Empowering Los Angeles:

A Vision for a New Urban Ecology

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

This thesis addresses the future of sustainable energy distribution and transportation in the United States. Predictions of future energy and transportation demands promote localized energy as the most likely situation. Existing proposals outlining the benefits of decentralized energy production fail to engage architecture. Cities will require new architectural typologies that can integrate new energy infrastructure in the city.

Los Angeles, the archetype of the decentralized American city, is introduced as a case study. The city is examined at multiple scales for the integration of a decentralized electricity network and an efficient transportation infrastructure. Siting the proposed facilities capitalizes on new and existing transportation infrastructures and local energy resources. The new electricity-transportation infrastructure is adapted to a decentralized network functioning on principles of ecosystems and energy economics at an urban scale.

Energy storage is paired with multi-modal transportation to develop new architectural and urban typologies. This enables the decentralized urban proposal to function as a network exhibiting mutually beneficial characteristics.

Acknowledgements

Advisor: Lola Sheppard

Committee: Val Rynnimeri and John Straube

External Reader: Kevin Stelzer

I would like to thank my committee Lola Sheppard, John Straube and Val Rynnimeri for their time and wisdom. Constructive criticism from visiting critics of the class including Mason White, and John McMorrough offered valuable insights to this work. I extremely appreciated key advice from my advisor Lola Sheppard during later portions of design. For help with electronic systems throughout this thesis, I acknowledge Sean Martin and Daniel Sufrin for their expertise and valuable insight.

I would like to give special consideration to key professors in my education as an architect. Tom Monteyne, Tijen Roshcko and Richard Milgrom. I believe my work today would be much less ambitious and thorough if not for their encouragement and thoughtful advice in my undergraduate education.

I would like to thank my mothers, siblings and friends for their unconditional love, encouragement and support.

Dedication

To my father, my hero.

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All illustrations, maps, and photographs have been produced by the author unless otherwise sourced in the list below.

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List Of Abbreviations

AC - Alternating Current
CASE - Cities As Sustainable Ecosystems
CHP - Combined Heat and Power
CNG - Compressed Natural Gas
DC- Direct Current
DG - Distributed Generation
DOE - United States Department of Energy
EIA - U.S. Energy Information Administration
EROEI - Energy Returned on Energy Invested
EV - Electric Vehicle
HV- High Voltage
kV - Kilovolt
kW - Kilowatt
kWh - Kilowatt Hour
LA- Los Angeles
LADOT - Los Angeles Department of Transportation
LADWP - Los Angeles Department of Water &Power
MTA - Metro Transportation Authority
mV - Megavolt
mW - Megawatt
mWh - Megawatt Hour
PHS - Pumped Hydroelectric Storage
PE - Pacific Electric Railway
PV - Photovoltaic
ROW - Rights of Way
TOD - Transit Oriented Development
Wh - Watt Hour

Thesis Question:

What new architecture will emerge with the advent of a new cooperative electricity-transportation infrastructure?

Introduction

The electrical infrastructure throughout North America is overtaxed and antiquated. Cities rely on massive imports of energy from distant power-plants, which entails considerable energy losses. Just over 80 percent of the United States population resides in urban or suburban areas.[1] Supporting these urban populations requires extensive transportation infrastructures that currently depend on non-renewable energy resources. Cities must look to renewable energy resources and high efficiency infrastructures to support their future populations.

The future of energy in North America is dependent on current energy practices. Hubbert's curve, global climate change and oil-motivated hostilities are indicators that new energy strategies are required.

This thesis is founded on a speculative future scenario. This scenario is supported by expert predictions[2] on future energy demands and energy crises of the past. There are few if any sustainable future projections that do not include a drastic reduction

Fig 1.01 Los Angeles

Right: Satellite photo of Los Angeles and surrounding areas.

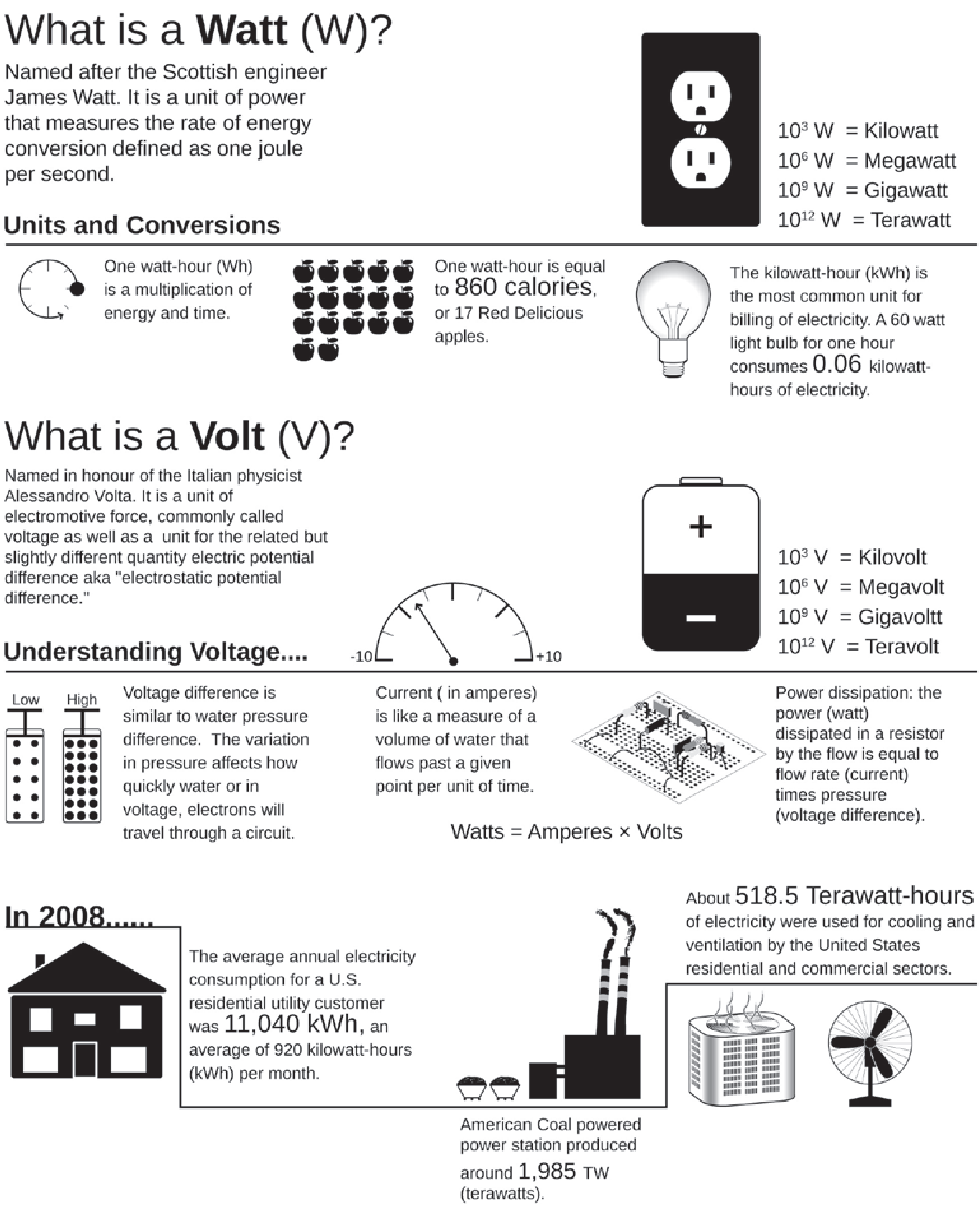
Fig 1.02 Los Angeles, California

Positioning Los Angeles within the United States

1 U.S. Census Bureau, "Population, Housing Units, Area, and Density for Metropolitan Areas: 2000," Density Using Land Area For States, Counties, Metropolitan Areas, and Places, 2010, http://www.census.gov/population/www/censusdata/density.html (accessed. Dec 20, 2010).

2 These include forecasts from the Energy Information Administration, The Department of Energy, and Writers from the Post Carbon Reader Series.

Fig 1.03 What is a Watt?



in energy consumption for the sustainability of future societies. Therefore, reducing consumption of energy will be at the forefront of the thesis' future scenario. Energy markets can be weaned off oil and coal dependent energy systems through smart and integrated campaigns for renewable energy systems that append onto existing energy infrastructures. Renewable energy resources will increase their contribution to the electrical power industry. This in turn will promote electricity infrastructures to become more sophisticated and efficient in North America. The demand for quality electricity for commercial use and more electricity for transportation will forever alter the city as we know.

The implementation of a decentralized electricity network will improve energy systems in the city and accommodate intermittent renewable energy systems. This will lead to improved energy efficiency and lower land-use. Current trends in electric automotive innovation and renewable resource technology complement energy-conscious initiatives but fail to recognise the systemic incongruencies. One significant conflict is the lack of energy storage infrastructure for intermittent power supplies. This thesis pairs renewable energy resources with energy storage systems to allow for effective on-demand energy sources for utility providers. As Stephen Graham suggests:

> We might all decentralize from the Londons and Copenhagens of this world, and actually live as "prosumers" - hybrid producers and consumers- in individualized "electronic cottages."[3]

States such as California are leading the way with programs for renewable energy production. California is described as being the "precedent State in electricity generation from non-hydroelectric renewable energy sources, including: geothermal power, wind power, fuel wood, landfill gas, and solar power."[4] Given LA's polycentric urban form and its leadership in the renewable energy market, the city makes for an ideal case study to explore the architectural implications of a new distributed and smart energy infrastructure.

Existing urban design projects, economic proposals and engineering studies outline the benefits of city-localized energy production but fail to address the role of architecture in their proposals. Incorporating electrical infrastructure with local transportation architectures negotiates the relationship between intelligent distribution and patterns of energy use. Designing for a sustainable future of energy and transportation infrastructures will require new architectural typologies. This architecture is required to respond to the fragility of energy markets while informing the population of its functions. The pairing of transportation and energy networks can remedy planning discrepancies while simultaneously creating mutually beneficial conditions. Organizing the city's electric and transportation infrastructure requires each community to act as a microgrid[5] within the polycentric network. This system appends onto Los Angeles' organization as a collection of autonomous yet connected areas that initiating a new agenda for the management of electricity.

3 Stephen Graham, "Urban Network Architectures and the Structuring of Future Cities," in *New Urbanism and Beyond: Designing Cities for the Future*, ed. Tigran Haas, 212 (New York, NY: Rizzoli International Publications, 2008).

4 U.S. Energy Information Administration. "California Quick Facts," 2010, http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA (accessed. Dec 20, 2010).

5 A microgrid is a combination of electricity sources and loads within a given proximity that operates autonomously and cooperatively with the centralized grid responding to physical and/or economic conditions.

Literature Review

Energy Crisis

The international concern for global Peak Oil[1] and other resource depletions serves as inspiration for this thesis design and system choices. Predictions by the Energy Information Administration and the International Energy Agency illustrate the United States' heavy reliance on non-renewable resources for future energy needs. The work of Michael Brune and Steven Schafersman discusses cultural, political and economic strategies for weaning North Americans off oil. Brune's *Coming Clean*[2] offers a good introduction to how our society views energy and energy resources. Discussions on Peak Oil often lead to the theories by M. King Hubbert. Hubbert's predictions alongside other theories on oil extraction deadlines are included in Schafersman's transcription of the "Round Table Discussion on World Oil Supply and the Consequences for America."[3] Schafersman's notes also provide a background to the thesis' assumption that hybrid and electricity transportation will replace those based on oil.

Complementing Brune's and Schafersman's arguments are several essays from *The Post Carbon Reader*[4], a collection of online essays from talented individuals tackling issues of our current and upcoming decades. These essays provide insightful recommendations to threats of worldwide sustainability. Specific chapters in *The Post Carbon Reader* discuss available energy resources, concerns of urban power outages, infrastructure initiatives and transportation issues all within the context of sustainability. Supplemental research on energy storage media as well as electricity production resources are provided in figures and appendices. These works will give credence to a future state of energy in North America. The various theories construct a chronicle of predicted events that establishes the context for this thesis. This narrative is specific to the United States; it is a speculation of the country's state of energy and the resulting effects on urban lifestyles in 2030.

The *Post Carbon Reader* establishes a need to evaluate the United States' plans for future electricity generation. A revised plan will be complemented by the DOE's "National Electric Delivery Technologies Roadmap - Transforming the Grid to Revolutionize Electric Power in North America." This document outlines critical technologies for the 2030 grid architecture. Appended to this is the "Potential Benefits of Distributed Generation... 2005"[5] by the U.S. Department of Energy. Together these documents outline a future grid framework encompassing Smart[6] energy technologies, energy storage and distributed energy production.

Los Angeles

The city of Los Angeles is used as a case study for a decentralized electricity production network paired with transportation infrastructure. This combination cooperates with existing and newly planned public transportation

1 Peak Oil is the point where production of petroleum reaches a point of total ultimate production.

2 Michael Brune. *Coming Clean: Breaking America's Addiction to Oil and Coal* (San Francisco: Sierra Club Books, 2008).

3 Steven Schafersman. "Petroleum Experts Debate Impending World Oil Shortage. Round Table Discussion on World Oil Supply and the Consequences for America," October 10, 2002, http://www.freeinquiry.com/skeptic/badgeology/energy/debate-review.htm (accessed. October 16, 2008).

4 Heinberg, Richard, and Daniel Lerch, eds. *The Post Carbon Reader*. University of California Press, 2010. http://www.postcarbon.org/reader (accessed. November 28, 2010).

5 U.S. Department of Energy "The Potential Benefits of Distributed Generation and Rate-Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of the Energy Policy Act of 2005," 2007, http://www.otii.com/pdf/DOE_1817_Study_2_05_07_%282%29.pdf (accessed. March 3, 2009).

6 Smart technologies are electric based devices which allow for greater feedback between electricity production, consumption and distribution agents.

infrastructure. Los Angeles is chosen for its existing polycentric organization and its known commitment to renewable energy initiatives. Based on Reyner Banham's depiction of the city in *Los Angeles: The Architecture of Four Ecologies*[7] this thesis proposes the notion of a fifth ecology "Electric City" for Los Angeles.

According to Banham's work the patterns of movement throughout the city were historically dominated by public transportation, specifically the original rail infrastructure.[8] The extensive historical evolution provided by Banham serves as a guide to understanding the role and growth of transportation within Los Angeles, offering insight into the historical connections between transportation and energy. The remnants of the previous rail infrastructure support new transit and energy infrastructures in Los Angeles. Proposed as an evolution of the previous four ecologies, the "Electric City" ecology provides the context for the thesis design proposal.

City Of Quartz[9] by Mike Davis offers a range of political, demographic and economic criticism of what Los Angeles has become. *City Of Quartz* describes the evolution of Los Angeles into a celebrity, scientific, engineering, car-centric world city. Davis is especially interested in the paradigm of privatized public space in Los Angeles. This is exemplified in his criticism of downtown Los Angeles and its unforgiving public space. Davis's characterization of Los Angeles' public space was inspiration for the inclusion of higher quality public space networks in this thesis.

The unique urban morphology of Los Angeles is presented in *Postmodern Geographies*[10] by Edward Soja. Soja depicts Los Angeles as a *technopolis*, a nineteenth-century industrial metropolis. Los Angeles is presented as an iconic city that embodies the American dream. This dream is built on capitalist ideals that are dependent on cheap and abundant oil. Soja describes Los Angeles' as founded on capitalist suburbanization, the proliferation of the personal automobile, and a stimulated war-time economy. Soja's economic-urban theories of Los Angeles' character imply that any future proposal for the city should positively impact peripheral centers, highway travel and industrial practices. Soja regards Los Angeles as a carefully planned spatial realm that incorporates labour and social interconnections. In this sense the city is a place-maker that provides segregated areas with distinct activities and populations that result in a unique character. Each new energy-transportation typology integrates itself with local situations to form responsive energy and transportation hubs.

7 Reyner Banham, *Los Angeles: The Architecture of Four Ecologies* (London: The Penguin Press, 1971).

8 Banham, *Los Angeles: The Architecture of Four Ecologies*, 78.

9 Mike Davis, *City of quartz : Excavating the future in Los Angeles* (London: Verso, 1990).

10 Edward W. Soja, *Postmodern Geographies: The Reassertion of Space in Critical Social Theory* (New York: Verso, 1989).

Transportation

Dead Cities[11] by Mike Davis provides evidence of the political and economic wars that the Metropolitan Transportation Authority (MTA) has fought in the past. Davis recognizes past mistakes and political/economic inefficiencies but remains insistent that Los Angeles needs a sophisticated and diversified public transit system. Reyner Banham's account of the development and destruction of the electric rail system in Los Angeles follows Davis's argument on the present state of public transportation but describes the resulting cultural effects. Banham provides a greater understanding of the role of public transportation for the city's population.

In 2008 The Los Angeles County Metropolitan Transportation Authority (METRO) published the "I want a Mobile Future: 2009 Long Range Transportation

11 Mike Davis. *Dead Cities: And Other Tales* (New York: The New Press, 2002).

Plan"[12] (LRTP). This report establishes a benchmark for the METRO's goal for municipal public transportation networks by 2030. This plan outlines strategies for expansion, maintenance, cooperation with similar transportation entities, new proposals and development strategies. This thesis expands upon the strategies and propositions of the LRTP with the intention of coordinating appropriate transportation infrastructure.

Energy, Mobility and Diffuse Urbanism

Gilbert and Perl describe a necessary Transportation Revolution[13] in their report, "Transportation in the Post Carbon World." Gilbert and Perl illustrate the changes required for grid-connected vehicles in order to shift mobility toward an electricity-based system. The implementation of an electric transport system is presented as more convenient and productive compared to a petroleum based system. Gilbert and Perl's confidence in electric vehicles (EV's) supports a new cooperative electric and transportation infrastructure.

Amy Friedlander's *Power and Light: Electricity in the U.S. Energy Infrastructure 1870-1940*[14] and James C. Williams' *Energy and the Making of Modern California*[15] provide a history of the public utilities in the United States and California. Water is presented as an exemplary utility. The implementation of its infrastructure serves as a model for the telegraph, telephone, railroad, gas and electricity utilities. Friedlander's account verifies the major shifts in lifestyle that are accompanied by shifts in the structure and type of public utilities. Introducing a new infrastructure will rely on examples from past utility transitions and historical accounts to predict possible shifts in lifestyle and daily activities within the affected network. Williams offers a detailed historical time-line of the technological electrical advances and major shifts in how electricity was produced and consumed.

The National Technology Laboratory's Modern Grid Initiative[16] for the United States Department of Energy examines future electricity needs and scenarios. The initiative helps to outline electricity providers' responsibilities and the expectations consumers have of them. The ultimate goal of the initiative is to promote sustainability in existing cities and energy networks. This parallels the goals of the Department of Energy's "Smart Grid"[17] proposal. Both documents promote decentralized urban energy networks and inform urban design considerations for production-plant configurations and distribution. The United States Department of Energy's report "The Potential Benefits Of Distributed Generation And Rate-Related Issues That May Impede Their Expansions"[18] provides insight into the limiting factors of a decentralized network. The report provides a catalogue and analysis of energy production strategies in the United States and looks for possible energy solutions through decentralized energy production.

12 Metro - Los Angeles County Metropolitan Transportation Authority, "I want a Mobile Future: 2009 Long Range Transportation Plan," 2010, http://www.metro.net/projects_studies/images/final-2009-LRTP.pdf (accessed. December 20, 2010).

13 Richard Gilbert and Anthony Perl, "Transportation in the Post Carbon World," in *The Post Carbon Reader*, ed. Heinberg, Richard, and Daniel Lerch, (University of California Press, 2010. http://www.postcarbon.org/reader (accessed. November 28, 2010).

14 Amy Friedlander. *Power and Light: Electricity in the U.S Energy Infrastructure 1870-1940* (Virginia: Corporation for National Research Initiatives, 1996).

15 James C. Williams, *Energy and the Making of Modern California* (Akron, OH: The University of Akron: 1997).

16 National Energy Technology Laboratory, "A Vision for the Modern Grid," August 2008, www.netl.doe.gov/moderngrid/docs/A%20Vision%20for%20the%20Modern%20Grid_Final_v1_0.pdf (accessed. April 14, 2010).

17 U.S. Department of Energy, "Smart Grid," 2010, http://www.oe.energy.gov/smartgrid.htm (accessed. December 20, 2010).

18 U.S. Department of Energy "The Potential Benefits of Distributed Generation and Rate-Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of the Energy Policy Act of 2005."

System Principles

North American cities' energy production and distribution systems will have to aim towards a state of zero entropy[19] if they hope to survive Peak Oil and increasing populations. This means that constraints and feedback should be the principle concern of our infrastructure. Richard Heinberg's "Limits to Growth"[20] describes a design strategy that contradicts current supply and demand strategies. Heinberg asserts that the catalyst of a sustainable society is "the realization that we are living today at the end of the period of greatest material abundance in human history."[21] The strategy presented by Heinberg considers the economic, population and environmental factors of growth which are all linked to dependence on fossil fuels. Heinberg outlines a "post-carbon transition" in thinking and resource allocation. This transition is characterized by a shift towards renewable energy resources that are promoted as the only solution to sustain quality human life.

The urban proposal component of this thesis is informed by Peter Newman and Isabella Jennings' book *Cities as Sustainable Ecosystems*[22]. Newman and Jennings organize cities based on nature ecosystems and biospheres. These systems operate on a set of rules that utilize resources in an efficient and effective manner. Newman and Jennings' system based theories for design have a sustainable goal of zero entropy within food, energy and cultural systems. The energy system they describe introduces many new renewable energy production modes into the city. These zero entropy systems rely on a decentralized network to function. Sven Stremke's paper "Energy-Conscious Regional Design: Synergy between Ecosystem Thinking and Spatial Planning"[23] integrates ecosystem and energy strategies. Stremke's paper specifically addresses the transition to renewable energy resources and the creation of self-sufficient regional networks. The polycentric urban network component of this thesis will share characteristics with Stremke's autonomous networks. As a result, this thesis will include an integration of renewable energy strategies into a decentralized system.

Design

Architecture is often absent in discussions of energy infrastructure in contemporary America. Average electricity customers have little knowledge about where their energy is coming from and how it is distributed in their region. Michael Jakob's work is an exception. Michael Jakob's article, "Architecture and Energy of the History of an Invisible Presence"[24] situates neglected energy infrastructures within the built landscape. Jakob attributes all architecture as an end result of energy, claiming the history of architecture and the history of energy are parallel. Jakob promotes architecture as a significant symbol of advances and changes in the use of energy for human consumption. "What the grandeur of those impressive structures symbolizes is the grandeur of energy's 'mission', and of the 'epoch-making' electrical

19 Zero entropy refers to the state in a system where there is no measure of energy that is not useful for work. It should be noted that zero entropy cannot exist in reality, it is a mathematical ideal for mechanical systems.

