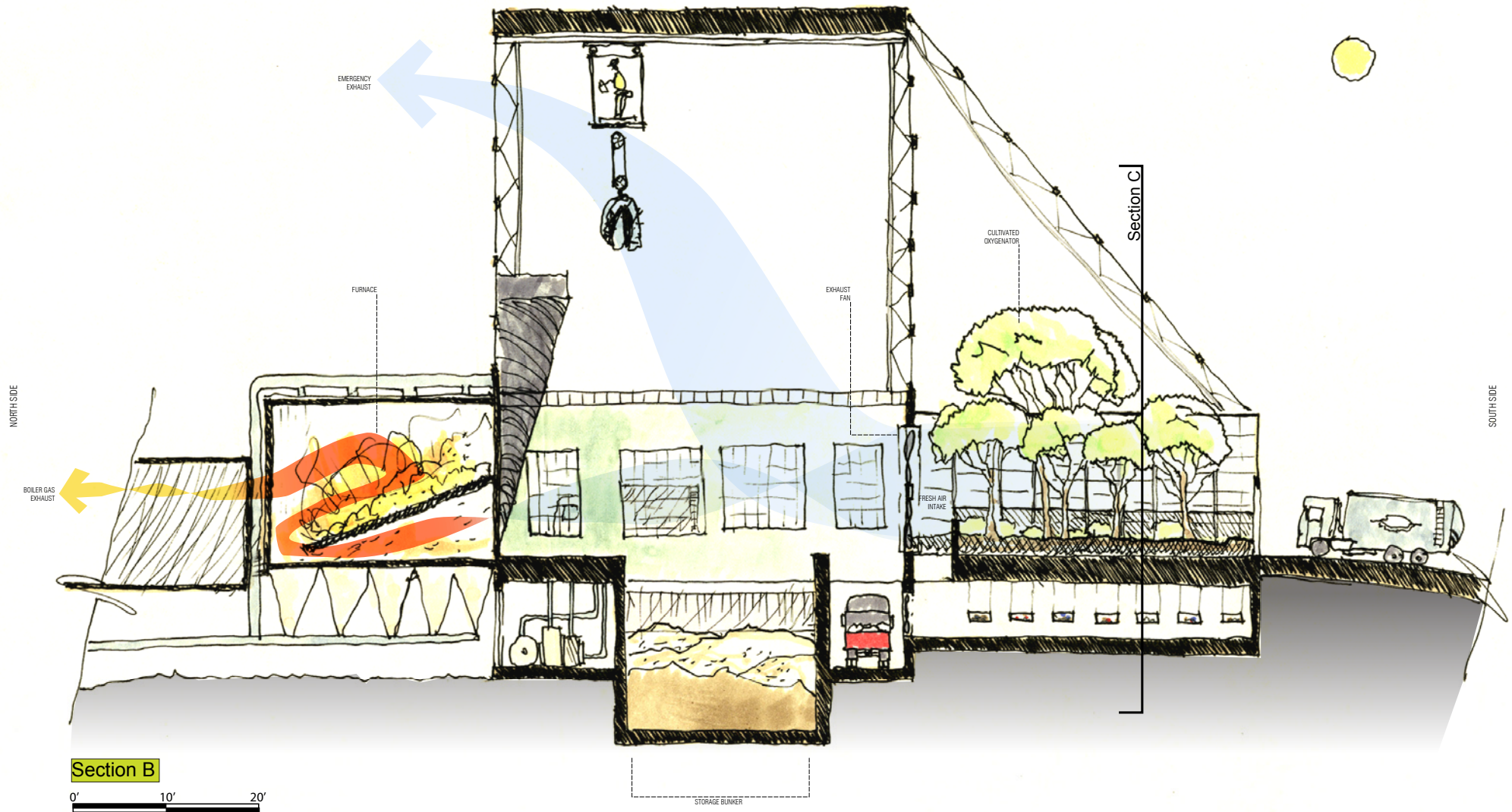
PROCESS - SECTION

SCHEMATIC DESIGN/ DESIGN DEVELOPMENT



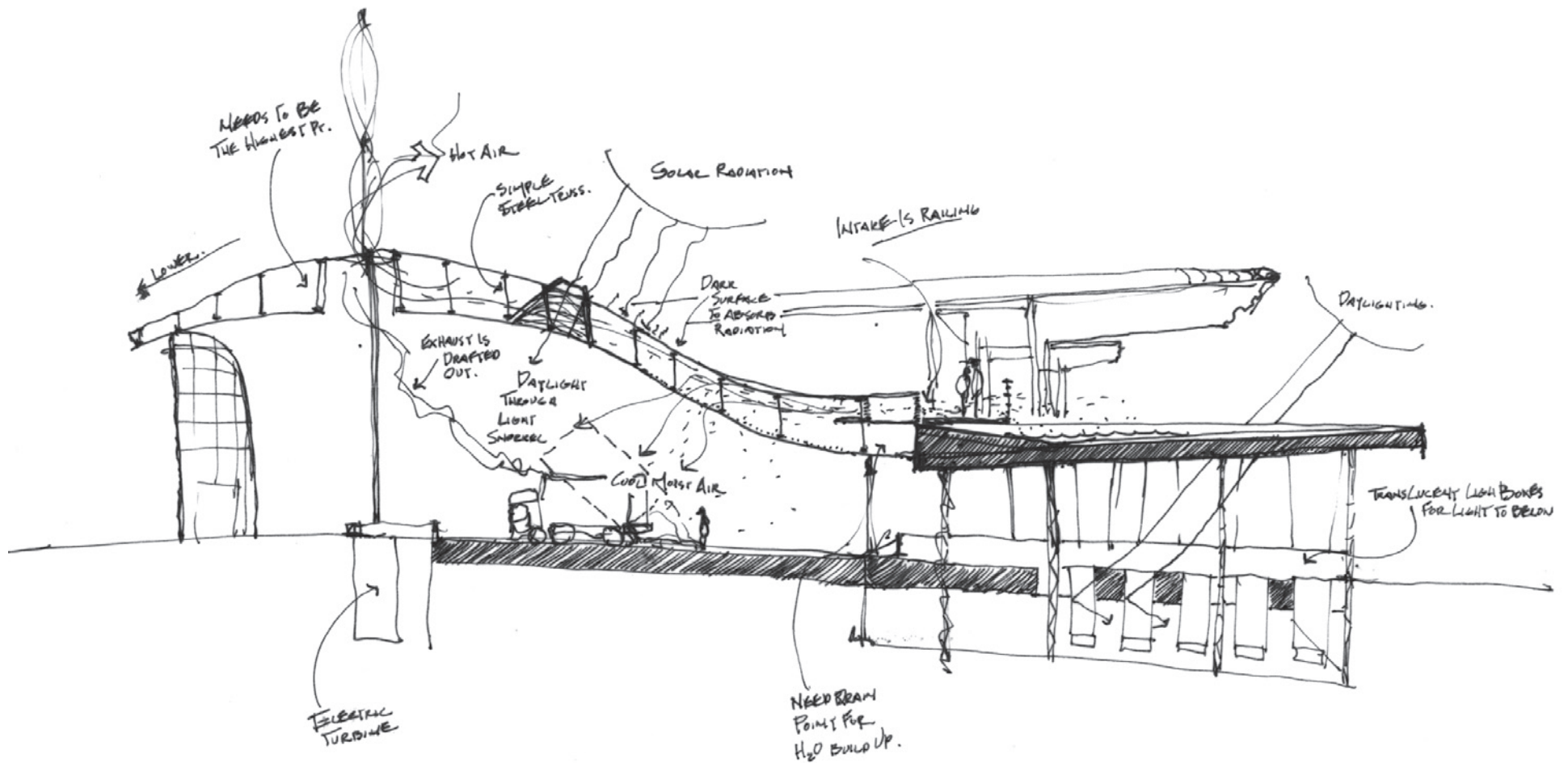
PROCESS - SECTION
SCHEMATIC DESIGN/
DESIGN DEVELOPMENT