20 Richard Heinbergs "Limits to Growth" in *The Post Carbon Reader*, ed. Heinberg, Richard, and Daniel Lerch, (University of California Press, 2010. http://www.postcarbon.org/reader (accessed. November 28, 2010).

21 Heinberg, "Limits to Growth," 3.

22 Peter Newman and Isabella Jennings, *Cities as Sustainable Ecosystems: Principles and Practices* (Washington: Island Press, 2008).

23 Sven Stremke "Energy-Conscious Regional Design: Synergy between Ecosystem Thinking and Spatial Planning," October 2008, http://architecture.ucd.ie/Paul/PLEA2008/content/papers/oral/PLEA_FinalPaper_ref_227.pdf (accessed. December 20, 2010).

24 Michael Jakob, "Architecture and Energy of the History of an Invisible Presence," *2G:International Architecture Review*. no. 18 (2001).

society which has made them possible."[25] Jakob promotes energy infrastructure as a symbol of civilization and a monument to technological innovation.[26] This thesis is sympathetic to Jakob's position and promotes an appreciation of architectural energy infrastructure.

There have been several past initiatives to create buildings that will 'save' North American culture from a petroleum crisis. The most famous incident sparking such initiatives was the oil crisis of 1973. This is well documented in the book *Sorry Out of Gas*[27] by Giovanna Borasi and Mirko Zardini. The design responses catalogued in this work respond to energy use and efficiency as well as establishing trends and building practices. The optimistic ideologies in the future design proposal of this thesis for a decentralized energy-transportation network is comparable with responses to the oil crisis of the 1970s. The innovative futuristic proposals for a better future and responsible communities will be adopted in this thesis, inherently presenting the possibility of an ideal situation.

25 Jakob, "Architecture and Energy of the History of an Invisible Presence," 8.

26 Jakob, "Architecture and Energy of the History of an Invisible Presence," 10.

27 Zardini, Mirko., and Giovanna Borasi, eds. *Sorry Out of Gas: Architecture's Response to the1973 Oil Crisis* (Montreal: Canadian Centre for Architecture, 2007).

Thesis Outline

This thesis consists of three chapters that progressively describe the design principles of the proposed facility.

The first chapter introduces the motivation for the thesis by establishing the pressing oil crisis and the United States' current dependence on petroleum resources. The implementation of energy and transportation technologies such as Smart Grid, Grid Wise, Distributed Generation and Electric Vehicles are described. These proposals are highlighted as the most promising solutions for future urban energy and transportation needs. The thesis proposes that energy and transportation networks combine to form a new type of collaborative infrastructure to benefit the urban population. The city of Los Angeles is presented as the ideal case study. The text highlights factors contributing to the segregated, highway-dominant lifestyle of the city. Any useful geographic, climatic, environmental conditions are catalogued for the introduction of the proposed collaborative infrastructure.

The second chapter focuses on the urban implications of the proposed collaborative infrastructure. This section of the thesis creates transportation and energy districts in Los Angeles. These districts are expansions of the city's transportation plan[1] and expert proposals for future electrical delivery systems (such as Smart Grid). Patterns of energy consumption, production and storage in the city establishes an urban plan of diverse energy communities and districts. Once established, the districts will reveal their dominant energy and transportation features, and their respective relationships to the larger system. The organization of communities within the districts is complemented by principles of urbanism and ecology. This method of community planning will support an urban to local economy of energy. The design of the energy and transportation network is described through a series of maps and diagrams, which communicate storage, distribution, production and transportation strategies.

Expanding on Reyner Banham's *Four Ecologies* the third chapter introduces a possible "fifth ecology" and provides a narrative on the ecology of energy communities and energy infrastructure in Los Angeles. The cooperative nature of the network is highlighted by describing the system's objectives and components at a neighbourhood scale. The relationship between energy facilities (storage, production, distribution) and their corresponding transportation hubs (stations, bus stops, etc.) is detailed through a series of drawings. The chapter focuses on one specific neighbourhood: Lincoln Park. The specific details of the system are identified using Lincoln Park as an alpha-test[2] site for the cooperative infrastructure. The neighbourhood investigation exhibits the facilities necessary for this network to function and outlines the responsibilities of the proposed facility within the context of a microgrid-neighbourhood. Various Los Angeles communities are depicted within a future setting based on a fifth energy-ecology. The neighbourhood area is depicted through examples of typologies at the scale of the community. The last section of the third chapter illustrates a local interface of the proposal. This facility is expanded from one of the previous typologies. The focus is on a specific site providing an example of how the electricity network coupled with public facilities would coexist in the surrounding community. The transportation and electrical performance of the facility are described in parallel to the design. This exhibits the juxtaposition of energy and transportation at a building scale.

1 METRO - Los Angeles County Metropolitan Transportation Authority, "I want a Mobile Future: 2009 Long Range Transportation Plan."

2 Alpha testing is a simulated testing before the proposal goes to Beta testing, in which the proposal is implemented in a limited area for further testing.

The final section summarizes the discovered effects of implementing the proposed energy-transit system. The urban and local ramifications are noted and offer a criticism of the greater spectrum of expertise required to achieve the ambitions presented by this thesis. The proposed typology is promoted for adaptation within other cities with emerging polycentric populations.

Presumptions

This thesis assumes that the finite amount of existing fossil fuels will diminish rapidly within the next thirty years. This oil crisis will create greater dependence on existing and future electrical infrastructures in cities. Personal automobiles will not disappear from North American culture, but will become less popular and transportation will have more public initiatives. Electric vehicles will offer a viable substitute but the moderation of vehicular traffic will occur. This will increase reliance on public and multi-modal massive transportation options.

There is a variety of emerging renewable energy production technologies in theoretical and preliminary stages of development. These technologies are not far from reaching our markets today, thus it is assumed that they will be available in future markets.

The introduction of electric powered and hybrid vehicles into transportation markets implies a paradigm shift in mobility and energy itself. This thesis assumes that the shift will manifest itself physically in the architecture/infrastructure of the American city.

There is no accurate prediction when and how the next oil energy crisis will emerge but what is certain is that it is coming. New strategies and agendas must begin to be developed to ensure future generations will have the potential to sustain generations to come.

Smart Grid and Grid Wise initiatives are appearing in many electricity markets throughout North America. This thesis assumes that these initiatives will affect every electricity consumer in North America in the next 15 years.

01 Research and Motivation

01-1 Power

Energy resources in America are finite. Population growth, economic crisis, and global environmental degradation are all determined by these energy resources. Amazingly, 78 percent of all of the United States energy consumption comes from fossil fuels (coal, natural gas and petroleum).[1] Investments in energy are crucial to the national economy of the United States. The United States Department of Homeland Security *National Infrastructure Protection Plan* states:

> The U.S. energy infrastructure fuels the economy of the 21st century. Without a stable energy supply, health and welfare are threatened and the U.S. economy cannot function.[2]

The current approach of the United States Department Of Energy is to maintain coal as the major electricity generating fuel, while aiming to diminish "environmental concerns" by utilizing technologies for the capture and storage of carbon dioxide; this is

1 U.S. Energy Information Administration, "U.S. Primary Energy Flow by Source and Sector" 2009, http://www.eia.doe.gov/aer/pecss_diagram.html (accessed. November 28, 2010).

2 U.S. Department of Homeland Security, "National Infrastructure Protection Plan," 2010, http://www.dhs.gov/xlibrary/assets/nipp_snapshot_energy.pdf (accessed. December 20, 2010).

Fig. 1.04 Peak Oil and the Road Ahead

Fig. 1.06 The Black Thunder surface coal mine in Wyoming.

Surface mining of coal is the predominant method of coal extraction in the United States. Of all available energy resources coal has the worst environmental impacts: in both mining and energy releases it is a primary source of green house gas emissions. Some nations have already depleted most of their original reserves, which could lead to global disputes coupled with a declining energy returned on energy invested (EROEI).

Fig. 1.05 Cleanup of the Deepwater Horizon oil spill.

Two ships work together to skim oil off the surface of the ocean in the Gulf of Mexico from the Deepwater Horizon oil rig leak. Until recent decades petroleum has been a favoured resource because it is highly transportable, can be easily stored at room temperature, is energy dense, and has been historically cheap to produce, and use.

unrealistic.

Oil companies aim to extract any viable fossil fuel resource remaining on our planet including shale oil, tar sands and bio-fuels. These fuel sources are not sustainable (see A1) and fail to consider *net energy* or *energy returned on energy invested* (EROEI).[3] Precedents noted in Fig 1.06 and 1.07 illustrate the detrimental effects of human dependence on oil.

As oil resources diminish and the environmental effects of their extraction increase, we must look to alternative energy[4] to prepare for the inevitable oil-free future. Building on M. King Hubbert's theory (Fig. 1.08) of predicting peak oil Dale Allen Pfeiffer suggested that global peak oil occurred in 2004.[5] Michael Brune pleads for society to take notice of the immediacy concerning vanishing resources:

> "For every barrel of oil we discover, we now consume three, and global demand is expected to increase nearly 40 percent in the next few decades."[6]

Currently a mere seven percent of energy consumption is a mixture of renewable resources dominated by hydroelectric and biomass. Focusing research and development on alternative energy technologies appears to be the only solution for a sustainable future of energy in modern societies.

Strategies for implementing alternative energy must consider previous trends in resource transitions. In the past these changes have occurred slowly and after decades of infrastructure and policy developments. Alternative energy depends on specialized equipment and infrastructure for energy production and distribution. Wind and solar technologies are currently the most promising renewable resources for clean energy production[7] but these are not without limitations. These and other renewable sources have variable production cycles that would require mitigation by storage and supply strategies on top of extensive investments in transmission infrastructure to connect with local electric grids. The development of alternative energy technologies are currently dependent on petroleum. Thus, the challenge of alternative energy is to become prevalent enough to break American dependence on fossil fuels for manufacturing, transportation and mining.

With the ensuing oil crisis, trends in demand versus supply will reverse. For instance, water in Southern California is a socialized resource sector. Water shortages became a state-wide concern causing California to instate *Prior Appropriation Water Rights*, forever reversing California's water sector to a supply-led market[8] by attaching annual quantity and appropriation dates to water rights. The paradigm shift toward a supply-led market will appear in our electricity markets in the close future (Fig 1.09). As non-renewable energy sources become scarce and costly, alternative energy sources' favorable EROEI and responsible resource investments will prove to have promising qualities for a sustainable energy future. It must be noted that alternative energy sources are not a substitute for our current liquid and solid fossil fuel based infrastructure. This means that the current model of centralized energy infrastructure will have to cooperate with the distributed locations of

3 These are measurements in the quality of an energy source in numerically different ways. EROEI calculates a ratio of the energy extraction process where Net Energy offers a difference between harvested resource and energy inputs for that harvest.

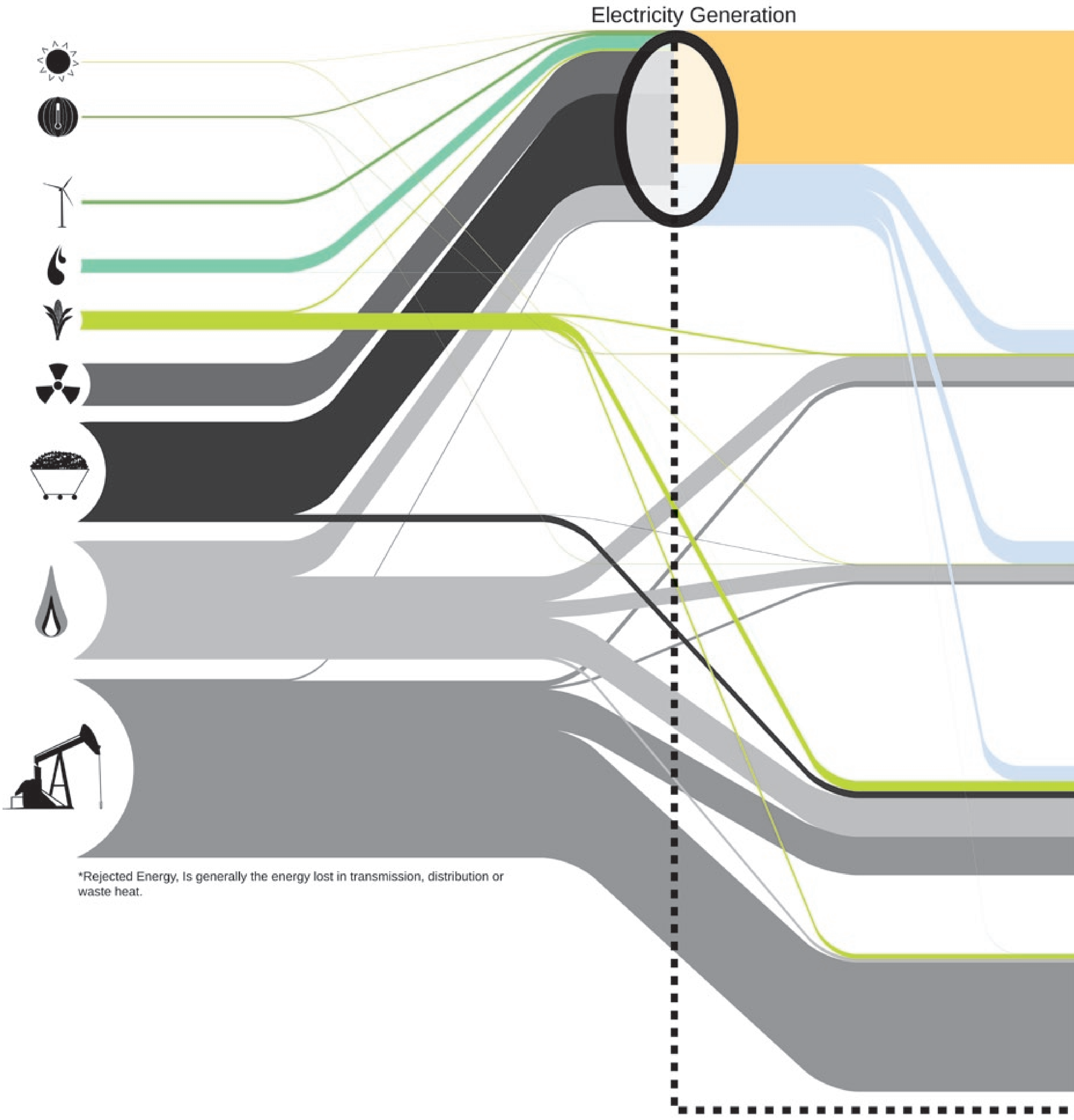
4 Alternative energy is power generated from wind, solar, photovoltaic, solar thermal, tidal, biomass, and power storage technologies.

5 Dale Allen Pfeiffer, *The End of the Oil Age* (From The Wildreness, 2004), 15.

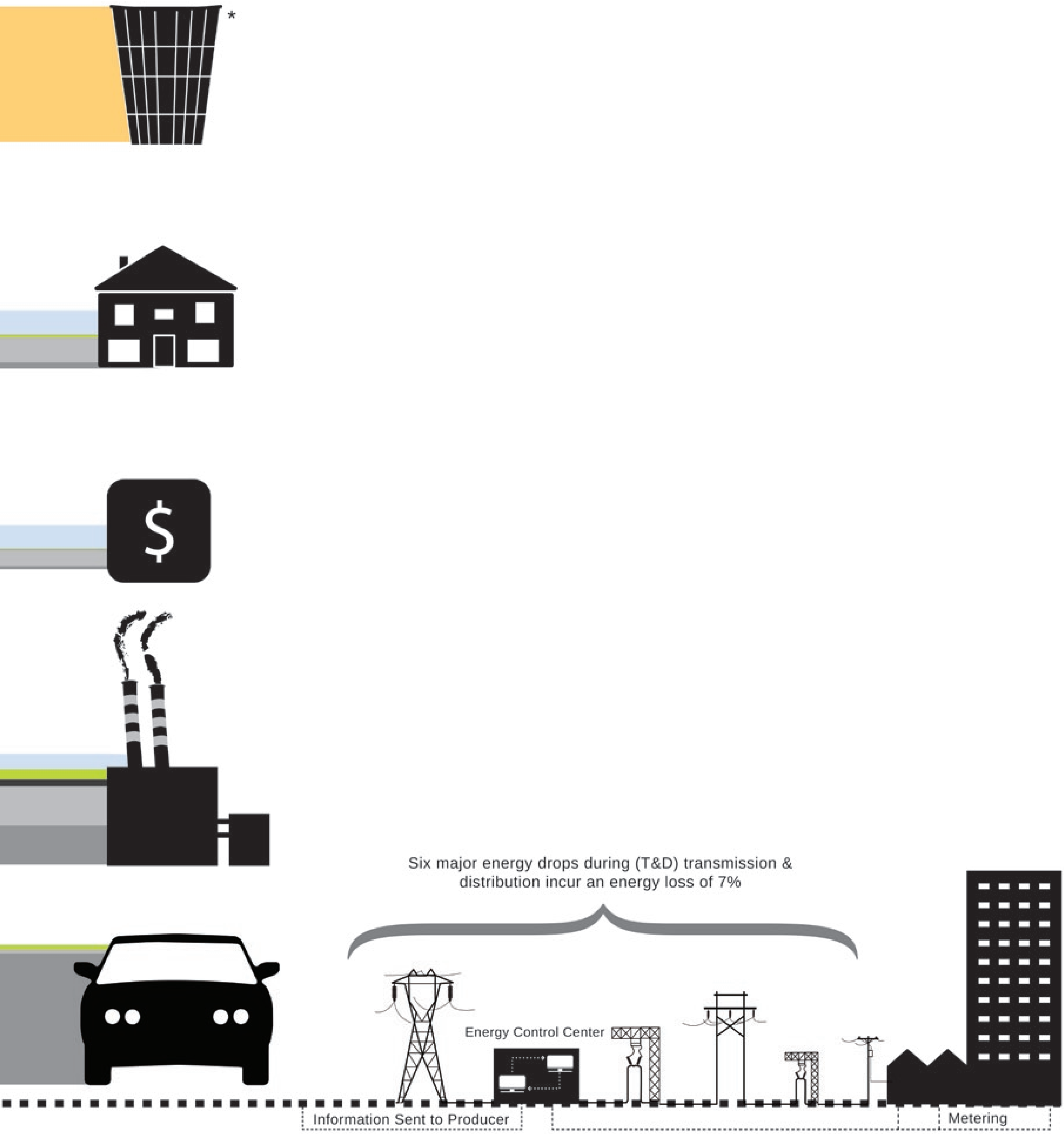
6 Michael Brune, *Coming Clean: Breaking America's Addiction to Oil and Coal*, 28.

7 See Appendix A1. p, 180.

8 A supply-led market refers to a state in the utility market where the quantity of a resource supplied decreases. This causes the equilibrium of the market price to increase while decreasing the quantity.



*Rejected Energy, Is generally the energy lost in transmission, distribution or waste heat.



Current: Centralized Electricity Generation and Distribution

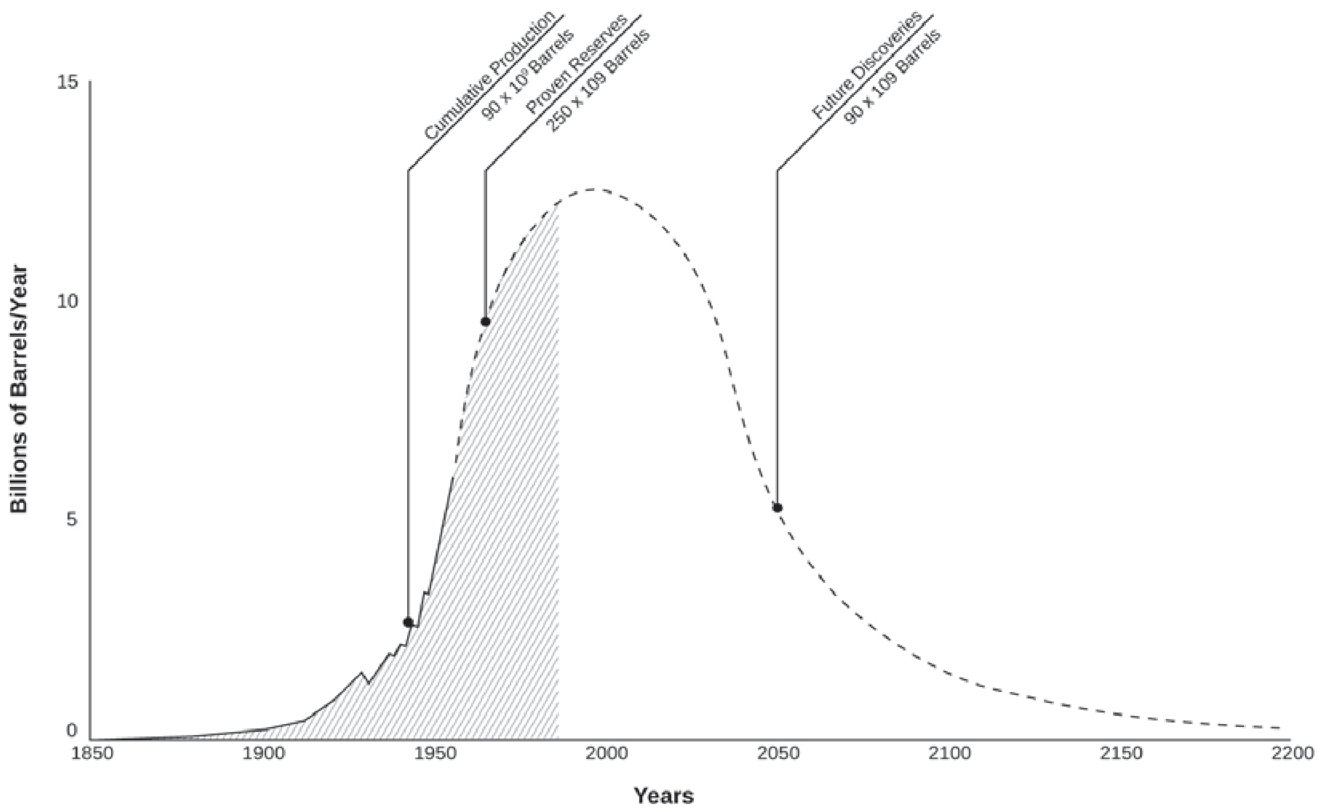


Fig. 1.08 Hubbert's Curve

M. King Hubbert's prediction of global petroleum production rates. Using past oil discovery and production data the graph attempts to provide estimates for future production. This formula had particular relevance in predicting the 1965-1970 US peak oil production from conventional sources.

alternative resources.[9]

Ideally a sustainable society would be based on a systems engineering approach to energy.[10] This requires the production of energy efficient initiatives funded by government and oil-based corporations. Krumdieck proposes the following:

> "What do people need for a high quality of life and what resources are available for sustainable human use?" The answer is a new system where sustainability is achieved by design, not as an option.[11]

Society will benefit most from a diverse and scalable energy portfolio that is able to produce large amounts of energy while incurring minimal to no environmental effects. As indicated in the Hirsch Report[12] and noted by David Fridley:

> To properly mitigate the economic impacts of peak oil, we would have needed to start fundamentally redesigning our national energy infrastructure twenty years in advance of the peak.[13]

9 David Fridley, "Nine Challenges of Alternative Energy," in *The Post Carbon Reader*, ed. Heinberg, Richard, and Daniel Lerch, (University of California Press, 2010. http://www.postcarbon.org/reader (accessed. November 28, 2010).

10 Sustainable systems based on control systems engineering is a theory described by Susan Krumdieck in "Systems Approach to Posing Problems and Finding Sustainable Solutions" .

11 Susan Krumdieck, "Systems Approach to Posing Problems and Finding Sustainable Solutions" Sept, 2004 http://ir.canterbury.ac.nz//handle/10092/210 (accessed. Dec 20, 2010).

12 The Hirsh Reoport is a document on the risks and mitigation of Peak Oil commissioned by the US Department of Energy in 2005, named after the author Robert L. Hirsch.

13 Fridley, "Nine Challenges of Alternative Energy," 3.

Electric Power

California has low energy consumption due to its mild climate and the wide spectrum of non-hydroelectric renewable energy facilities, however, it still imports more electricity than any other state.[14] The consequences of importing a vast amount of energy from extremely distant sources are evident in Fig. 1.07. Long distance transmission lines incur heavy line losses and require extra energy inputs to maintain reactive power.[15] Additionally, land acquisitions for transmission line Rights of Way (ROW) dominate thousands of acres of land, rendering it useless. In California approximately 494,000 acres of land are dedicated to electrical utility ROW. Operating these transmission lines at high voltages aims to decrease energy losses and voltage drops while delivering massive quantities of electricity. In reality the line losses are about seven percent of total power transmitted. This loss amounts to enough to provide all of Spain's annual electricity consumption.[16]

Transportation

The majority of air, land and water mobility rely on oil resources for fuel. The cheap and abundant nature of oil resources in the past enabled quick and easy expansion of gas fueled transportation but neglected

14 U.S. Energy Information Administration, *California Quick Facts*, 2010, http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA (accessed. November. 24, 2010).

15 Reactive power is energy used within the transmission lines to maintain a constant voltage and prevent voltage drops over long distance transmission. A steady current is necessary to decrease line losses from resistive heating.

16 U.S. Energy Information Administration, *International Energy Statistics: Electricity: Consumption, 2010, http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=2 (*accessed. September 2009).

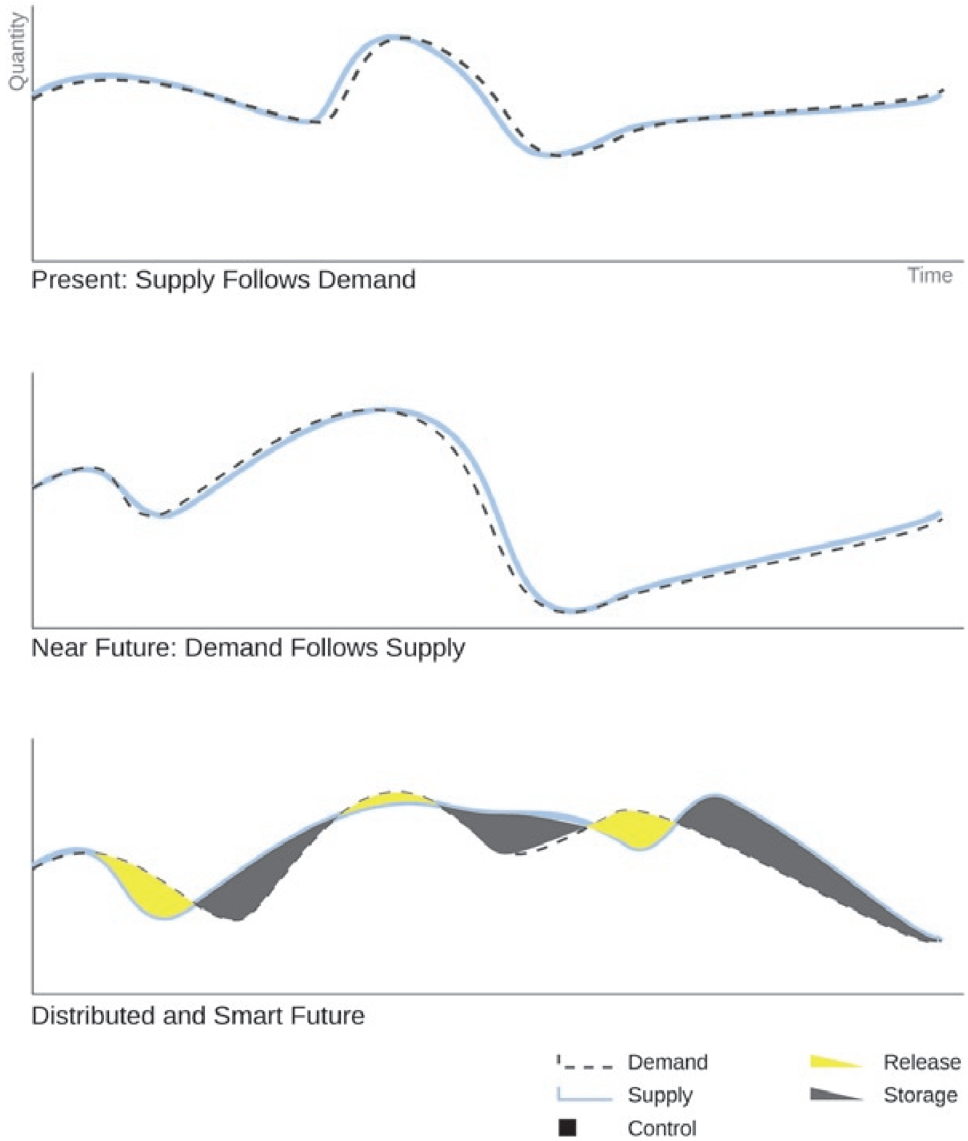


Fig. 1.09 Electricity Flow denoting supply and demand trends.

The present graph and near future graph are basically the same in that the supply and demand waves are parallel, the main difference being the paradigm shift of demand for electricity needing to follow supply in the future. The decentralized future incorporates the notion of storage where intermittent energy producers generate energy at ideal times and that energy is stored for later use.

to encourage necessary advances in energy efficiency. The pressing adjustments in energy infrastructures due to the impending oil-crisis will entail huge changes in the volume and energy sources for urban mobility. As Gilbert and Perl state:

> With some 94 percent of transport currently fueled by a derivative of crude oil, our mobility modes are positioned to be on the leading edge of the change that will be driven by the need to shift energy sources.[17]

Alterations to mobility will include transitions to alternative energy based technologies and strategies encouraging massive transport. These changes in urban mobility will have to range from progressive to extensive. Gilbert and Perl describe this as a *Transportation Revolution.*[18] This revolution is expected to be propelled by emerging vehicle markets such as hybrid and fully electric vehicles (EVs). Electric based transportation systems would loosen transport's dependence on oil energy while introducing greater capacity to move people and goods through massive and efficient transportation methods.

17 Richard Gilbert and Anthony Perl, "Transportation in the Post-Carbon World," in *The Post Carbon Reader*, ed. Heinberg, Richard, and Daniel Lerch, (University of California Press, 2010. http://www.postcarbon.org/reader (accessed. November 28, 2010).

18 A transportation revolution is defined by Gilbert and Perl as a significant alteration of a society's transport activity that occurs in 25 years or less.

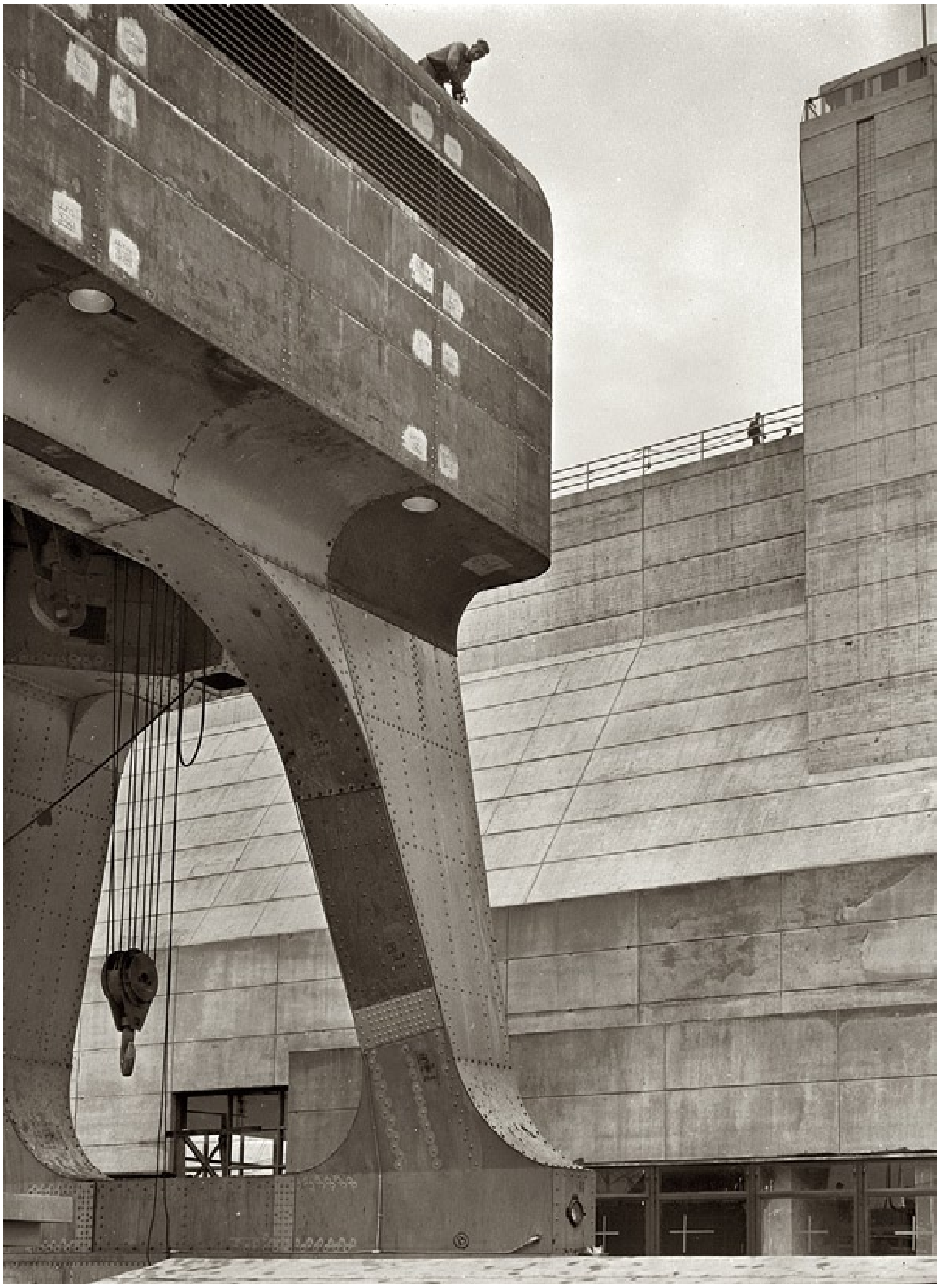


Fig. 1.10 Cherokee Dam on the Holston River

Legible Energy Infrastructure

Substations and energy infrastructure are hidden and yet ubiquitous in the modern American metropolis. These powerful units are vital in supporting the speed of information exchange and the activities of modern lives in a contemporary city. They are highly protected entities throughout the city but invisible to the lives they support. The average citizen does not have an understanding of what this infrastructure means to the life of his or her city. In the past these buildings were celebrated as monuments to the human achievement of electricity, at first locally and then nationally in examples such as the Cherokee Dam (Fig. 1.08). Now global connections such as our high-voltage transmission lines can be mapped across the continent. What happened to our appreciation of innovation in the world of energy? Today's inventions are cleverly marketed and packaged commodities; small non-solutions for energy resource depletion. Designing a sustainable future will require a new typology of architecture that make the fragility of energy markets legible while informing the population of its function. This architecture must reconnect society's ideological projection of humanity's achievements: a new architecture that revisits what was once a grand and celebrated typology. As Michael Jacob states, "Only from the synthesis of the old visibility and its ideological involvement with invisibility, which has now existed for half a century or more, can a meaningful form of energy architecture arise.[19]

It is necessary to locate energy-transportation facilities in parts of the neighbourhood, where architecture will be able to trigger complex relations. Amongst the interrelations between people and places energy stations can once again be prominent in the modern urban landscape:

19 Jakob, "Architecture and Energy or the History of an Invisible Presence," 25.

Fig. 1.11 Klösterle, Austria power station by Bruno Spagolla

> Where energy is concerned, technical colonization of the landscape is always accompanied by symbolic processes, so that the technological signs of energy are not presented as ghostly things, but as symbols of civilization.[20]

Energy infrastructures are icons of progress. They should not be hidden behind shrubs and wire fences. Modern architecture has had a fascination with industrial facilities and apparatuses for some time. Re-appropriation of industrial sites into residential or recreational programs is not uncommon. This is because the buildings they are converting are architecturally rich. A variety of previous energy centers have elegant and site specific design features. But, they are anomalies of built energy infrastructure that exhibit an integrated design strategy. These range in program but all are able, as Jacob describes, "to endow technical fact with aesthetic meaning."[21]

Current Examples (Precedence)

Energy infrastructure is present in every city. Each system has separate contextual relationships because of varying design motivations. Designing with particular adjacencies in mind can provide a thematic architecture that speaks to particular values. In some examples, pivotal energy facilities are paired with natural landscapes as instruments for understanding energy. The power station in Klösterle, designed by Bruno Spagolla, reveals the dichotomy of energy and nature through built form in Fig. 1.11. This power station performs the important task of a main switch-gear within the energy system but

20 Jakob, "Architecture and Energy or the History of an Invisible Presence," 10.

21 Jakob, "Architecture and Energy or the History of an Invisible Presence," 10.

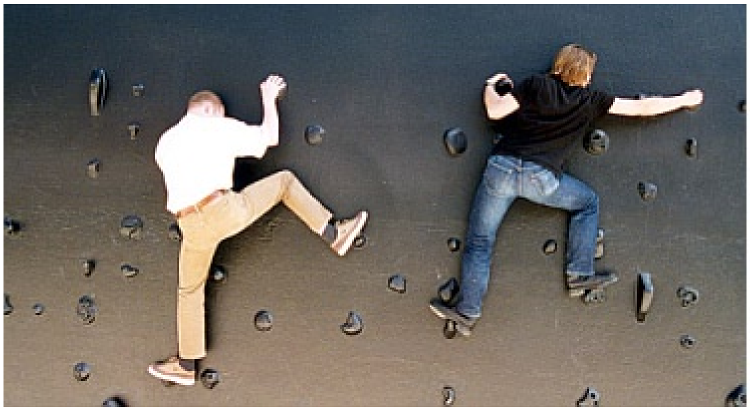


Fig. 1.12 Legible Energy Infrastructure and Facilities

Top Left and Right: The WOS 8 Heat Transfer Station combines an integral heating facility with a recreational skin. The envelope of the building is covered with interactive elements, including grips for a climbing wall.
Middle: Heatherwick Studio's BEI Teesside biomass power plant unites park and power infrastructure with existing communities. The collocation of park and power displays the dichotomy between power and nature.
Bottom: RADD Office's Power Tower/Detroit exhibits the role energy infrastructure can play in place-making and way-finding. The Power Tower would serve as a locating monument in the city while also providing energy.

while being accessible and visible to any passer-by.

Some power stations have attempted to make their latent functions visible by using bright colours and glazed enclosures. By exposing and detailing energy systems the onlookers would have a new awareness of their energy systems. The design concept of a Power Tower by RADD office (Fig. 1:12: Bottom) juxtaposes power and nature while acting as a monument in the urban landscape. The building introduces new vertical community gardens, community composting (powered by the turbine above) and social ares within the park in the form of community gathering space.

The WOS 8 Heat Transfer Station (Fig 1:12: Top Left and Right) is an ideal example. The building envelope of the station is merged with clever devices that transform the wall faces into interactive planes. A climbing wall, slide and eye-holes engage people with an infrastructure that would otherwise be invisible.

These projects serve as precedent for the end design case study of this thesis. Michael Jakob reminisces about past energy facility and infrastructure design:

> What the grandeur of those impressive structures symbolizes is the grandeur of energy's 'mission', and of the 'epoch-making' electrical society which has made them possible. [22]

Each of the previous examples exemplifies a shift back towards what Michael Jakob calls 'grandeur'. The monumental quality of each project as well as their integration with existing urban area and multi-functional agendas are values that the design proposal for a future energy infrastructure must encompass. As Jean-Gilles Décosterd states, "[a]rchitecture needs to engage with the possibilities of sustainable development and the reconciliation of development and sustainability, through the exploration of strategies that go beyond the mere advancement of green technologies."[23] This idea and the projects in Fig. 1.12 will serve as precedent models for the creation of a design agenda in the case study facility proposed later in the thesis.

22 Jakob, "Architecture and Energy or the History of an Invisible Presence," 15.

23 Jean-Gilles Décosterd, "The Osmotic Territories," in *Sustain and Develop*, eds. Joshua Bolchover and Jonathan D. Solomon, Vol. 13, 306090 Books (New York, NY: Princeton Architectural Press, 2009) 258.


US LISTED
AVERTISSEMENT:

01-2 Prediction and Proposal

The subsequent sections of this thesis are predicated on the following proposals compiled from a variety of sources. Currently, both electricity and transportation infrastructures are based on coal and petroleum. As part of the transition from nonrenewable resources, American infrastructure initiatives will need to utilize renewable energy strategies such as The Pickens Plan[1] as well as updated Renewable Portfolio Standards.[2] California, and particularly Los Angeles have taken significant initial steps toward emphasizing renewable energy-based systems in their energy portfolios.

1 The Pickens Plan is a proposal initiated by T. Boone Pickens to install new wind generation facilities along what pickensplan.com calls the "world's greatest wind power corridor." This wind proposal is expected to produce 20 percent of United States electricity.

2 Renewable Portfolio Standards are state-wide legislation with specific mandates for including renewable energy generation in energy production portfolios. Currently only 30 states have program mandates.

Fig. 1.13 An Ideal Future

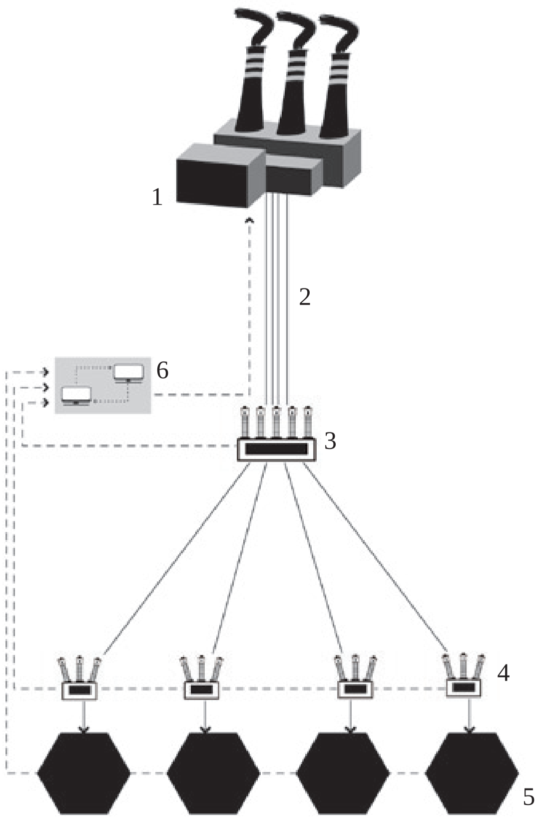


Fig. 1.14 Current Electricity System

1. Coal-fired power plant in Utah with a capacity of 1500 MW.

2. Miles of 500 kV electricity transmission lines carry power from producer to receiving stations.

3. Energy receiving stations drop voltage for transmission to power distribution stations.

4. Energy substations/distribution stations drop voltage further for local transmission and suitable levels for customer use.

5. Consumer area fed electricity by substation.

6. Energy Control Centers monitor demand from municipalities and determine plant power output.

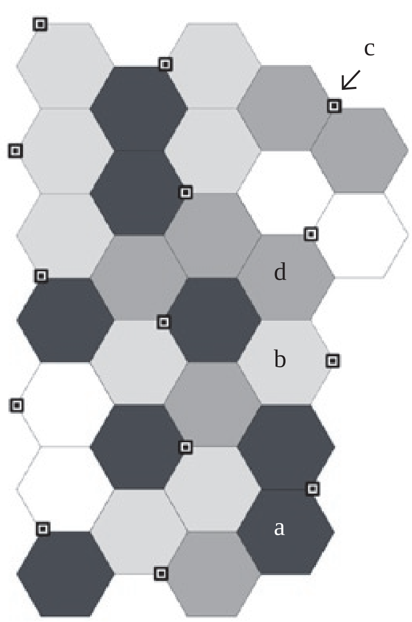


Fig. 1.15 Distributed electrical network

This network displays relationships among energy production control, distribution and consumption. Programs like Smart Grid by the Department of Energy are proposing to render the electricity grid more sophisticated and modern.

a. Energy Production Cell produces energy from local resources and transmits surplus energy to storage cells for future use.

b. Energy Storage Cell acts as a depository for excess or unused energy from neighboring Production Cells.

c. Data Centers communicate between each other to coordinate production-storage-distribution and consumer activities and respond in real-time.

d. Composite Cells produce and store energy. They are potentially autonomous cells but do contribute to the greater network.

Smart Energy Systems

The health of the electrical transmission and distribution system is the crux of the United States electricity network. There is a new agenda in the United States, the Smart Grid initiative (Fig. 1.16). The initiative acknowledges the electrical infrastructure as the key to the future of energy. Smart Grid creates feedback among consumer, distributor and producer through communication between appliances, energy control centers and energy production plants (Fig. 1.17). The future grid will rely on delivering energy appropriately according to real-time energy requirements. The proposed grid also encourages active consumer participation by facilitating communication between electricity producers and end use applications.

A dependable electric energy infrastructure twenty years from now must consist of distributed generation coordinated through smart technologies. The sequence of smart grid infrastructure starts at the generator output, through the transmission and distribution systems and ends at the loads of consumers. Information technologies for such systems are currently being designed, field tested and standardized by the Modern Grid Strategy.[3] One such field test site is in West Virginia. The key benefits of implementing smart systems are local, and far outweigh initial costs. Additionally, operating expenses will be significantly less than today's costs in municipal utilities.[4]

The implementation of a smart grid system takes approximately eight years for one municipal region. Thus, to anticipate issues occurring due to future electrical demand Smart Grid infrastructure should be initiated now.