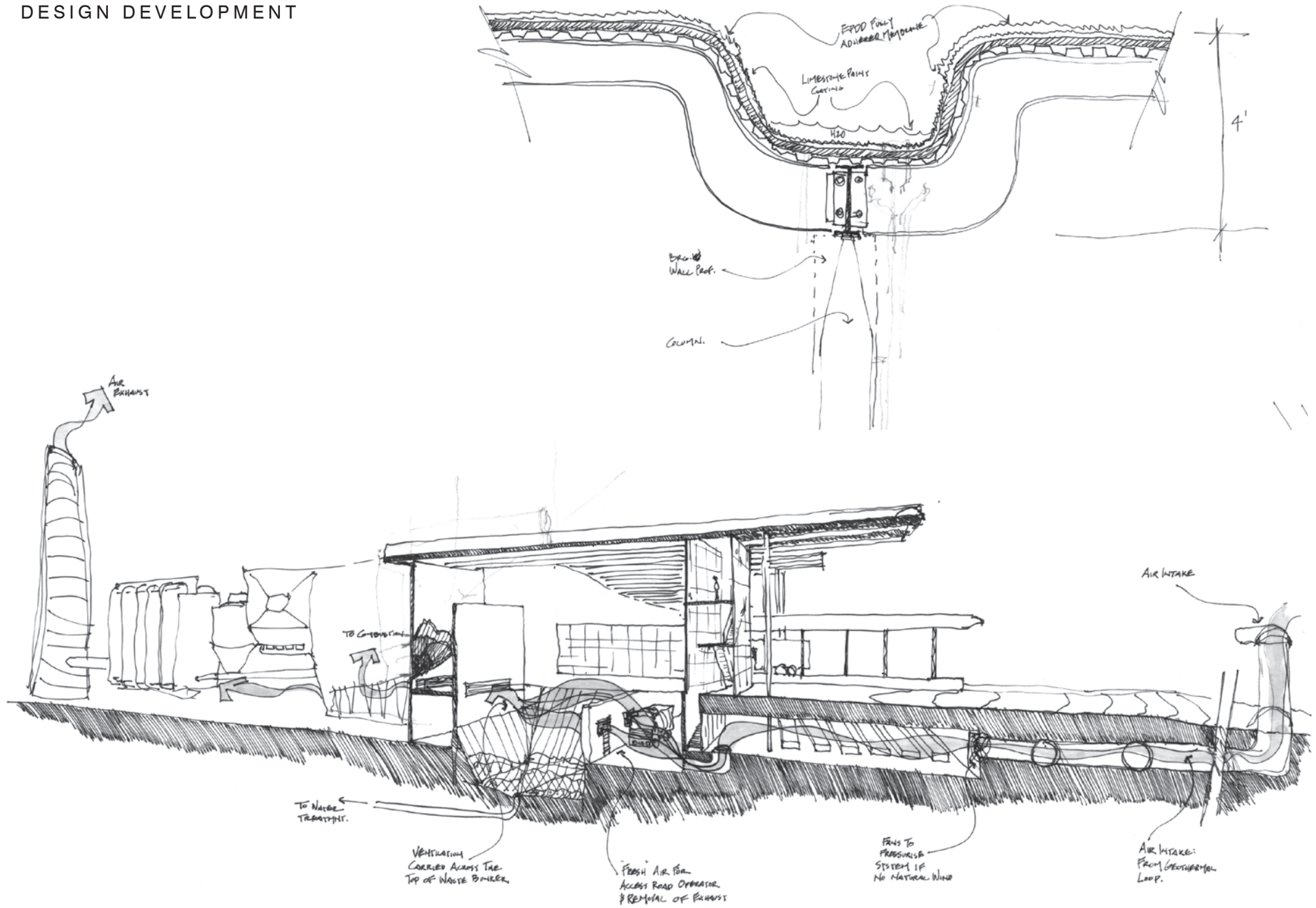
PROCESS - SECTION

SCHEMATIC DESIGN/ DESIGN DEVELOPMENT

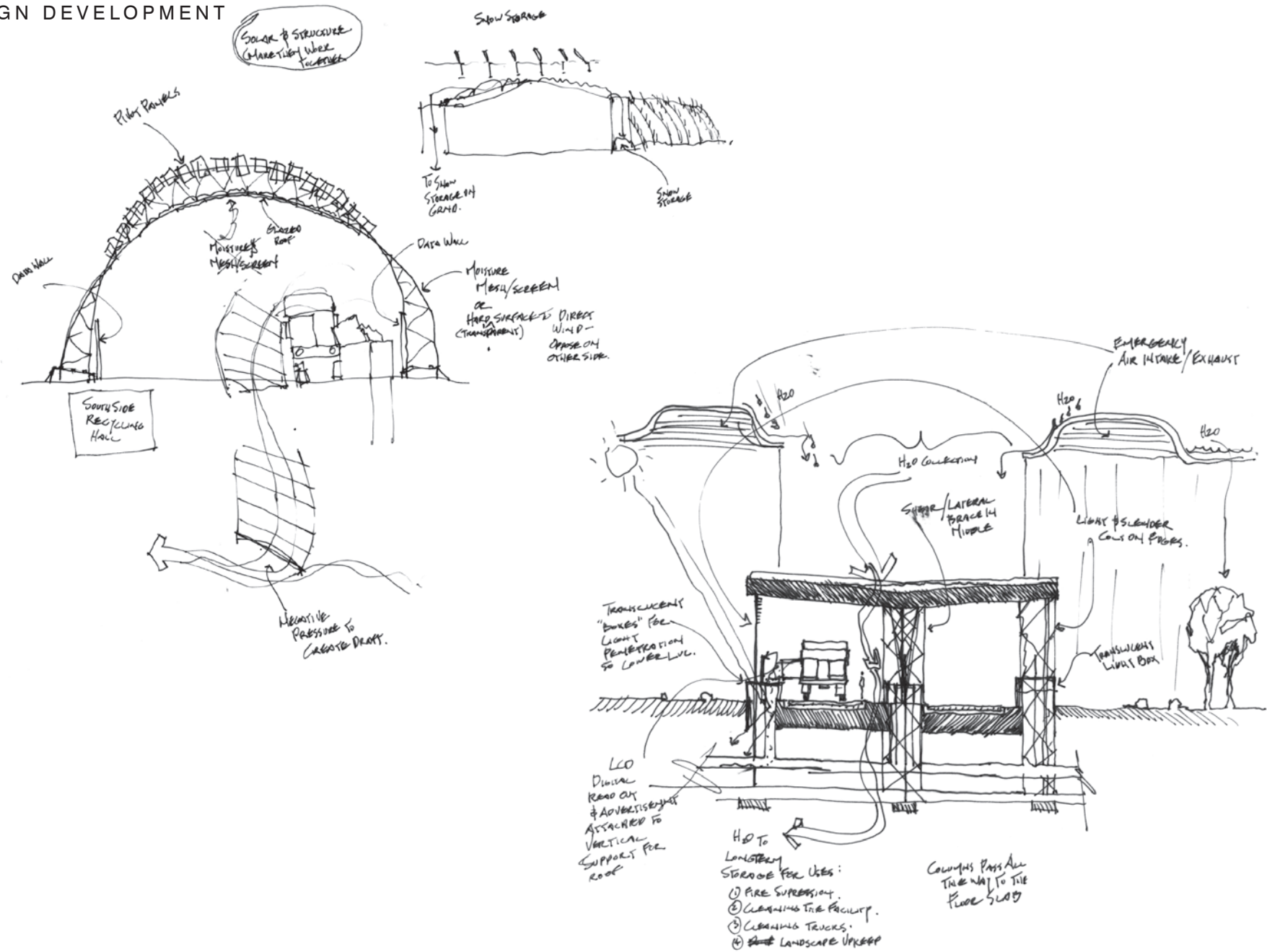


PROCESS - SECTION

SCHEMATIC DESIGN/
DESIGN DEVELOPMENT