Distributed Generation

Distributed Generation (DG) is electric power provided locally from dispersed locations at the tail end of the electricity distribution network. These typically include small scale hydro, wind photovolatic, diesel, fuel cell and gas generators scattered within an area. A fully matured DG network serving 30% of local networks loads can greatly benefit distribution systems.[5] The International Energy Agency's World Energy Investment Outlook 2003 indicates a 40 percent savings in transmission and 36% savings in distribution with an Alternative Policy Scenario for 2003.[6] Another advantage of implementing DG is the resulting stimulation of competition in electricity supply technologies.

The benefits of DG are not isolated to the electric network. DG allows residents to contribute to their local energy network. DG generators and can be designed to meet specific application requirements. Specific DG types can multiply benefits for its surrounding area. For example, combined heat and power generation (CHP) can provide useful heat and electricity for nearby buildings. This reduces their electricity costs while contributing to a better network. Fig. 1.13 presents a diurnal time-line that illustrates the production and generalized storage patterns of future Los Angeles working with distributed generation.

There is a number of projects, campaigns and theories emerging in the last decades concerning

3 Started in 2005 the Modern Grid Stratey's agenda is to "accelerate the transition to a smart grid in the United States through the development of implementation strategies and tools."

4 National Energy Technology Lab, "West Virginia Smart Grid Implementation Plan," U.S. Department of Energy, August 2009, http://www.smartgrid.gov/sites/default/files/pdfs/wv_smart_grid_implemenation_plan_09-2009.pdf (accessed December 20,2010).

5 The benefits include: capacity support, line loss reduction, stabilizing voltage, equipment longevity, power factor control and phase balancing.

6 The Alternative Policy Scenario entails more generating options resulting in higher electricity prices which ensures return on invested capital. This is found in the World Energy Outlook 2003. p. 404.

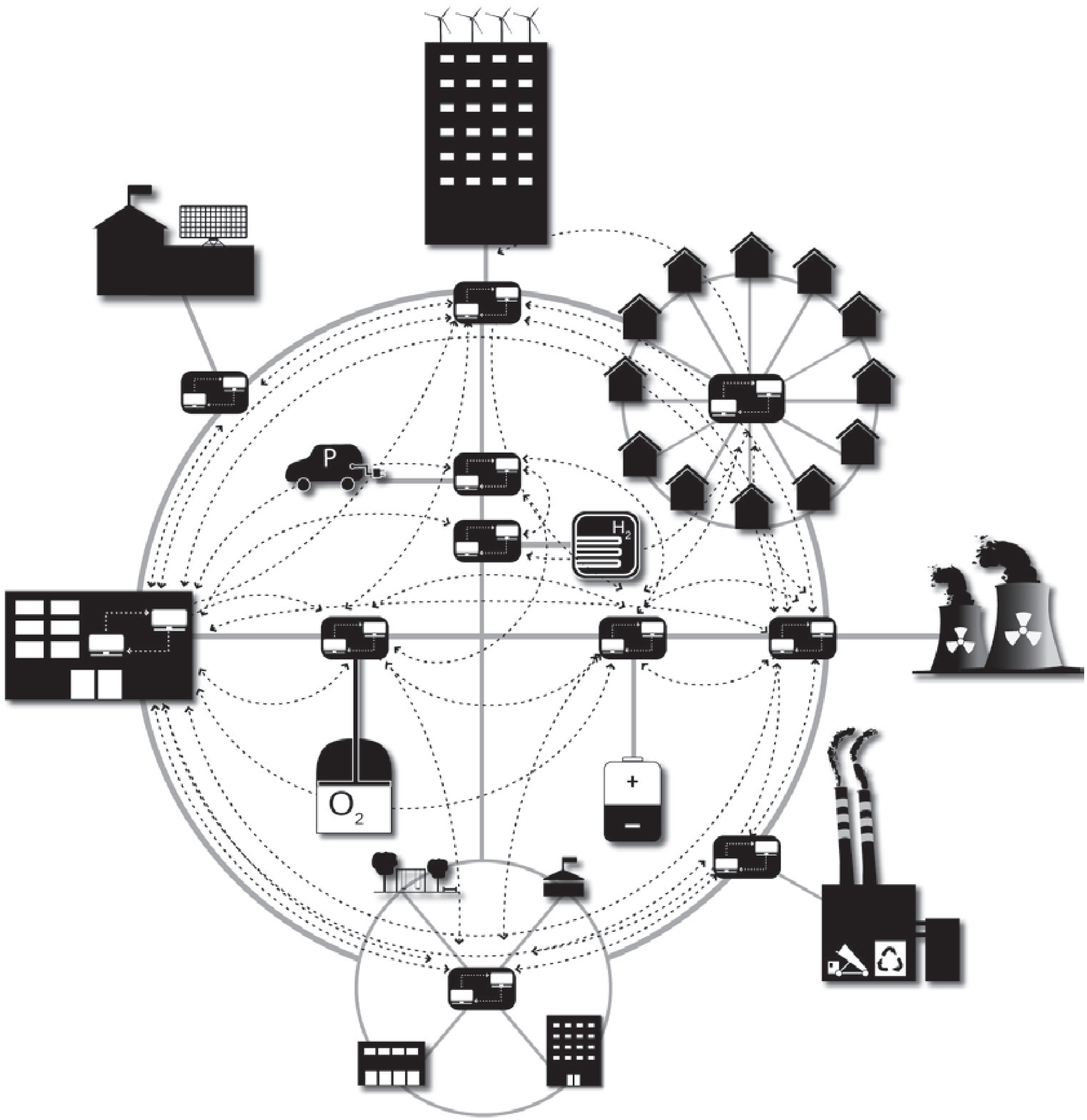
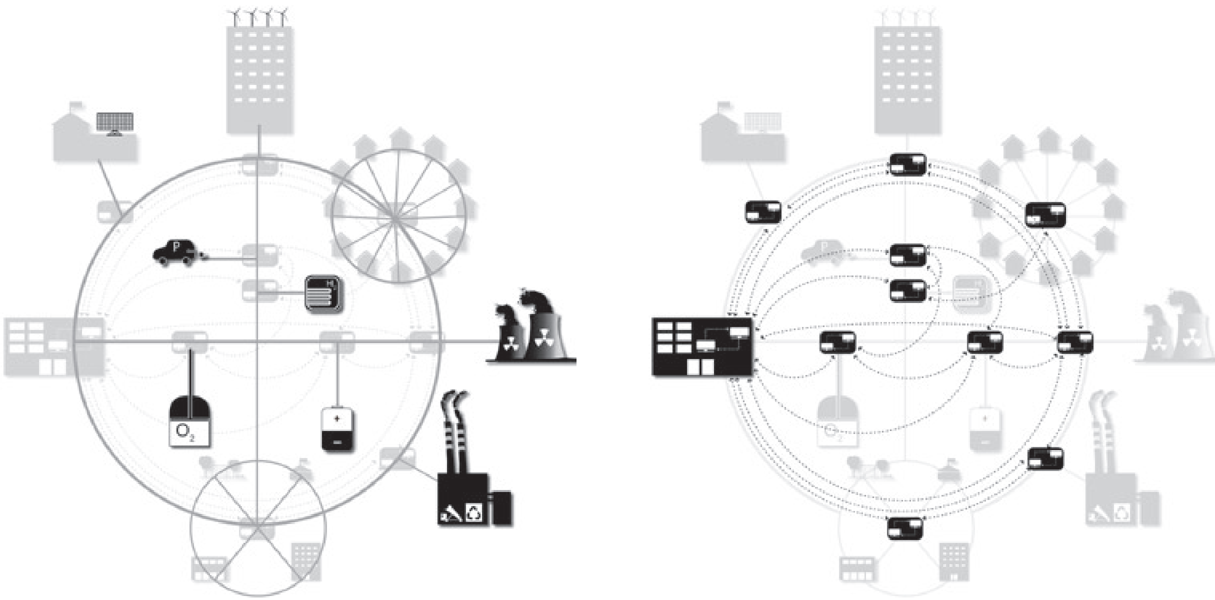
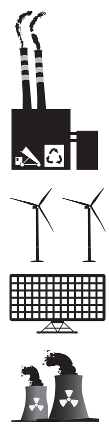


Fig. 1.16 Smart Grid

Smart Grid is a proposal for a future electricity grid promoted by the US Department of Energy. This network consists of integrated microgrids. Each microgrid functions uniquely, responding to specific neighbourhood characteristics, such as a large number of wind turbines (intermittent energy producers). Energy control centers, smart-appliances and energy monitoring devices allow the grid to monitor and heal itself.

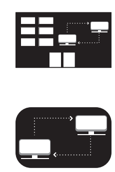


Electricity producers



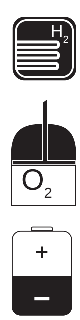
Energy from distributed and diverse producers range from photovolatic arrays on a roof to a mid-size nuclear plant in the city periphery.

Energy Control Centers



Voltage is monitored at local centers. This allows for immediate reaction to disruptions in energy provision. Local control centers allow for optimized utilization of energy assets and efficiency in distribution.

Energy Storage

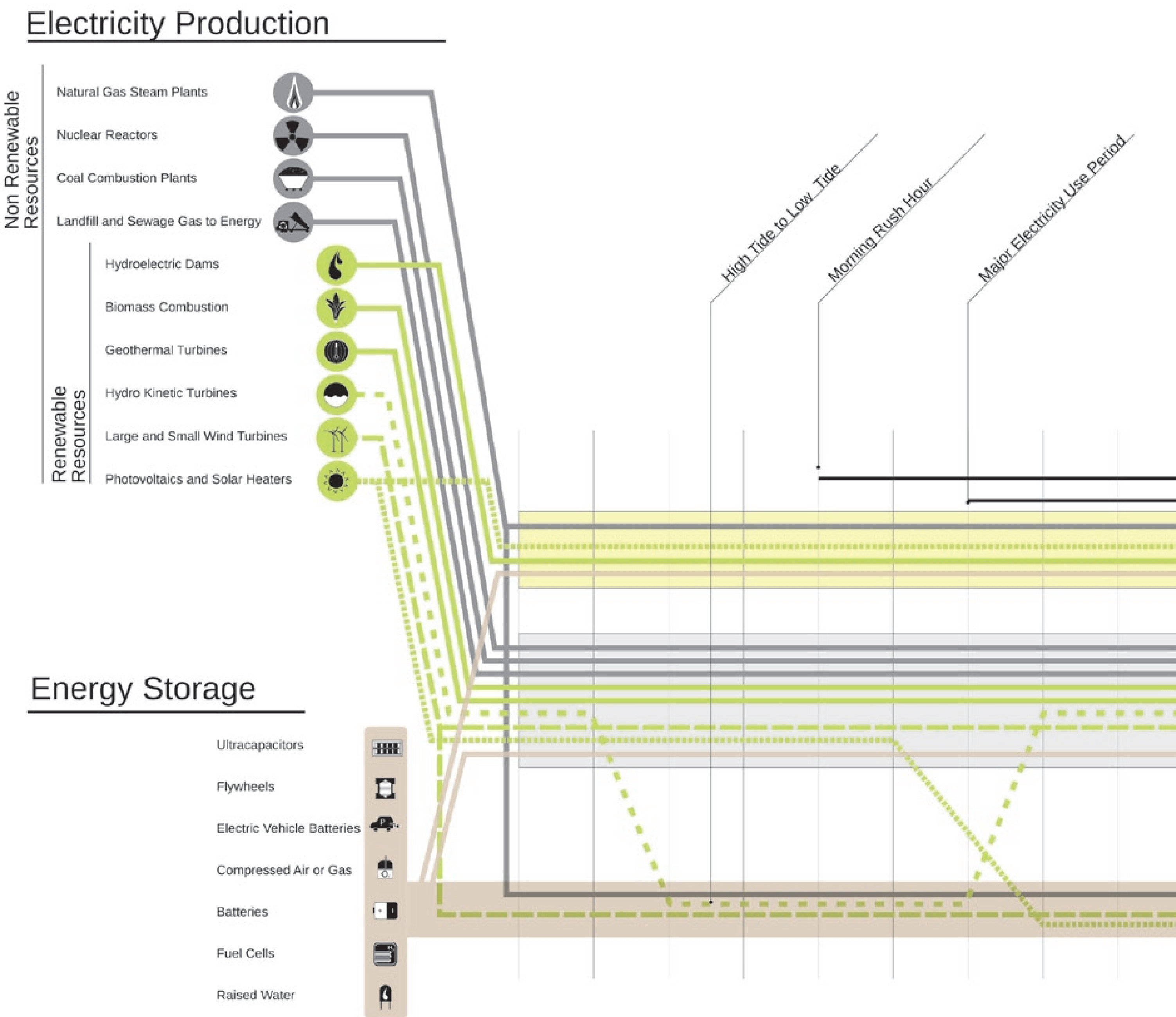


Energy from intermittent renewable resources such as wind and photovoltaic cells require storage to take advantage of off-peak production for use during higher demand periods.

Electric Vehicles

Plug-in electric vehicles can be charged by plugging into the grid. This promotes the development of new EV products. Larger parking lots can use power from vehicle battery packs when not in use.

Fig. 1.17 Smart Grid: Elements


Electricity Production
Non Renewable Resources
Natural Gas Steam Plants
Nuclear Reactors
Coal Combustion Plants
Landfill and Sewage Gas to Energy
Renewable Resources
Hydroelectric Dams
Biomass Combustion
Geothermal Turbines
Hydro Kinetic Turbines
Large and Small Wind Turbines
Photovoltaics and Solar Heaters
High Tide to Low Tide
Morning Rush Hour
Major Electricity Use Period
Energy Storage
Ultracapacitors
Flywheels
Electric Vehicle Batteries
Compressed Air or Gas
Batteries
Fuel Cells
Raised Water

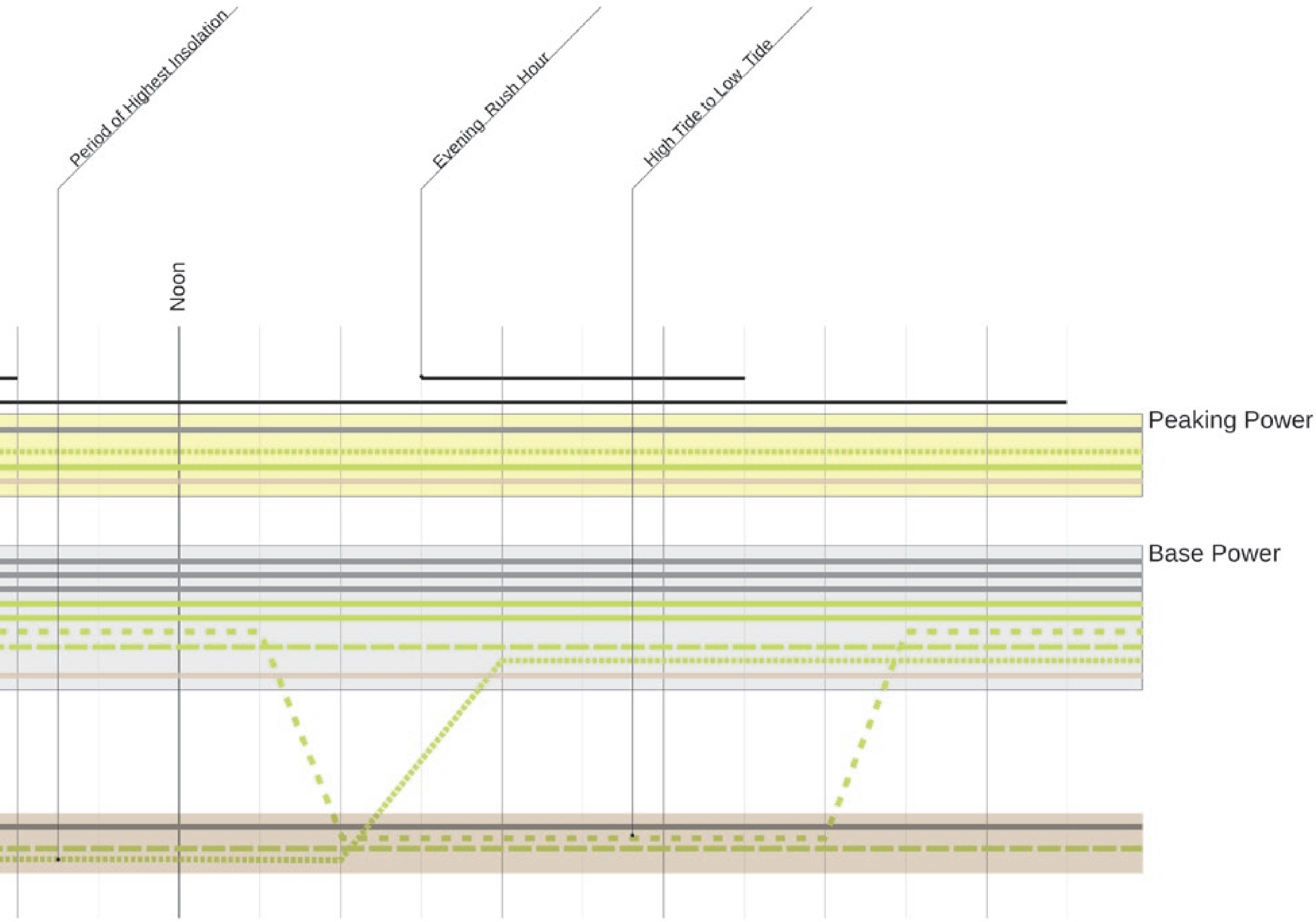


Fig. 1.18 Electricity Production: A 24 Hour Time-line

This is a future hypothetical daily energy flow diagram. The major difference from our current time-line is energy storage. Energy storage would work in tandem with intermittent energy producers that have unpredictable cycles.

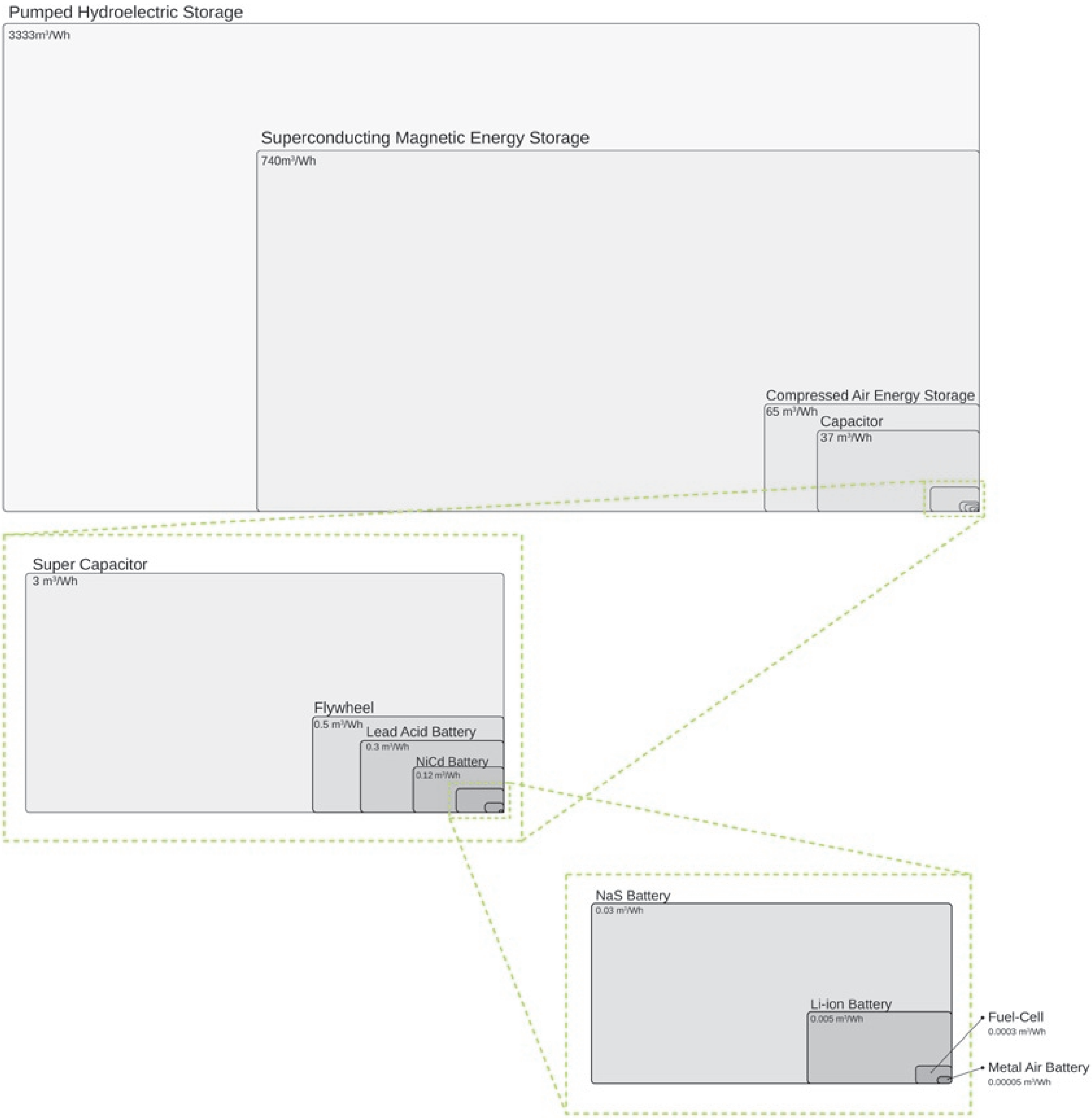


Fig. 1.19 Energy Storage Systems

Comparison of area in cubic meters for an energy storage capacity of one Watt-hour.

the building of sustainable environments based on localizing food production and waste management. These are practices that are being adopted by the Glocal movement[7]. But of these initiatives few consider solutions to an energy drought. Municipal food, waste and water systems require energy inputs to operate.

Energy Storage

American cities will undoubtably need to implement energy storage into their future municipal energy systems. Each action plan mentioned above has small references to implementing energy storage into the future electric grid. The "National Electric Delivery Technologies Road Map" states that "large- and small-scale electric storage devices are needed that have lower costs and are more durable and reliable."[8] Locating energy storage facilities throughout populated areas would alleviate peak power demands as well as improve power supplies from intermittent power sources. Renewable energy plans need to outline the variety of energy storage systems available and describe the processes of siting such facilities. The various power ratings, discharge times and energy density (Fig. 1.19) require that each storage option be paired cooperatively with a respective generation source. Coupling electricity production and storage facilities with transportation infrastructure would create a parallel infrastructure with mutually beneficial agendas.

7 Glocalization is a movement following the popular term "Think Globally, Act Locally" coined by Patrick Geddes.

8 Office of Electric Transmission and Distribution, "National Electric Delivery Technologies Road Map," U.S. Department of Energy, January 2004, http://www.oe.energy.gov/DocumentsandMedia/ER_2-9-4.pdf (accessed December 20, 2010).

Electric Transportation

Although these sustainable developments and plans seem to be on the right path, it is obvious that their solutions remain superficial. There also seems to be an underlying connection between energy and transportation sectors, which is not addressed by any current plan. The transportation sector consumes 28 percent of the nation's energy (second only to industry). Transportation and electricity infrastructures are the main urban support systems and should be available to every inhabitant.

The demand for electricity from urban transit services and personal electric vehicles is growing. There are already over 20 electric vehicle models being produced worldwide. The International Energy Agency's World Energy Outlook 2010 states that plug-in hybrids and fully electric vehicles are the most promising transportation technologies for eliminating dependence on oil-based fuels.[9] Electric vehicles have more efficient engines that create zero emissions. They have low maintenance and are currently cheaper to operate. The incorporation of electric vehicles into our transportation market is imminent. The US federal government is already issuing grants to expand the nation's electric vehicle recharging infrastructure. The Energy Commission awarded California $1.9 million to enhance their electric vehicle infrastructure, to be completed in 2011.[10] California is leading the way in converting its transportation to electric vehicles. The state is encouraging consumers to purchase electric vehicles through incentives and large rebates and the California

9 International Energy Agency. "World Energy Outlook 2010: Executive Summary," 2010, http://www.worldenergyoutlook.org/docs/weo2010/WEO2010_es_english.pdf (accessed December 20, 2010), 14.

10 Green Car Congress, "Energy Comission Awards $1.9 Million for Improving California's Electric Vehicle Infrastructure," August 2010, http://www.greencarcongress.com/2010/08/cec-20100812.html (accessed December 20, 2010).

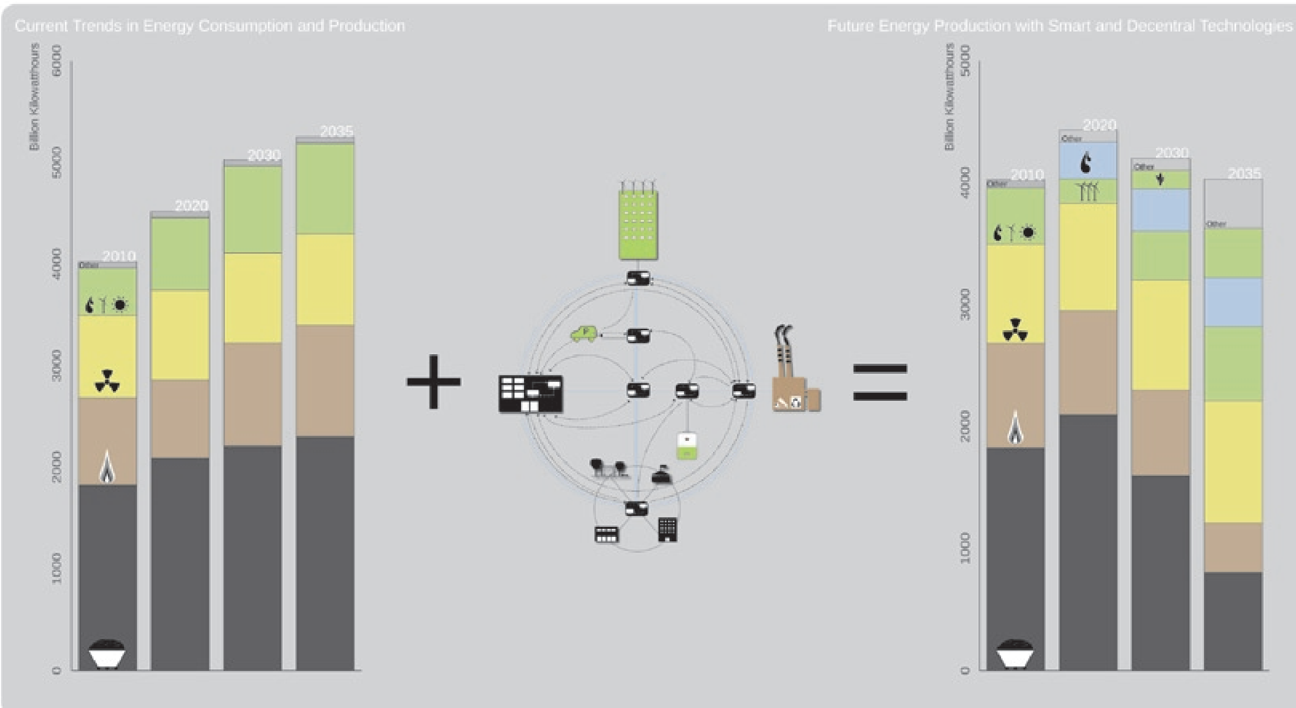


Fig. 1.20 Predicted Power Sources

Energy Commission has created a $108 million dollar investment plan for the research and development of electric vehicle technologies. EV infrastructure will rely heavily on energy storage and massive electric energy inputs. The batteries and regenerative breaking systems of EVs would also offer greater storage opportunities and additional power respectively.

Proposal: Collaborative Infrastructure

Smart Grid, Distributed Generation, energy storage and electrified transportation are individual proposals for a better future in the United States that require unification. Smart Grid, Distributed Generation and Electric Vehicle proposals allude to the existence of each other but the greater picture of what this future means for our urban lifestyle is missing. Combining the strategies of smart infrastructure with distributed generation, storage and transportation allows for a harmonized and mutually beneficial infrastructure. The combined strategy has benefits beyond infrastructure efficiencies as stated by Hegger, Fuchs, Stark and Zeumer:

> Biogenetic energy sources enable the re-establishment of local jobs in rural areas, the diversification and stabilization those areas, the creation of additional sources of income, the creation of additional sources of income and the closure of the life cycles of diverse materials. The production of energy is no longer reduced to a centrally controlled coverage of needs, but instead allows specific solutions based on local circumstances.[11]

The proposal of this thesis is to integrate future energy networks and transportation systems into urban life. Through legible and cooperative transportation and energy infrastructures new types of public spaces can be introduced into the city through the foundation of new interfaces among community, transportation and energy.

11 Manfred Hegger, Matthias Fuchs, Thomas Stark and Martin Zeumer, eds. *Energy Manual: Sustainable Architecture.* Boston: Birkhäuser Publishers, 2008. p 63.


LOS ANGELES, CALIFORNIA
NO TRESPASSING
DUMPING
PROHIBIDO

01-3 Los Angeles

A Brief

Los Angeles offers an ideal test-bed for exploring the benefits of a decentralized metropolitan proposal that pairs energy and public transportation infrastructure. The city's existing polycentric organization provides a foundation for the proposed distributed and smart electricity network.

The shape of Los Angeles is unconventional. As characterized by Mike Davis, Los Angeles is "planned or designed in a very fragmentary sense (primarily at the level of its infrastructure) but it is infinitely envisioned."[1] Los Angeles is overwhelmed with conflicts of interest concerning its municipal infrastructures. Public amenities are being shut down, parks and beaches are neglected. The public spaces of the downtown area have been compromised by privatization. Pershing Square is Los Angeles' best example of failed public space due to a defensive design agenda (Fig. 1.22). The public transportation system is no more coordinated than public spaces. The automobile has taken full reign of the city's infrastructure resources. An increased sales tax in 2008 was approved by taxpayers under the assumption that this money was going into public transportation improvements such as a new high-speed rail system and

Fig. 1.21 All of Los Angeles' major infrastructures are present.

The Los Angeles River, high voltage transmission lines, highway and railway all following the same corridor.

1 Davis, *City of Quartz: Excavating the Future in Los Angeles*, 23.

Fig. 1.22 Pershing Square

subway-line extensions. However, recently the city has seen increases in fares for all three public transportation services.[2]

Urban theorist Edward Soja situates Los Angeles as the representation of New Urbanism in the modern metropolis. Soja describes Los Angeles as “a provocative and often fearsome model of the suburbanized city of the future”[3] formed by what he calls a “regional urbanization process.”[4] As Los Angeles’ suburbs transformed into peripheral cities they inherited corresponding nodes generating higher volumes of activity. Soja’s criticisms of Los Angeles’ urban sprawl focus on detachment of the suburban dweller from the regular function of a central core causing opposing social and economic planning. The solution for Los Angeles must commence from an urban-regional approach. This New Urbanist paradigm of decentralization builds on Los Angeles’ strengths and addresses areas of previous neglect.

To understand the sprawled quality of Los Angeles one must examine its history of growth and prosperity. In many circumstances these were in detriment to other municipalities and people. The creation and growth of Los Angeles was made possible by expanding water, power and transportation infrastructures. These share patterns of growth and a long history of corrupt administrations. Land-use and residential patterns function on a decentralized model but municipal utilities and transportation infrastructures operate city-wide as fundamental support systems of the city. These infrastructures are routed through the city along parallel pathways connecting population centers. To develop intelligent connections among regional urban centers it is important to look at the unique causes and contributors of decentralization. Examining these factors will reveal shared aspects of planning and infrastructure that can inform the transportation-energy system proposal

2 Amtrack, METRO and DASH.

3 Edward Soja, “Another New Urbanism,” in Tigran Haas , ed. *New Urbanism and Beyond: Designing Cities for the Future* (New York: Rizzoli, 2008), 293.

4 This is the combination of decentralization and re-centralization in new urban villages or peripheral cities, which differs from the suburban growth processes approaches adopted during postwar population surges.

Fig. 1.23 Panorama of Los Angeles.

The various poly-centers appear branching out from the original core.

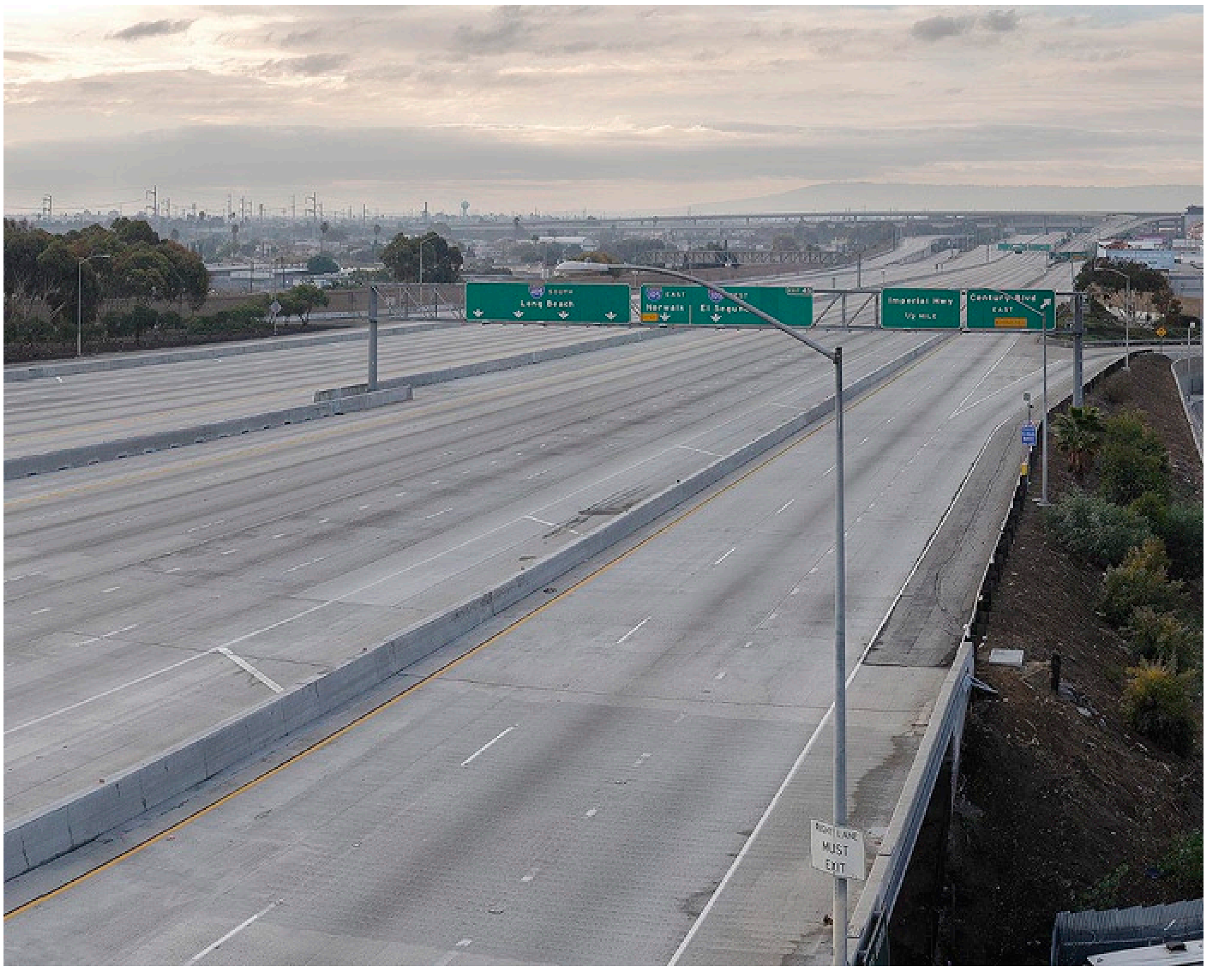


Fig. 1.24 Empty LA photographic series, By Matt Louge.

Los Angeles without traffic is an unfamiliar concept, but not an impossible one.

Fig. 1.25 Empty LA photographic series. By Matt Louge

This image this presents may unintentionally characterize the future of oil-restricted Los Angeles.


Huntington Beach, Calif.

01-4 Los Angeles : A History of Infrastructures

The remainder of this chapter discusses specific characteristics of LA's deficient public transportation system and overtaxed electrical network. A documentation of the existing electrical infrastructure demonstrates the rapid growth and structure of the network. Key energy production facilities are described and outlined in order of their construction and acquisition. Specific events in the development of transportation and electricity infrastructure display the city's previous misguided infrastructure initiatives. The chronology of transportation and energy distribution includes the shift in the dominant mode of transportation from rail to automobile, specifically addressing the resultant effect on the city's structure and connectivity.

Power and Electricity

Massive construction initiatives enabled water, rail and power corridors to parallel one another. This led to a condition of interdependence. Since its transformation from a rural to urban population, Los Angeles has been familiar with water shortage. The original 72.5 square kilometer city area received all of its water needs from the Los Angeles River. When the area tripled by 1910, the city was forced to construct the Los Angeles Aqueduct. The development of the Los Angeles Aqueduct corridor

Fig. 1.26 Long Beach public beaches.

The beaches are framed with the backdrop of oil derricks in the mid 1900s.

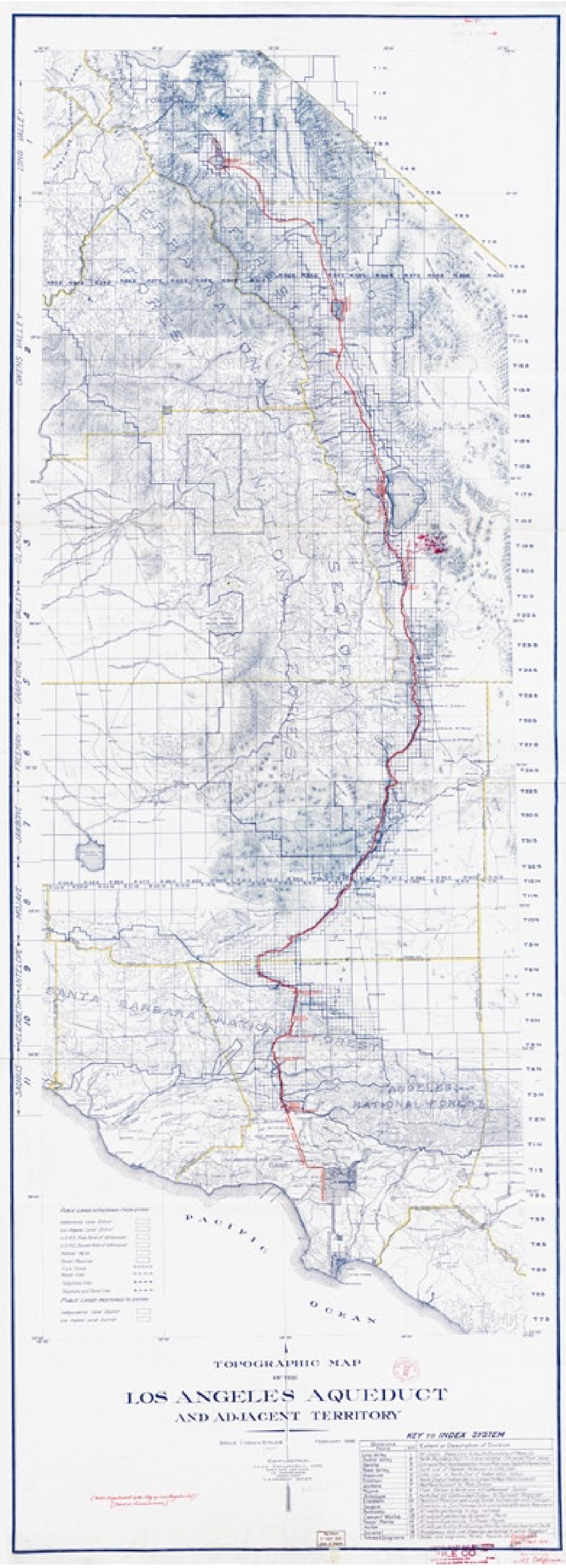


Fig. 1.27 Map of Los Angeles Aqueduct and Adjacent Territories.

Completed in 1913 the 375 kilometer pipeline carries water by gravity from the Eastern Sierra Nevada into the Los Angeles Basin. Los Angeles' municipal water system relies on a series of water reservoirs and the Los Angeles Aqueduct to supply the city 35% of its water. This percentage is decreasing each year due to projects for environmental enhancement of the Eastern Sierra watershed, presumed to be among the most widespread environmental restoration projects in United States history.

was the impetus for the city's electricity network. Los Angeles' first hydroelectric power plant was erected to power construction of the aqueduct.

Until 1955, 90 percent of Los Angeles' energy was generated from hydroelectric power sources.[1] Growing energy demands prompted the LADWP to build four large natural gas - oil power plants. The LADWP also needed to acquire the infrastructure for urban scaled energy distribution. After obtaining Southern California Edison's distribution system as well as the Los Angeles Gas and Electric Corporation's properties, the LADWP became the sole electric power supplier in the city and the largest municipally owned utility in the United States. Supplying the city's power became difficult without imports from distant generating stations. The LADWP chose to import power from Boulder Dam (Hoover Dam). After World War II the city incorporated four new power projects to satisfy the city's continually escalating electricity demands.[2] With a population reaching three million the city began to require major energy imports. These came from Utah's coal-fueled station and Arizona's nuclear power plant forever altering Los Angeles' electric energy portfolio from 90 percent hydroelectric to over 76 percent coal-gas based. In total, the LADWP owns five electricity facilities located in southern Los Angeles County. The utility also partially owns or has power purchase agreements with five facilities in Utah and Arizona.

The LADWP has promoted itself as being committed to reducing emissions and providing its customers with renewable energy options. The municipally controlled utility aims to provide appropriate solutions for contemporary issues such as global climate change,

1 Leonard Pitt and Dale Pitt, *Los Angeles A To Z: An Encyclopedia Of The City And County* (Berkely, California: University of California Press, 1997) 136.

2 These included: Valley Generating Station, Scattergood Generating Station, Haynes Generation Station, and the Owens River Gorge Hydroelectric Project.

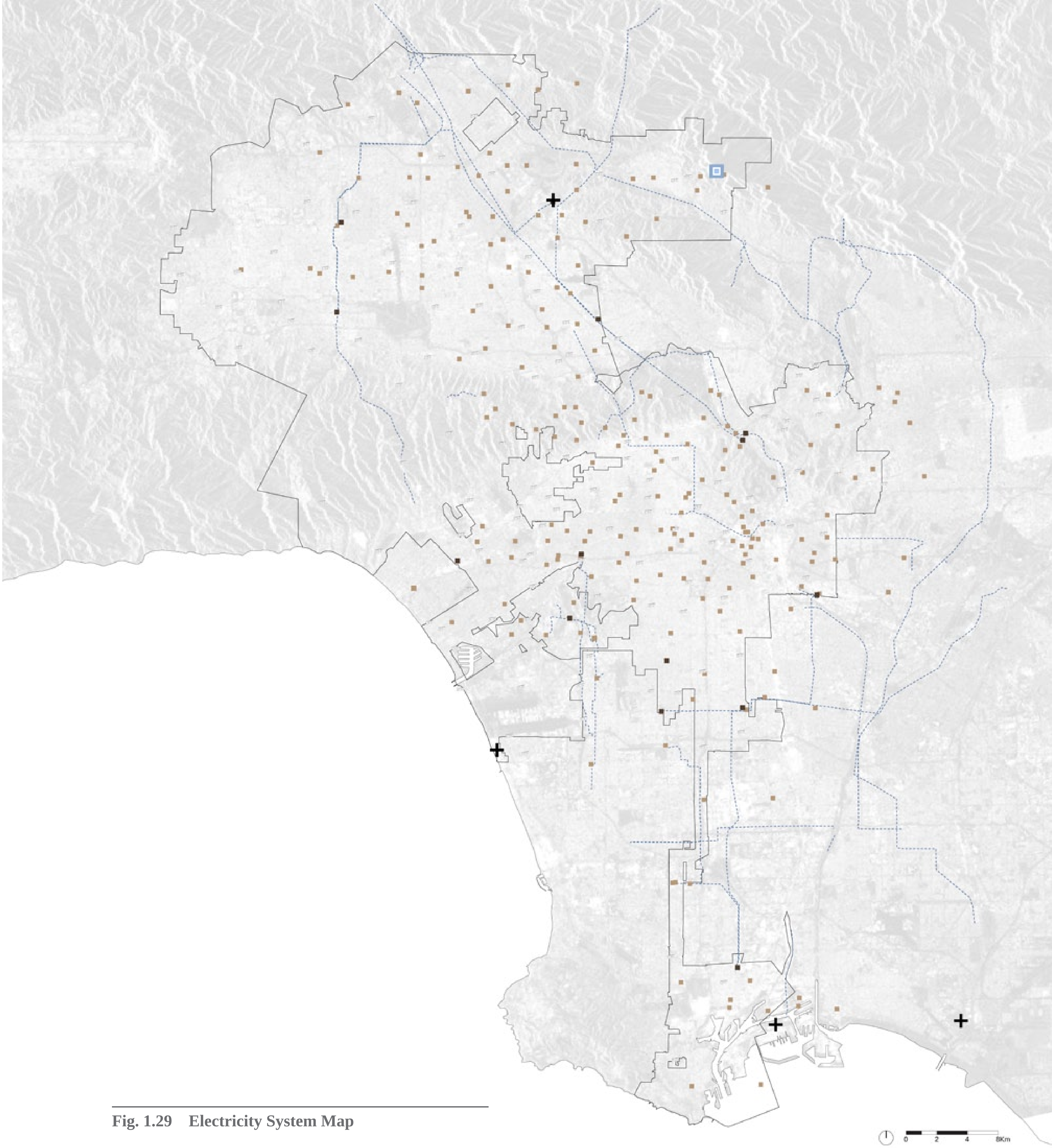


Fig. 1.29 Electricity System Map

Power Receiving Station

High Voltage Transmission Lines

Energy Control Center

Power Distribution Station

Natural Gas Power Plant

greenhouse gas emissions and electrical power reliability. The Green LA Program has created incentive based programs that aim to reduce emissions by increasing the use of renewable resources. An example is the electric vehicle program. Introducing power from renewable energy resources is a priority for Los Angeles' Renewable Portfolio Standard.[3] The LADWP has incorporated wind, fuel cell, energy recovery and photovolatic systems into its delivered energy investments. As a part of the city's distributed generation program three hydrogen-powered fuel cell power plants were added to increase energy efficiency and reliability to the city's electricity grid. Part of the Green LA Program is dedicated to improving the existing energy infrastructure and modernizing existing facilities. The Power Reliability Program is one of the few municipally run programs aimed at assessing and improving power transmission and distribution infrastructures. What is unique about this program is that it operates with the underlying agenda of energy efficiency and protection of the environment.[4]

Current electricity production practices in Los Angeles are natural gas, combined heat and power (CHP)[5] fuel cells, and photovoltaics. The LADWP has announced a newfound commitment to transitioning their energy generation technologies toward renewable resources. This includes diversifying the sources from which they receive energy production, modernizing existing facilities and replacing aging transmission and distribution infrastructure. Projected sources of renewable power generation come from: fuel cells, photovolatic, wind farms, methane harvested from

3 Renewable Portfolio Standard was introduced to increase the amount of energy the LADWP generates from renewable power sources to 20 percent by 2017. This program is promoted as increasing air quality and providing sustainable energy resources.