PROCESS - SECTION SCHEMATIC DESIGN/ DESIGN DEVELOPMENT




$$\begin{array}{r} 22 \\ 150,000 \\ \hline 200,000 \\ 220,000 \end{array}$$

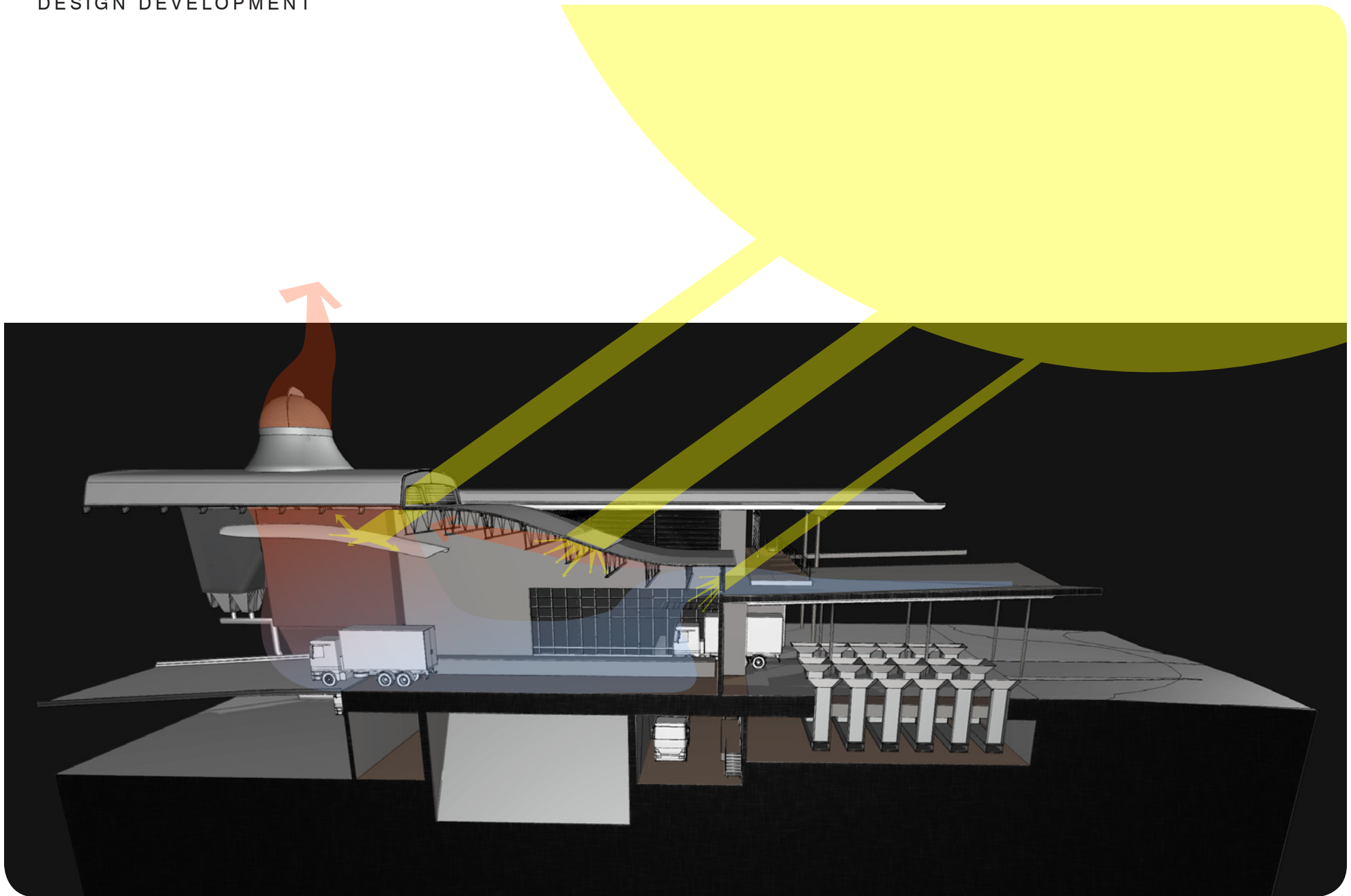

WASH WATER USE / DAY						SPRINKLER SPREAD	4.8
SH (GPD)	GPV	WASH WATER WHEEL WASH WATER WHEEL WASH	WASH WATER WHEEL WASH	WFW 1500	WPT 75000		
16	200	250		775	38750	1414	
GPV (GPD)	28	123	75				
					Total	2.214	6,027

MAKE 42" FOR ALUMINUM MAX AVAILABLE CAPACITY

96,000 Fr³
120 DAY CAPACITY
~~120 DAY CAPACITY~~
~~120 DAY CAPACITY~~

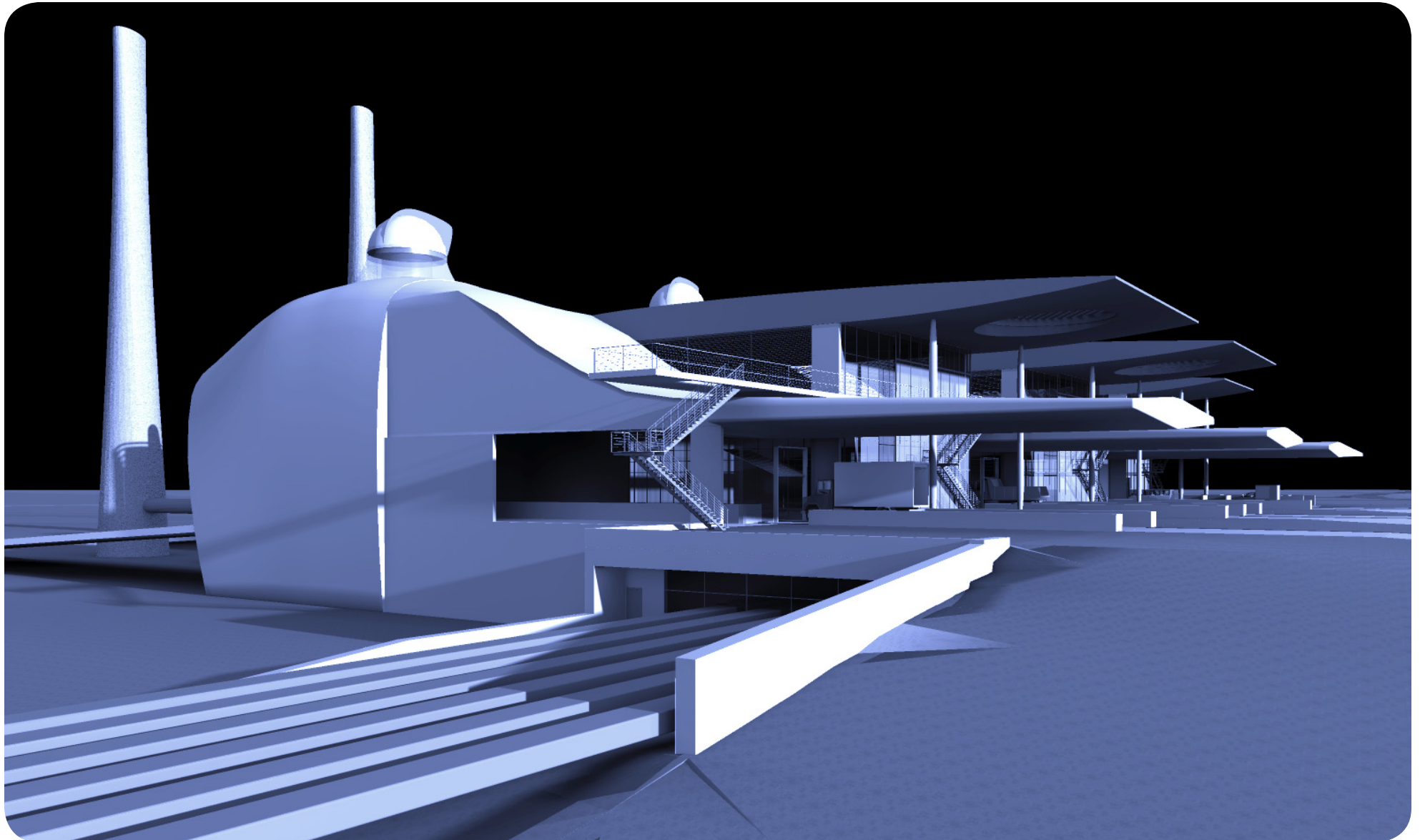
CATCHMENT AREA:
Total (Approx.) - 48,171
Collection Capacity - 362,340 Gall
(Based on Annual
Rainfall).