4 Los Angeles Department of Water and Power ,"LADWP Powers Up for Hot Summer", June 2007, http://www.piersystem.com/go/doc/1475/162101/ (accessed December 20, 2010).

5 This includes the landfill to gas facilities.

Fig. 1.32 Hyperion Energy Recovery System.

This treatment plant ignites dried sewage sludge in a staged fluidized bed combustor. The resulting gas combusts in several stages heating water to the point of producing steam, enough to drive a 10 MW steam turbine-generator.

Fig. 1.31 The Pine Tree Windfarm.

As of June 2009 the Pine Tree Wind Project has added 120 megawatts of renewable electrical power; this is the equivalent of powering 56,000 Los Angeles homes. The Pine Tree windfarm supplies less than two percent of the LADWP's generating capacity.

municipal landfills and pumped storage (hydroelectric). Fuel cell and hydroelectric sources function much like existing turbine-engine technologies, they have a start-up time but are more responsive to demand. Wind and photovolatic sources are intermittent power sources. If these resources were supplemented by energy storage facilities the adverse effects of their irregular production periods would be mitigated.

The challenges facing the electricity grid in California will be more daunting than the early 2000 energy crisis and will require inputs of technology, a retrofit of equipment, and evaluation of patterns of use. Even without intervention from Enron[6] the energy capacity of California's electrical grid is experiencing problems similar to those of the 2000 and 2001 energy crisis. Overburdened energy systems and new projects creating renewable energy infrastructures are creating blackouts and raising the price of electricity. Los Angeles is committed to weaning its energy production off coal and onto renewable resources on paper but the municipality has not yet engaged in renewable solutions beyond a handful of projects. The LADWP faces the challenges of a sensitive economy, environmental pressures, customer demand and an exhausted infrastructure. Major alterations to the Los Angeles electricity system will need to occur in order to power Los Angeles in a post-carbon future.

6 The Enron scandal in 2001 was one of the largest instances of misrepresentation of financial information for a public company in US history. Enron's manipulation of a deregulated energy market resulted in overpriced electricity in California as well as company instigated rolling blackouts.

Fig. 1.33 Double Standard, by Dennis Hopper, 1961.

Car Culture

Los Angeles' omnipresent highways and freeways enable the city to function regardless of its lack of a hub-and-spoke organization. The city's assemblage of various 'sub-regions' is connected through the city's 10 interstate highways, 21 California state highways, and one federal highway. Like the framework of the Pacific Electric Railway, the Los Angeles freeway system promotes instances of sprawled development. The freeways act as bridges from one region to another. However, they are barriers of community interaction within the regions they occupy. The freeway's duplicity contradicts Angelenos' appreciation of the automobile as a provider of high velocity, convenience and peripheral mobility. As Banham illustrates:

> One can most properly begin by learning the local language; and the language of design, architecture, and urbanism in Los Angeles is the language of movement. Mobility outweighs monumentality there to a unique degree.[7]

During the early 1900s the personal automobile started to reach the streets of Los Angeles. Car touring became a popular middle-class pastime during the 1920s. Commercial attractions, beaches, canyons, parks and camp grounds were now easily accessible by the personal auto. By 1937 80% of all local trips were made by the automobile. This new industry also instigated a mesh of various gas stations, mechanical shops, accessory stores, motels and roadside billboards forever changing the zoetrope of the Los Angeles street-scape.

Soon the personal automobile was used for commuting and daily shopping trips. By the late 1910s there were reports of traffic congestion in the downtown area. The rise in vehicle ownership and population growth began to concern the Los Angeles Department of Engineering. The growing popularity of suburban living and traffic congestion in the central business district quickly escalated from bad to unacceptable. The "Good-Roads" campaign eased some congestion issues by establishing paved and maintained roads.[8]

In the early 1900s, Los Angeles started to adopt automotive strategies for transportation parallel to residential development. The Federal Road Act of the late 1910's brought improved rural highways and $375 million in construction and maintenance to the city's automobile infrastructure. Rural areas soon became automobile accessible with upgraded highways and planned routes. Eventually highway and freeway infrastructure took over where the PE railway left off. New housing tracts burgeoned from highway access points defining Los Angeles' unprecedented structure as a multitude of suburban communities. Freeway exchanges and their clover-like shape became a symbol of Los Angeles and a monument to the automobile.

Motorized trucks soon took advantage of the convenient roadways for short haul trips adding to congestion and pollution in downtown Los Angeles downtown. Traffic jams and parking issues within the downtown area encouraged lane width and parking based planning strategies. This introduced acres of paved asphalt and concrete. Taking advantage of lower land prices and the car-centric culture, business moved to budding commercial enterprises in peripheral locations throughout the city. As these areas became more prosperous, their land-uses diversified and took advantage of commercial adjacencies. This created convenient strip malls and highway-based commercial developments.

Relocating economic centers prompted Los Angeles' decentralized structure to emerge. Medium-

7 Banham, *The Architecture of Four Ecologies*, 23.

8 Originally the Good-Roads campaign was solely supported by cyclists in the late 19th century improvements started in 1915 along postal routes and two years later along every main thoroughfare within the city.

Fig. 1.34 Highways, by Michael Light, 2004.

In 1940 Los Angeles constructed the Pasadena freeway, the first freeway in the Western United States. Gasoline taxes, real estate developers and contractors pushed a freeway building program which saw the construction of 444 square miles of freeway in under ten years. California never saw ,completion of more than 50 percent of proposed freeway initiatives. By 1970 construction costs, environmental impact studies and community organizations halted additional freeway construction.

sized neighborhoods transformed into small city centers and large neighborhoods began to appear as prominent downtowns. The relationship between the personal automobile and the single-family suburban lifestyle became symbiotic and emphasized the dispersed city form.

Los Angeles' infatuation with the personal automobile manifests in a far-reaching system of roadways, freeways, and highways. Over 2 million vehicles are registered in Los Angeles[9] and this figure excludes the millions of others commuting from neighboring municipalities. To conquer repeated traffic jams the city has attempted to alter speed limits and create traffic control devices at on-ramps. Public transit ridership statistics are meager compared to the highly traveled highways and freeways. As Reyner Banham explains:

> It will not be easy to persuade Angelenos, many of them able to remember the dying agonies of the PE, to leave the convenient car at home - in spite of their complaints about traffic jams - and climb into whatever colored rolling-stock the new dream-system offers.[10]

The linear corridors of Los Angeles are packed with car-dependent suburban developments. Such developments areas are identified as having high ecological footprints, costs of living and infrastructure costs. The streets are unsafe due to traffic based planning and public space is compromised by encroaching privatized areas. Public health is threatened by the lack of walkable destinations. Los Angeles is in need of a new approach to transportation. It is not to say that personal vehicle transportation should be removed, but it must be modified at appropriate scales. The future state of transportation in Los Angeles should consider the city's reliance on car-focused transportation by incorporating a system that can integrate public and private networks. Reshaping the city is not necessary for reducing car-dependence. Re-evaluating existing automobile infrastructure and retrofitting public transportation technologies can provide Los Angelenos with a composite transportation system, providing diversity in transportation methods.

9 An approximate value derived from Los Angeles County DMV records for 2009 and the US census bureau population estimates for Los Angeles City and County.

10 Banham, *The Architecture of Four Ecologies*, 83.

Fig. 1.35 Pacific Electric Streetcar "Redcar"

Public Transit

The Los Angeles public transportation fleet consists of taxis, buses, shuttles, light rail, and commuter rail. LADOT (Los Angeles Department of Transportation) operates separately from municipal (DASH) and METRO fleets. Together this system connects Los Angeles city with neighbouring municipalities. LADOT operates Transit Centers and Park & Ride facilities that aim to increase the radius of transit services in their areas. The Los Angeles Metro supports three light rail lines and one heavy rail line supplemented by dedicated busways.

Of Los Angeles' 1.6 million workforce only 10 percent uses public transportation.[11] Indications of lower ridership of the METRO, DASH and LADOT are unspecified but suggested causes include: lack of convenience, cost, travel times and operation hours. Lack of support from its residents has not stopped the city's public transportation transition towards more sustainable energy and climate practices. The METRO operates the largest Compressed Natural Gas (CNG)[12] bus system in the United States. The Metro has designated 624 miles to carpool lanes and 1,250 miles of bicycles lanes intended to reduce air pollution and encourage alternative methods of transportation.

Current methods of transportation in Los Angeles are ineffective without an automobile. The highway and freeway systems connect to their neighborhoods and allow millions of commuters to flow throughout the city and its neighboring regions. With additional cars on the road and an unsophisticated rapid transit system, congestion will continue to increase. Public transportation in Los Angeles is mediocre and lacks cohesion. There are over three major entities running uncoordinated separate services within the city, all of which are equally necessary for the average traveler. This means that individuals pay separate fares to each entity.

Los Angeles public transportation has a reputation for unsatisfactory performance and misguided development strategies. The lack of coordination among these entities contributes to the failure to develop a 'trip generating plan.' Generally rail systems are planned out to service transport between major destinations. The central hub of this system should be the major destination within this system. Like a hub and spoke typology these tend to be a city's central business district or 'downtown'; inherently they are places of employment, government, commerce, sport, and culture within a walkable area. Los Angeles has an undersized central business district relative to its large population, which directly contradicts a hub and spoke rail organization. In the last seven years the METRO has opened a mere two new electric rail transit lines and just began construction of a third.[13] Issues of traffic congestion and pollution are only now beginning to instigate renewed interest in rapid transit. If integrated with sustainable energy initiatives the METRO could once again have the momentum to become the country's most successful public transit entity.

The Long Range Transportation Plan (LRTP), by Los Angeles Metro Transportation Authority (MTA) outlines several phased strategies for transportation in Los Angeles. These are expected to see completion by 2030 and focus on expansions of existing public transportation systems. Some key elements of the LRTP are: to expand the Metro Rapid network by over 400 service miles, to continue operation and expand the Metrolink commuter rail system, to expand and improve bus and rail services, to develop new facilities with smart growth and transit

11 The Public Information Office of the Department of Transportation, "The City of Los Angeles Transportation Profile 2009," Los Angeles Department Of Transportation 2009, http://www.ladot.lacity.org/pdf/PDF10.pdf (accessed December 20, 2010).

12 Compressed Natural Gas (CNG) engines are 97% cleaner than the equivalent diesel engine, but share the same environmental concerns over resource extraction and limited quantities.

13 Los Angeles' period of construction was between 2003 to 2010. For comparison, starting in 1954 New York created more new lines in 11 years plus one line extension.

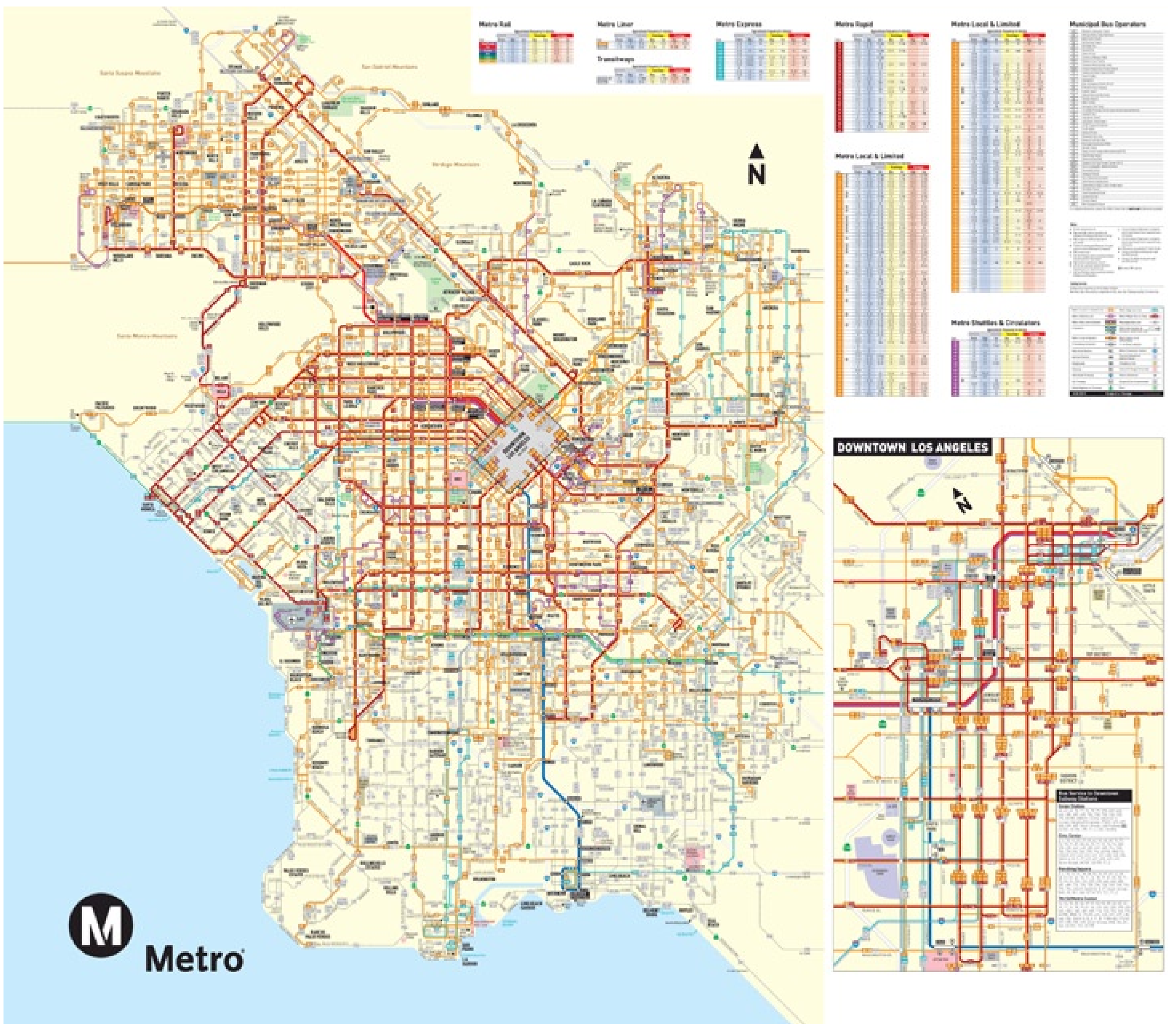


Fig. 1.36 Metro Bus and Metro Rail System Map

oriented development strategies.

Transit Oriented Development (TOD) was implemented to increase access to transit services while providing bicycle and pedestrian corridors. This coincides with the “complete streets” initiative where the needs of pedestrians, cyclists, drivers and transit riders are all considered. The METRO has also established local and regional task forces to solve problems occurring at varying scales called Intelligent Transportation Systems (ITS). These ITS’s monitor and integrate real-time information about system activities and use it to manage freeway, signal and transit flows. By compiling multi-modal data the system is able to coordinate around congestion and other disturbances.

Los Angeles’ public transportation sector will see major ridership increases with the emerging oil crisis. Increases in oil prices and availability will prompt those who cannot afford their normal means of transportation to take public transit. In Los Angeles the population affected would be over 800,000 people.[14] To prepare for the increase in ridership the LA Metro and related entities will have to consolidate their respective systems to serve their passengers better. This requires the introduction of singular payments, system-wide transfers, eliminating redundancy in route planning and most importantly the introduction of multi-modal nodes.

Los Angeles polycentric organization presents unique challenges for urban planning strategies. Each district should have a variety of transportation options. Introducing multi-modal transportation nodes at key locations throughout the city would provide this diversity and the opportunity to create more explicitly public development in the city.

14 U.S. Census Bureau “Los Angeles City, California: 2005-2009 American Community Survey 5-Year Estimates.” Economic Characteristics, 2009, http://factfinder.census.gov (accessed December 20, 2010).

02 Urban Framework

02-1 Transportation System

Reorganizing transportation and energy infrastructures to create a cooperative infrastructure in Los Angeles requires a cataloging of current and proposed urban transportation and energy elements. The proposed catalogue borrows elements from the city's transportation plan[1] and expert proposals for future electrical delivery systems as mentioned in chapter one. Patterns of energy consumption in the city and the arrangement of communities within unique neighborhoods are guided by principles of urbanism and ecology.

Fig. 2.01 Los Angeles at Night

Transportation and electrical systems are pictured due to their parallel configuration and reticulated structure.

1 Metro - Los Angeles County Metropolitan Transportation Authority, "I want a Mobile Future: 2009 Long Range Transportation Plan," 2010, http://www.metro.net/projects_studies/images/final-2009-LRTP.pdf (accessed. December 20, 2010).

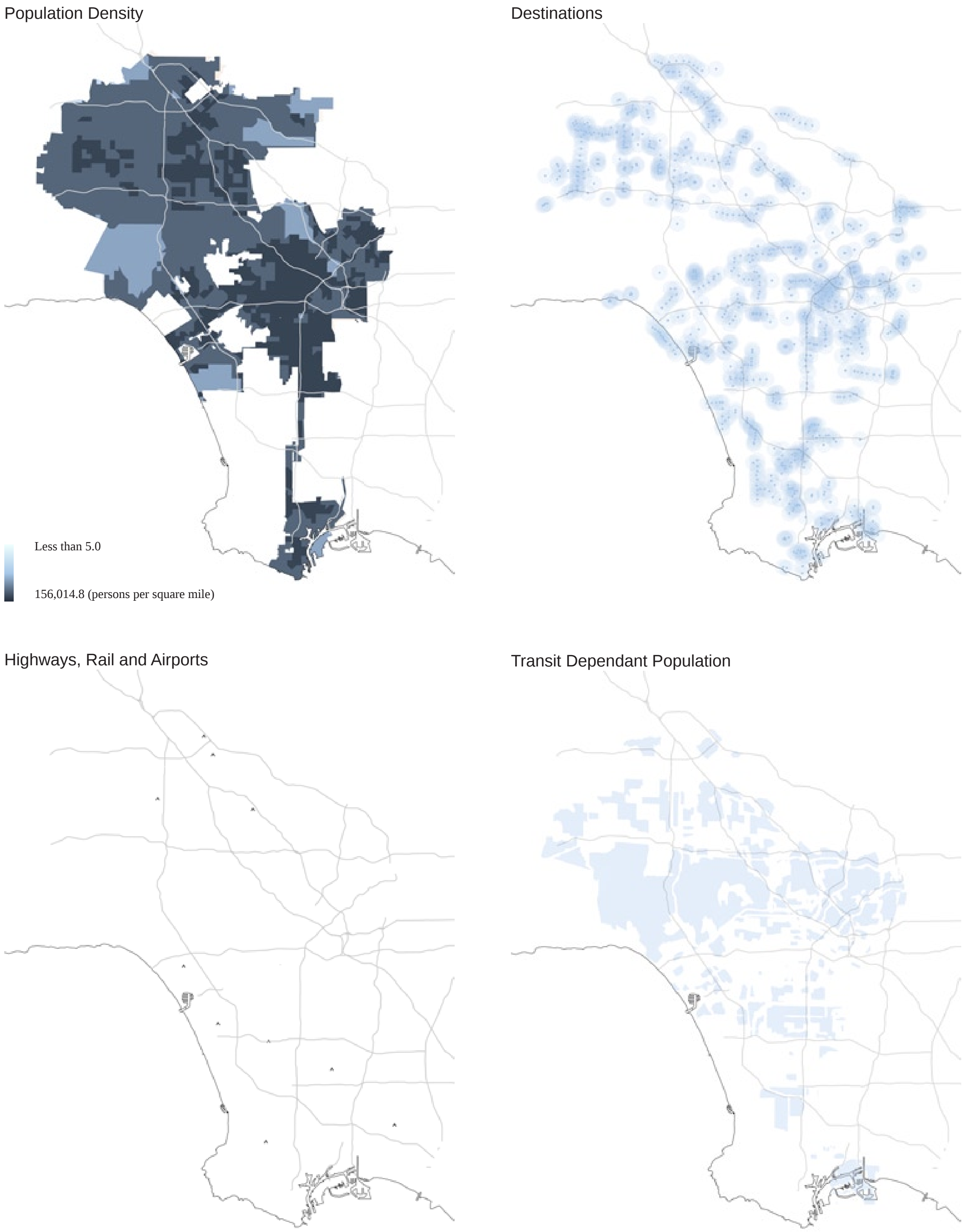
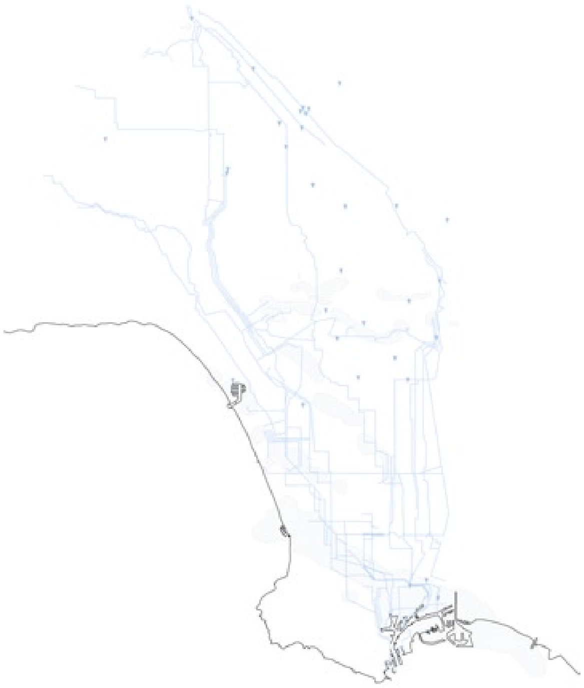


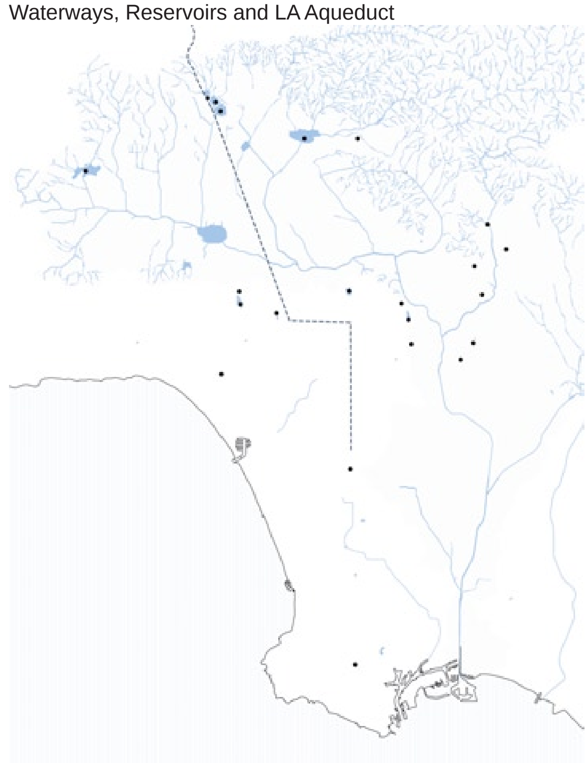
Fig. 2.02 Maps of Los Angeles

This series of maps exhibits several characteristics of the urban landscape which determined the location and type of each energy-transit facility as well as the energy-transit hubs.