PROCESS - SECTION
SCHEMATIC DESIGN/
DESIGN DEVELOPMENT

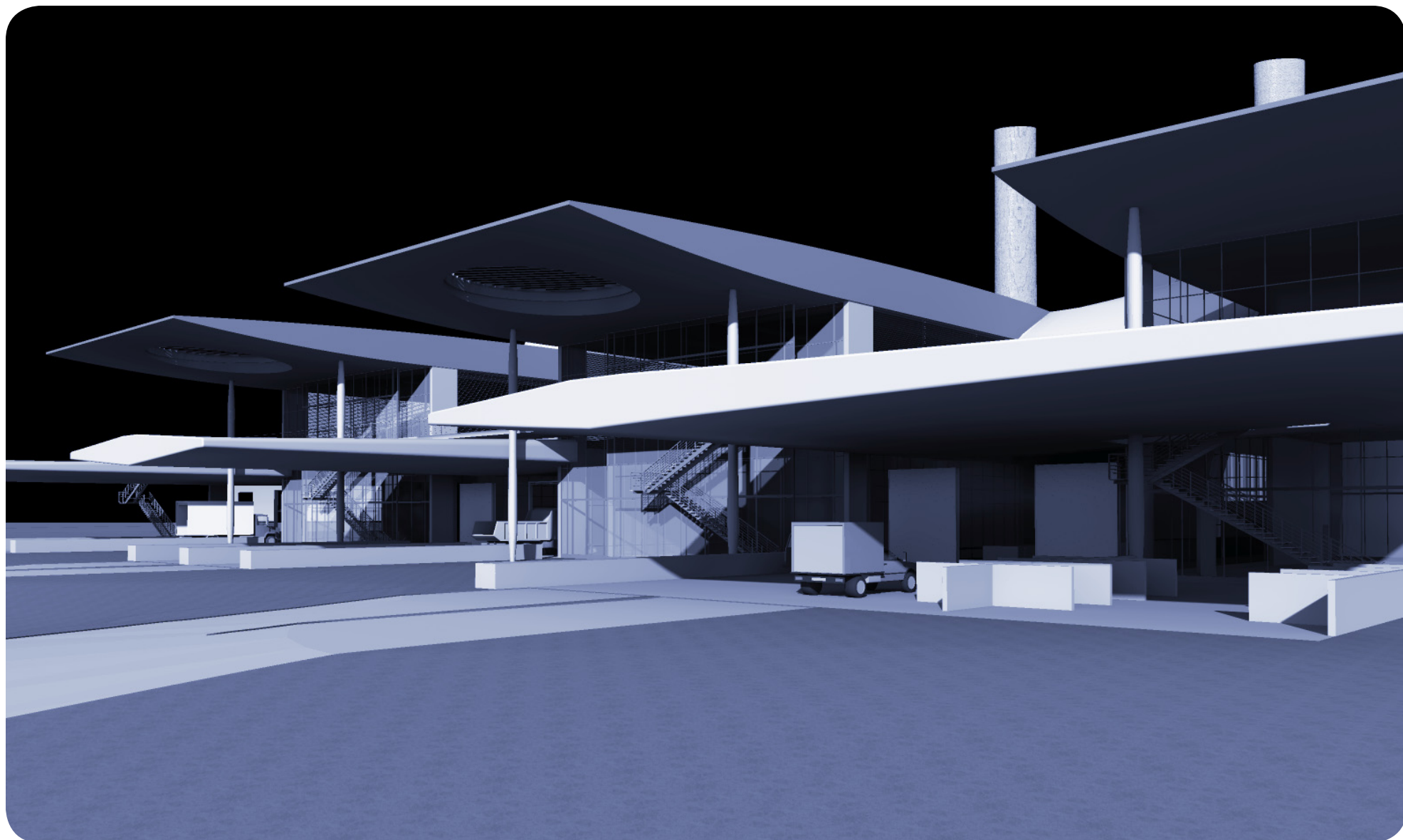


PROCESS - PERSPECTIVE

SCHEMATIC DESIGN /
DESIGN DEVELOPMENT

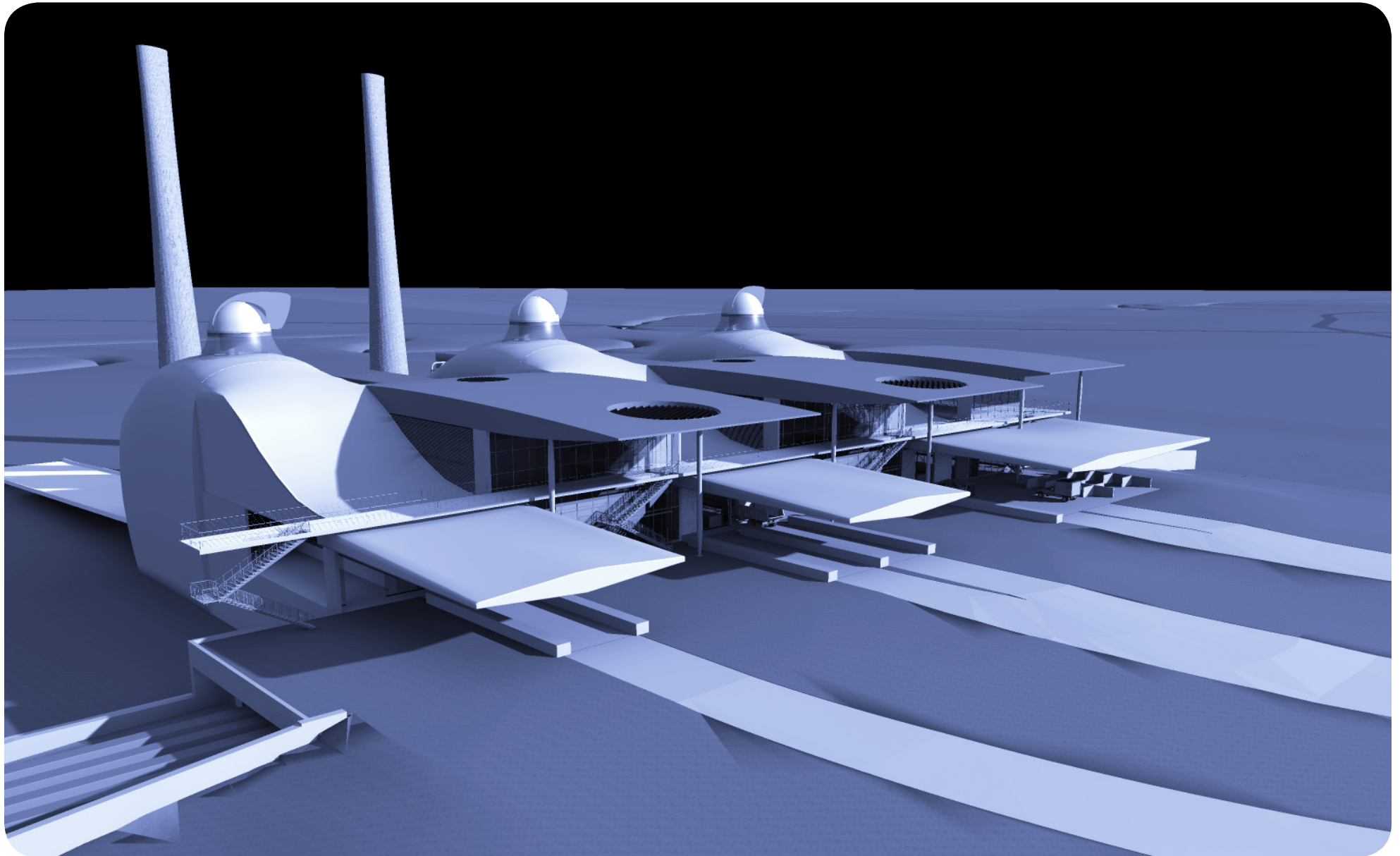