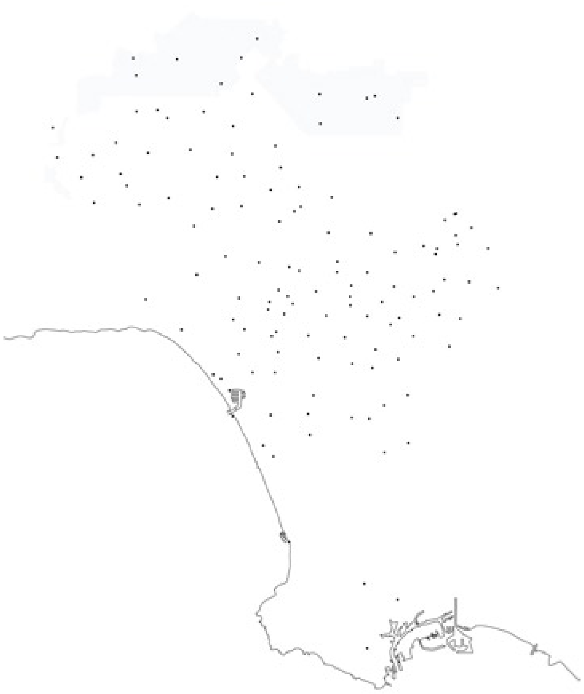
Oil Fields, Pipelines and Landfills



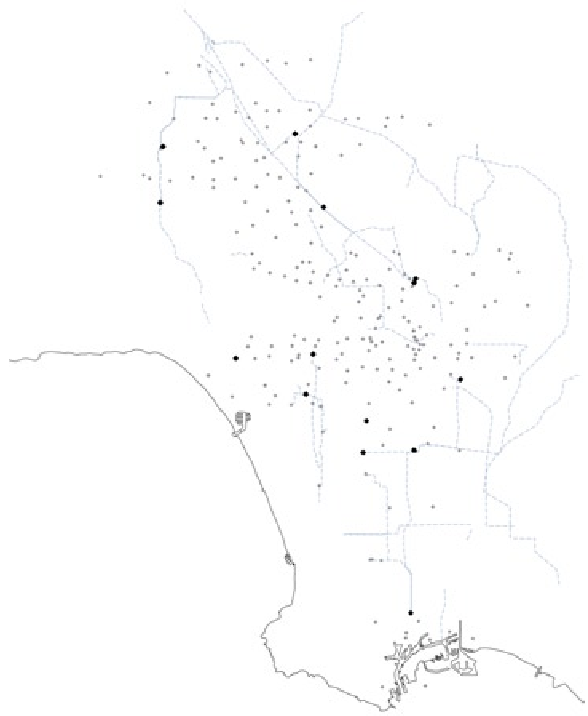
Waterways, Reservoirs and LA Aqueduct



High Wind Area and Existing Photovoltaic Sites



Electric Transmission Lines, Distribution and Receiving Stations



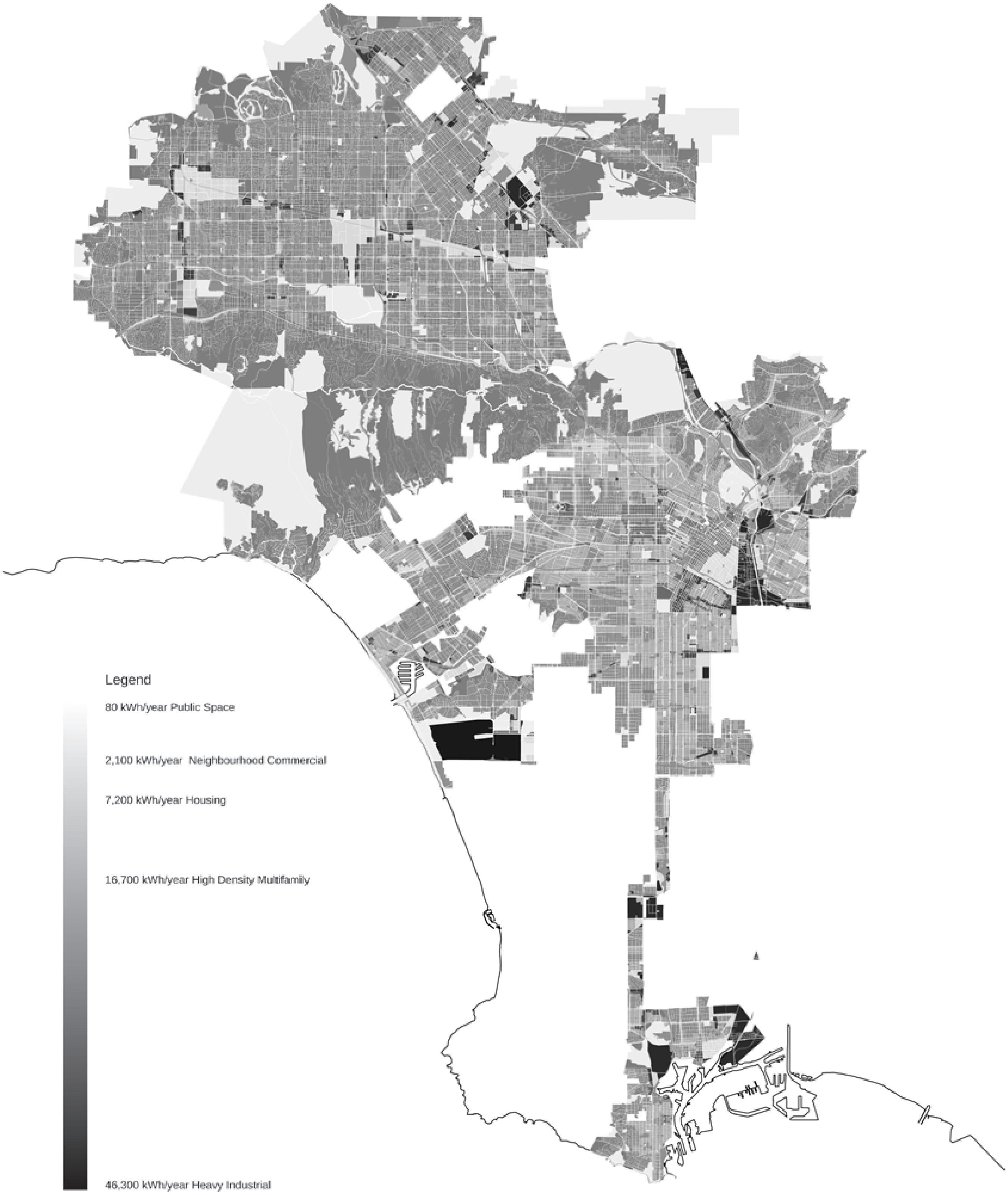


Fig. 2.03 Los Angeles Electricity Use

Fig. 2.04 Proposed Electricity Production Sites

These locations were determined by an extensive examination of the water, oil, wind, and urban infrastructures of the city of Los Angeles. (Appendix A3, p. 188)

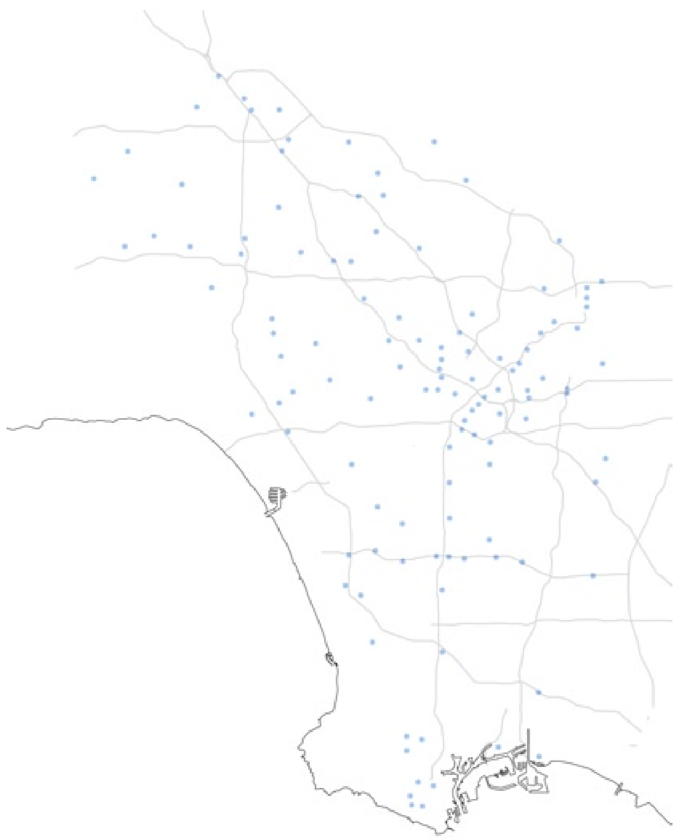


Fig. 2.05 Proposed Electricity Storage Sites

These locations were determined by an extensive examination of the water, oil, transit, and urban infrastructures of the city of Los Angeles. (Appendix A4, p.190)

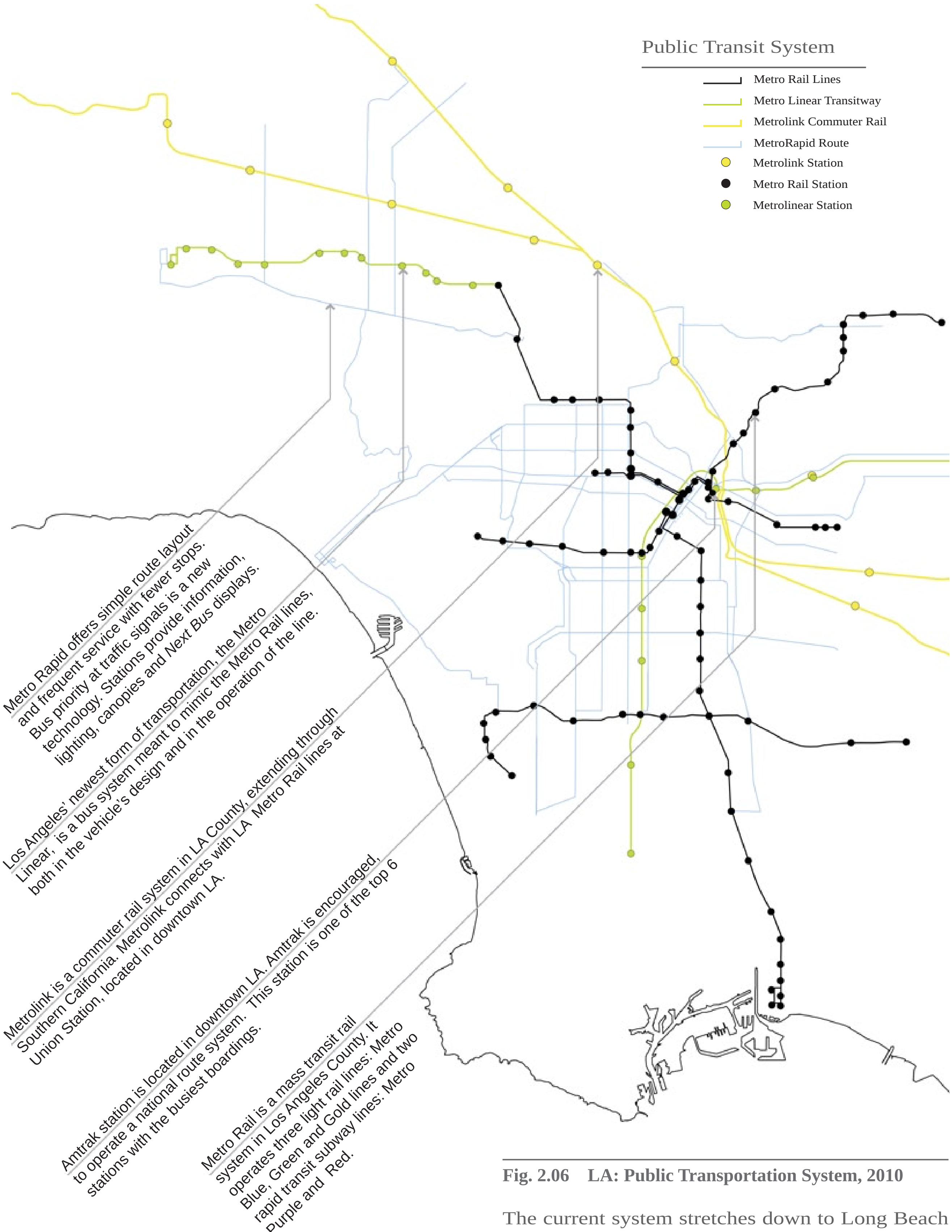


Fig. 2.06 LA: Public Transportation System, 2010

The current system stretches down to Long Beach and up accross the South Valley.

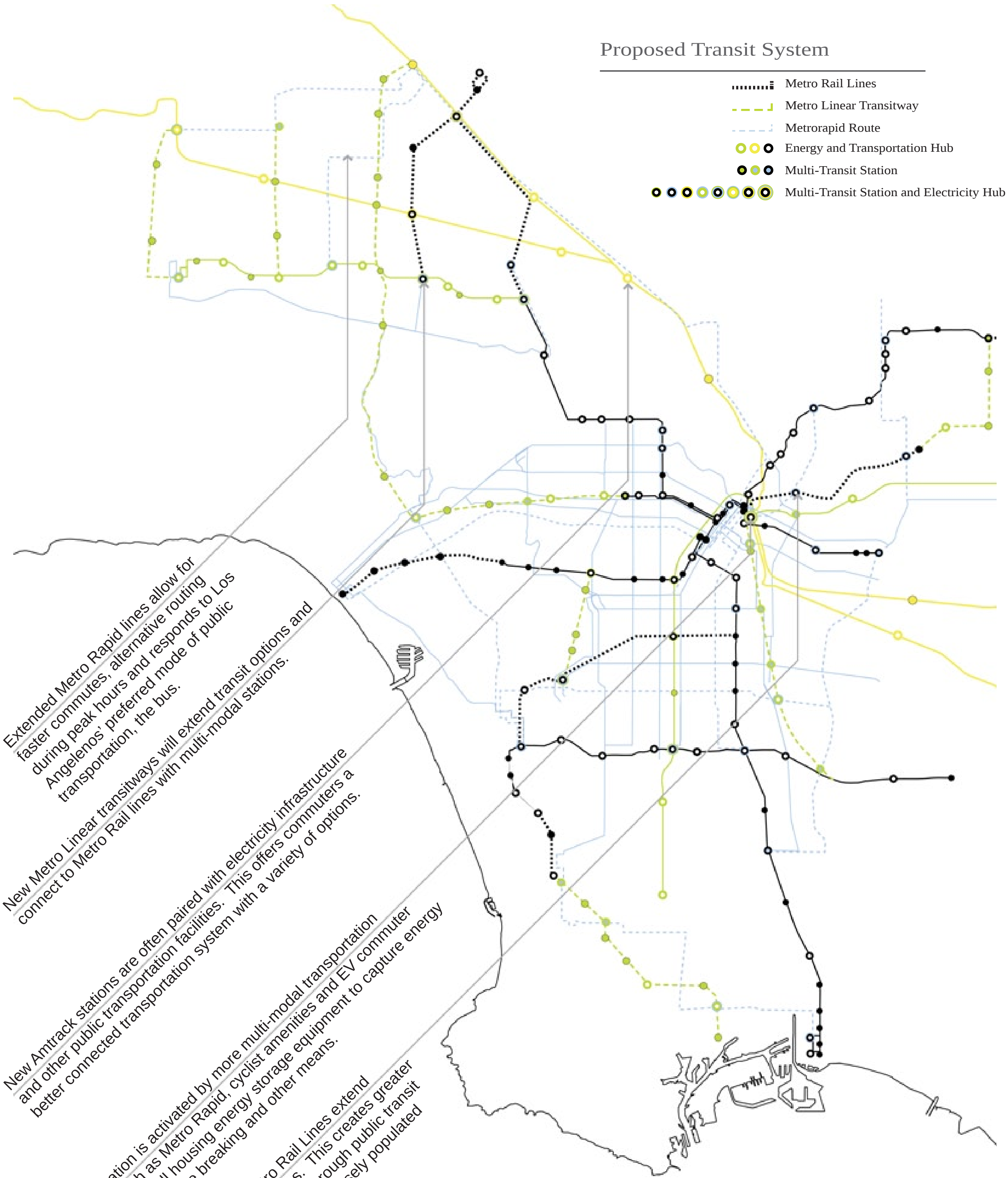


Fig. 2.07 LA: Proposed Transit System, 2040

This system is based on ideas in the Metro's Long Range Transportation plan and information gathered from population density, destination points and transit dependence patterns.


LA Municipal Area
LA Energy District
Energy Neighbourhood
Energy Facility

Coordinating cities as networks of urban microgrids will provide the public sector with greater connectivity and dependability. Each peripheral area has connected public transit nodes sited with priorities directed towards high population density, prominent activity density, travel time, transit dependence and existing infrastructure. Pairing energy control and distribution stations with new and existing transit stations works in the favour of both sectors due to the shared siting criteria. Like transit stations, microgrid facilities function better in areas of higher population, notable activity density, and transit dependence.

Situating nodes in areas with medium to high densities of people and activity creates instances of urban ecovillages.[2] Newman and Kenworthy promote eco-villages as being "the kind of city form that would enable sustainability solutions to be worked out"[3] due to the establishment of local urban management areas. The microgrid areas in this thesis act as local urban management areas (Fig. 2.08), simultaneously monitoring energy and transportation systems at local scales related to the regional system.

Placing nodes in areas with popular destinations makes it more likely that they will be surrounded by mixed programs, parks and integrated infrastructure. Transit access to existing activity intersections would stimulate local economies. The demand for transportation energy in these areas would effectively be decreased due to the elimination of car trips for diverse tasks and induce more pedestrian friendly communities and developments around transport-energy nodes.

Fig. 2.08 Los Angeles: Energy Districts

Left: Identifying energy districts are important for designating each microgrids extent in their respective district and role within the greater network.

2 Newman and Jennings, *Cities as sustainable ecosystems: Principles and practices*, 132.

3 Peter Newman and Jeffrey R. Kenworthy, *Sustainability and Cities: Overcoming Automobile Dependence*, (Washington, D.C. : Island Press, 1999), 281.

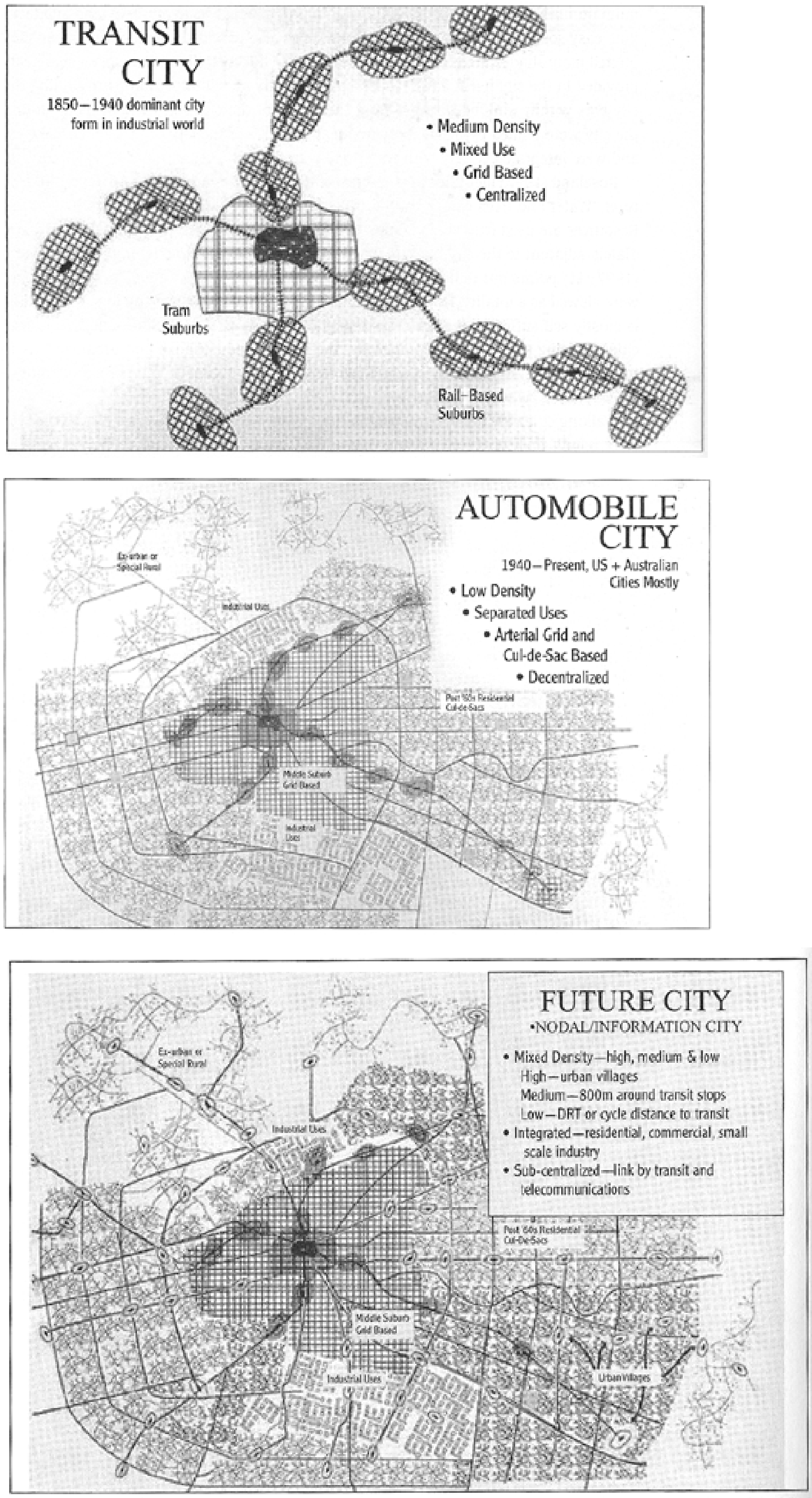


Fig. 2.09 City Patterns

Remodeling the city’s structure based on patterns of succession and adapting the existing structure.