PROCESS - PERSPECTIVE
SCHEMATIC DESIGN/
DESIGN DEVELOPMENT

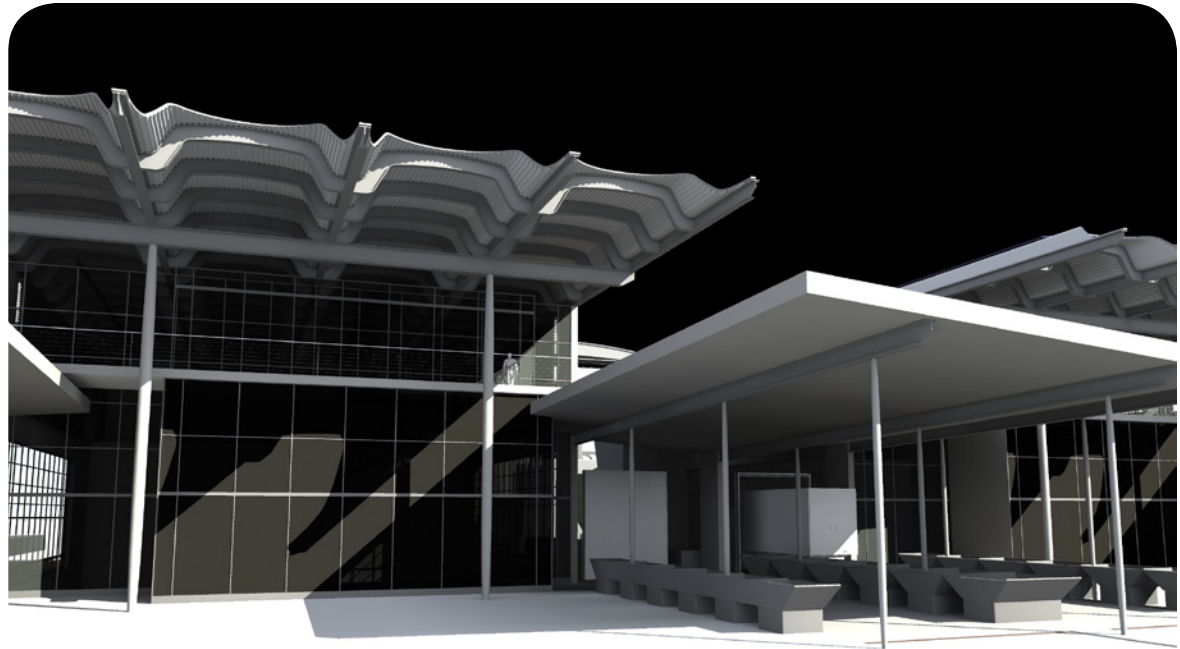
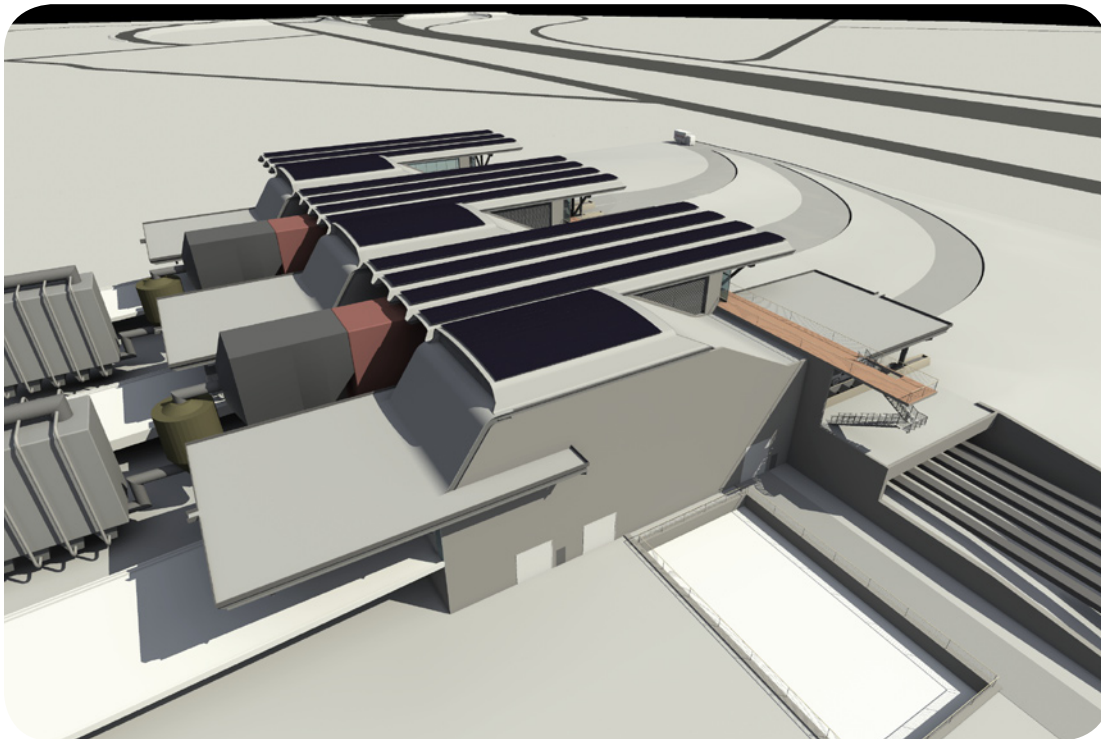


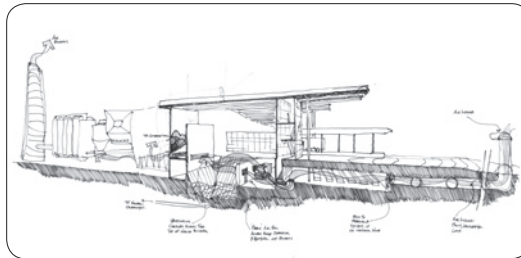
PROCESS - PERSPECTIVE

SCHEMATIC DESIGN/
DESIGN DEVELOPMENT



PROCESS - PERSPECTIVE
SCHEMATIC DESIGN /
DESIGN DEVELOPMENT





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