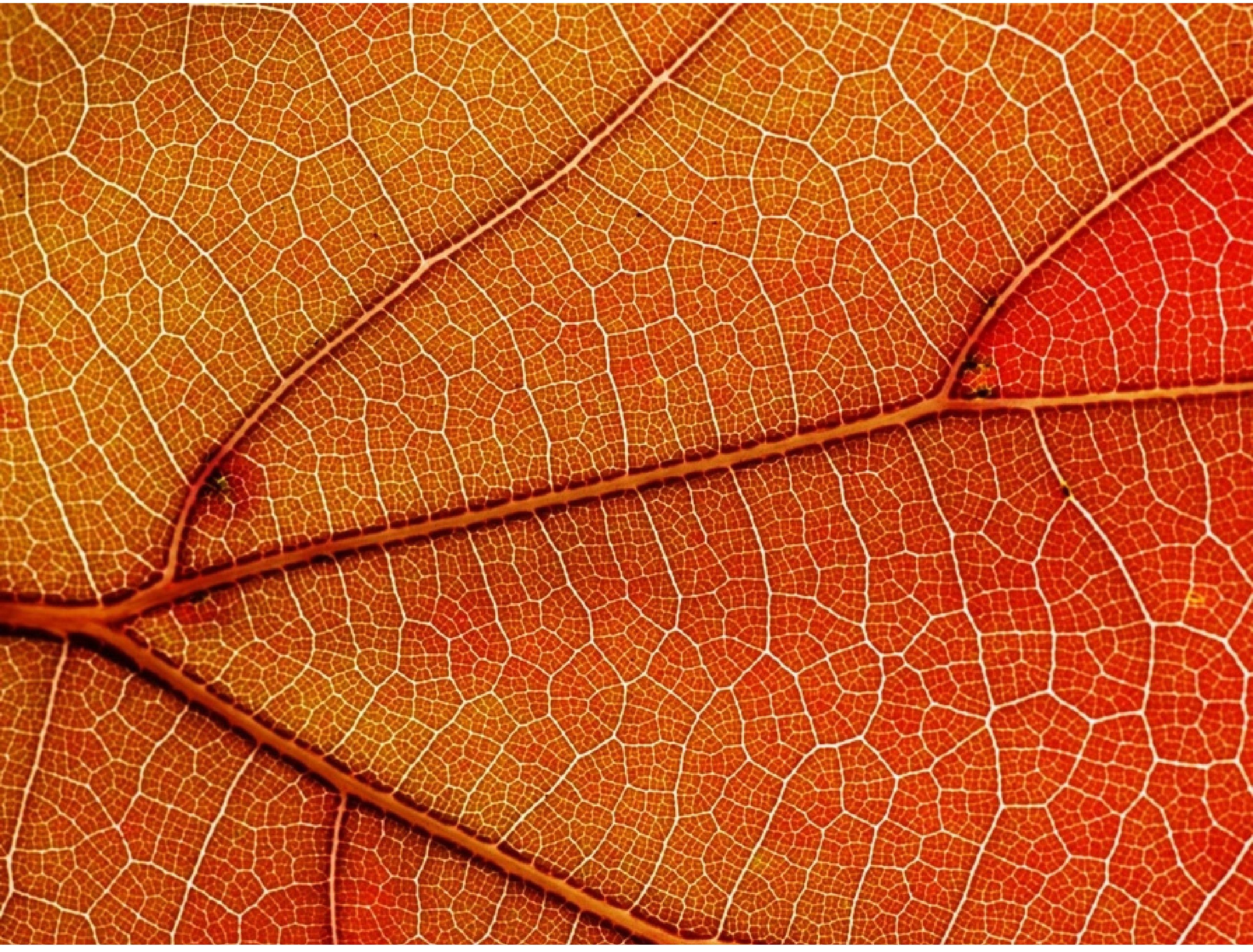
The transportation system functions at a hierarchical scale. Longer distance trips are maintained by rapid transit services, and shorter trips are enabled by local bus, shuttle, and bicycle services (car-share services can work on either trip level). In general these services are organized on this scale. Distances between stations are strongly influenced by the Marchetti constant. The Marchetti constant is a concept in travel time suggesting that people prefer to travel no more than one hour per day.[4] This means that the average traveler favours a 30 minute travel time to and from their main destination. Siting these transit stations based on distance among population densities and dominant destinations works in tandem with energy distribution station siting. A distributed energy and transportation system would ideally be completely homogeneous, but urban settlement and energy use patterns do not follow a homogeneous pattern. Thus, the system is scaled according to electricity use and population densities. This means pairing larger energy distribution and receiving stations with long distance transit stations, and smaller distribution stations with short distance hubs.

Many areas of the city are designated as transit dependent populations. These are populations without private transportation, over age 65 or under 18, and/or people below median income levels defined by the U.S. Census Bureau (Fig. 2.02). New transit lines, routes and extensions of existing transit services aim to provide rapid transit to transit dependent areas lacking proper connection to their city's transit infrastructure. New facilities are ideal sites for constructing completely integrated transportation-energy nodes.

Chosen transportation and infrastructure will be retrofitted with energy facilities and enhanced through cooperative design. Old railways, and commuter parking lots are just a couple of the transportation infrastructures that will benefit from introducing more diverse transportation elements and energy integrated design.

Instituting community managed transportation and energy services allows the city to manifest as an ecological network. Each micro-region is able to function individually while simultaneously being part of a greater system (Fig 2.08). Just as an ecosystem experiences patterns of succession, systems of transportation and energy in the city can evolve to optimize energy, materials, and information resource use. This would be manifest through the extension of Metro linear corridors supported by carpool lanes and transit-focused infrastructure, such as priority intersections.

4 Newman and Jennings, *Cities as sustainable ecosystems: Principles and practices*, 125.



02-2 Urbanism and Ecology (Economy of Energy)

> "Urban regions are emerging with multiple centers, multiple flows, and most importantly, highly dispersed and fragmented temporal and spatial structures."[5]

The condition of Los Angeles and other decentralizing American cities can be used to create a decentralized energy network. Peripheral areas are arms of the core but do not act as such. A polycentric energy and transportation network would link the areas together. This enables the city to function more like an ecosystem where resources and information are shared at a system-wide scale:

> "The integration of urbanism and ecology achieved through the design and planning process ... establishes links between a local and a larger bio-regional view, and makes connections between disparate elements to reveal possibilities that may not otherwise be apparent." [6]

For a future network it is important to synchronize the design agendas of transportation and energy systems

Fig. 2.10 A Leaf structure.

The system could use the metaphor of a leaf where energy is stored used and produced, all in a cooperative nexus'.

5 Graham, "Urban Network Architectures and the Structuring of Future Cities," 212.

6 Michael Hough, *Cities and natural process* (New York, NY: Routledge, 1995), 15.

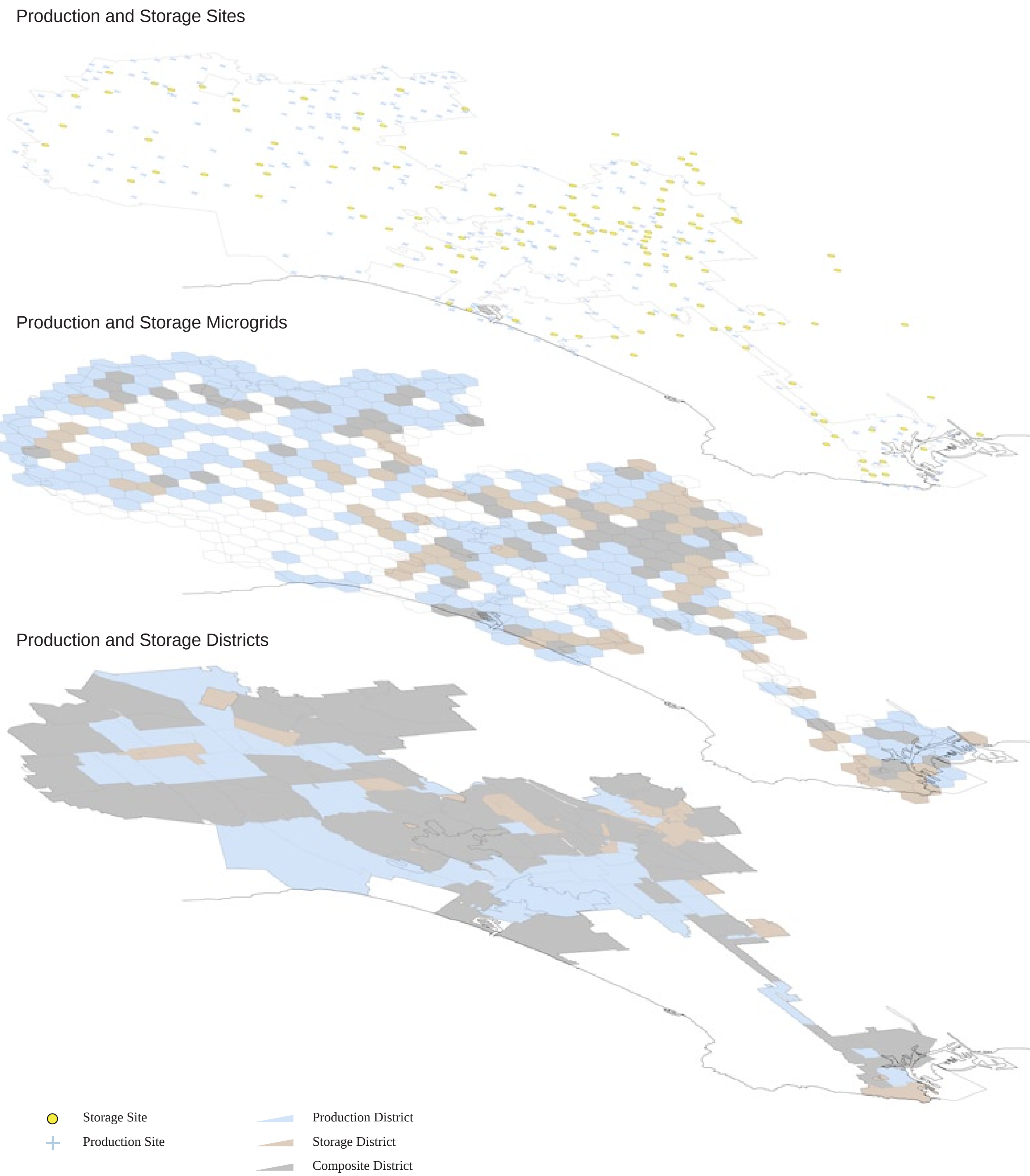


Fig. 2.11 Los Angeles: Energy District Assignment

From top to bottom: Energy Production and Storage Sites, Microgrid Network, Neighbourhood Energy Districts. Identifying energy districts is important for establishing each microgrids' role in its respective district and its role within the greater network. With microgrids in place and a smart system of feedback each neighbourhood can develop unique internal cycles of sharing. Concerning energy, each cycle is governed by the area's condition of have or need. This creates specific relationships between the local microgrid and its neighbors. For transportation cycles are based on demand from other areas.

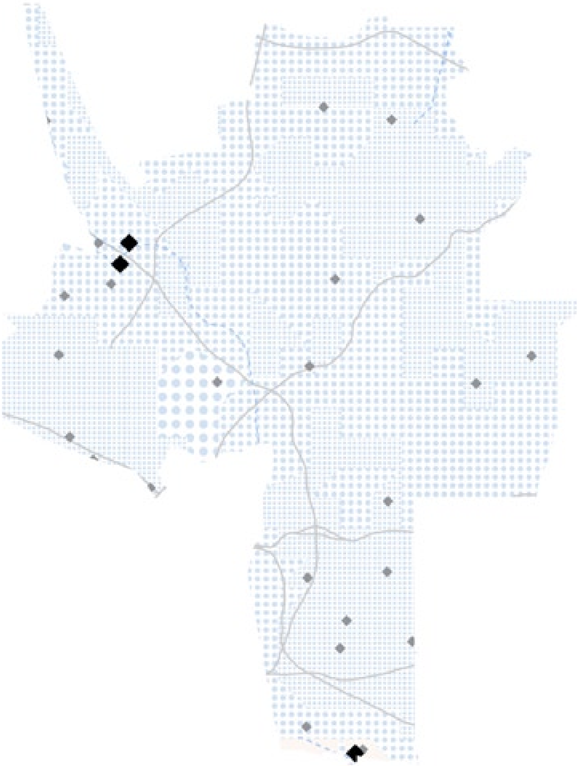
within these polycentric urban spaces. Electric energy and transportation systems are inherently linked. The transportation sector will rely heavily on electrical energy inputs. Electrical energy systems benefit from the distributed nature of transportation infrastructures. Energy consumption, population density and trip generation can be coordinated to locate power and transport facilities (Fig 2.02-2.05). By pairing transportation and energy, patterns will emerge to guide urban interventions coordinating the two and characterizing their presence within the city:

> "As open thermodynamic systems, the building and the city share the living organism's need to consume energy continuously in order to maintain the morphological organization on which its very existence is based."[7]

Currently the peripheral cities of Los Angeles function as parasites that rely on the center for basic infrastructure inputs and connections, however they do not contribute back to the city as a whole. Using the decentralized network morphology each microgrid-entitiy can retain specific functions within their local area. Through these energy districts the city can function with a macro objective. This is only through scaled micro-neighborhoods, each doing its part to maintain the city's decentralized energy system. Each microgrid would be first concerned with the energy and transportation demands of its designated area, then, any surplus or additional requirement would be communicated to the outside network. These transactions would be possible because the microgrids would be organized on a cellular network (Fig . 2.10). The resulting nodes in each microgid become hot-spots for mixed-use centres. Ideally, these nodes would create walkable neighborhoods that are accessed by multi-modal transportation systems.

7 Luis Fernandez-Galiano, *Fire and Memory: On Architecture and Energy*. trans, Gina Carino (Cambridge, MA: The MIT Press, 2000), 79.

Population density



Destinations

Highways and Roadways

New Transit Plan and Dependant Population

The activities of users in a local district can be changed with the introduction of various smart technologies. These technologies will become more and more sophisticated as they are given time to be scrutinized and tested in real situations. Each alteration to user activity and technology will be considered as a disturbance to the greater system. For example the introduction of electric bicycles will introduce a new energy demand but also energy production due to regenerative breaking and dynamo[8] generators. Disturbances are negative in nature but positive for alterations in the system organization and towards proactive control that enables the system to evolve.

Ecosystem Performance

Reducing energy consumed while providing for symbiotic energy transfers is fundamental to the structure of the distributed network. Relationships between production, storage, distribution and information agents are coordinated to encourage symbiotic interests.

While supporting modernism's global quality of efficiency this network moves beyond modernist strategies of curbing use of energy, water, traffic and housing. By employing methods of New Urbanists, the system engages in a network that uses one industry's waste as resources for another. As Newman Illustrates:

> Many modernist solutions in these areas of urban life are now found to be unsustainable. A systems perspective may offer a better chance of finding ways to live sustainably.[9]

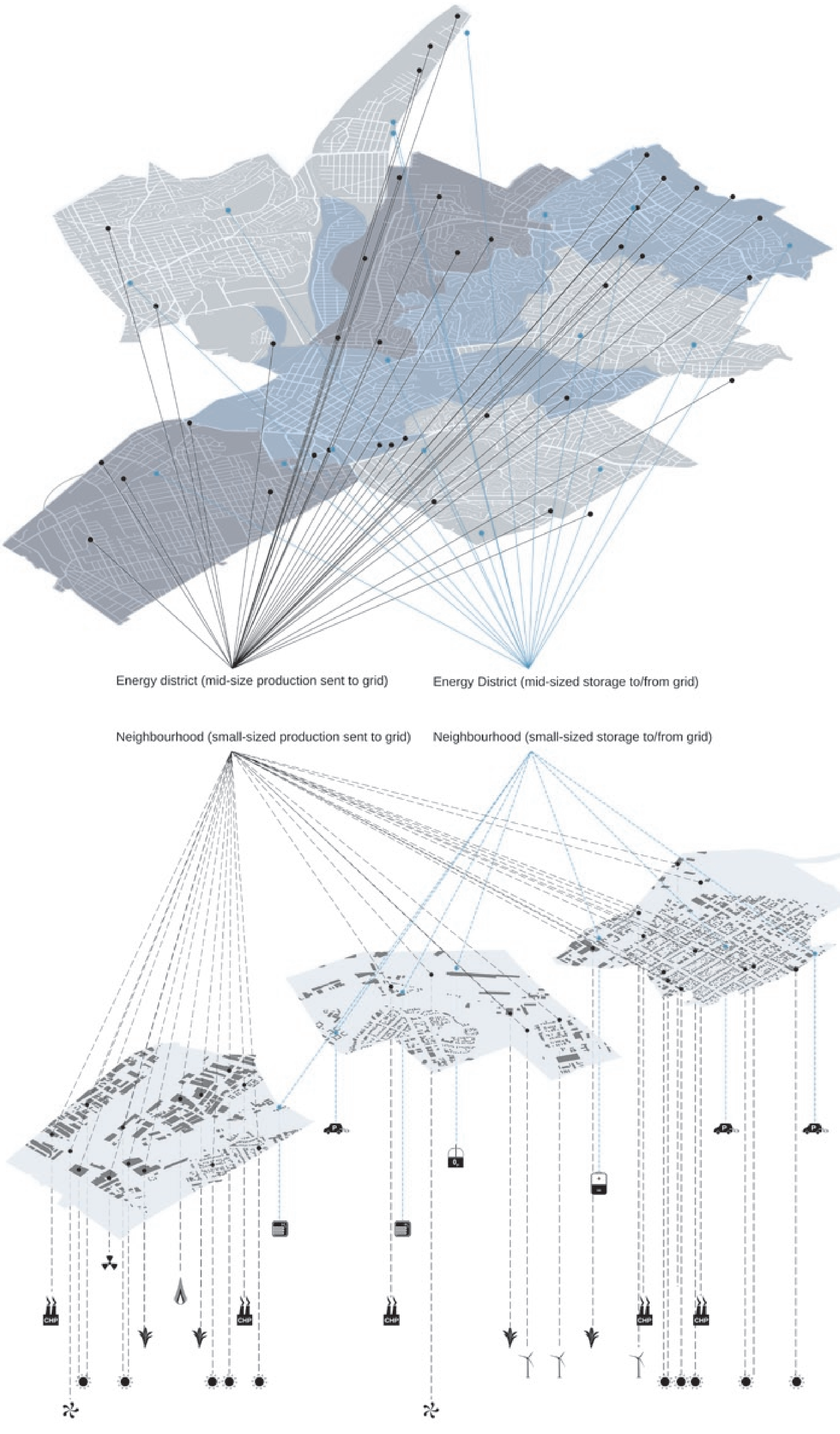
Systems theory combines the efforts of individual parties to the function of the entire network. Borrowing from

Fig. 2.12 District Case Study Area: East Los Angeles

The Maps to the left denote the several aspects of the area that were studied to inform the placement of transportation and energy infrastructure as well as specific transportation-energy hubs.

8 Dynamos are a type of generator that produces direct current. These are not widespread today due to the dominance of alternating current for our grid.

9 Newman and Jennings, *Cities as sustainable ecosystems: Principles and practices*, 92.



Energy district (mid-size production sent to grid)
Energy District (mid-sized storage to/from grid)
Neighbourhood (small-sized production sent to grid)
Neighbourhood (small-sized storage to/from grid)
CHP
CHP
CHP
CHP
CHP

living systems microgrid areas are established as "critical subsystems" distinguished by their regional energy capacities. Each microgrid has unique energy limitations that can be remedied by partnerships with adjacent grids. Like an ecosystem, interactions between the energy facilities are managed using symbiotic patterns. Storage and production sites communicate with data and systems to route energy appropriately. The reciprocal functions of the system rely on real-time feedback between neighbourhood subsystems. Competition between energy users is maintained locally rather than city-wide. This enables greater control over waste and unprincipled energy distribution. Newman explains:

> Bioregional economies reflect the capacities and limitations of their particular ecosystems, honor the diversity and history of local cultures, and meet human needs as locally as possible. Bioregional economies are diverse, resilient, and decentralized.[10]

Fig. 2.12 illustrates this concept. Three separate community areas are shown, each with a different composition of energy production and storage technologies. Each area also has a different composition of transportation needs and each reflects the capacity and limitation of its local area.

The municipal infrastructures of energy and transportation can then be governed centrally but maintained by individual microgrids. The microgrids are able to communicate at local and regional scales. The transportation system would integrate with the energy microgrids by providing a useful network for coordinating routes. A smart transportation system, much like a smart energy system, is able to send instant feedback detailing high and low demand areas. Bus frequencies can then be altered in real time to compensate ridership demand rather

Fig. 2.13 Microgrids in East Los Angeles

Left: With microgrids in place and a smart system of feedback each neighbourhood can develop unique internal cycles of sharing. Concerning energy, each cycle is governed by the area's condition of have or need. This creates specific relationships among the local microgrid and its neighbors. For transportation cycles are based on demand from other areas. Data Centers are sited to coincide with transportation nodes and energy distribution facilities where possible. Coordinating energy figures among microgrids supports the function of the decentralized city network.

10 Newman and Jennings, *Cities as sustainable ecosystems: Principles and practices*, 39.

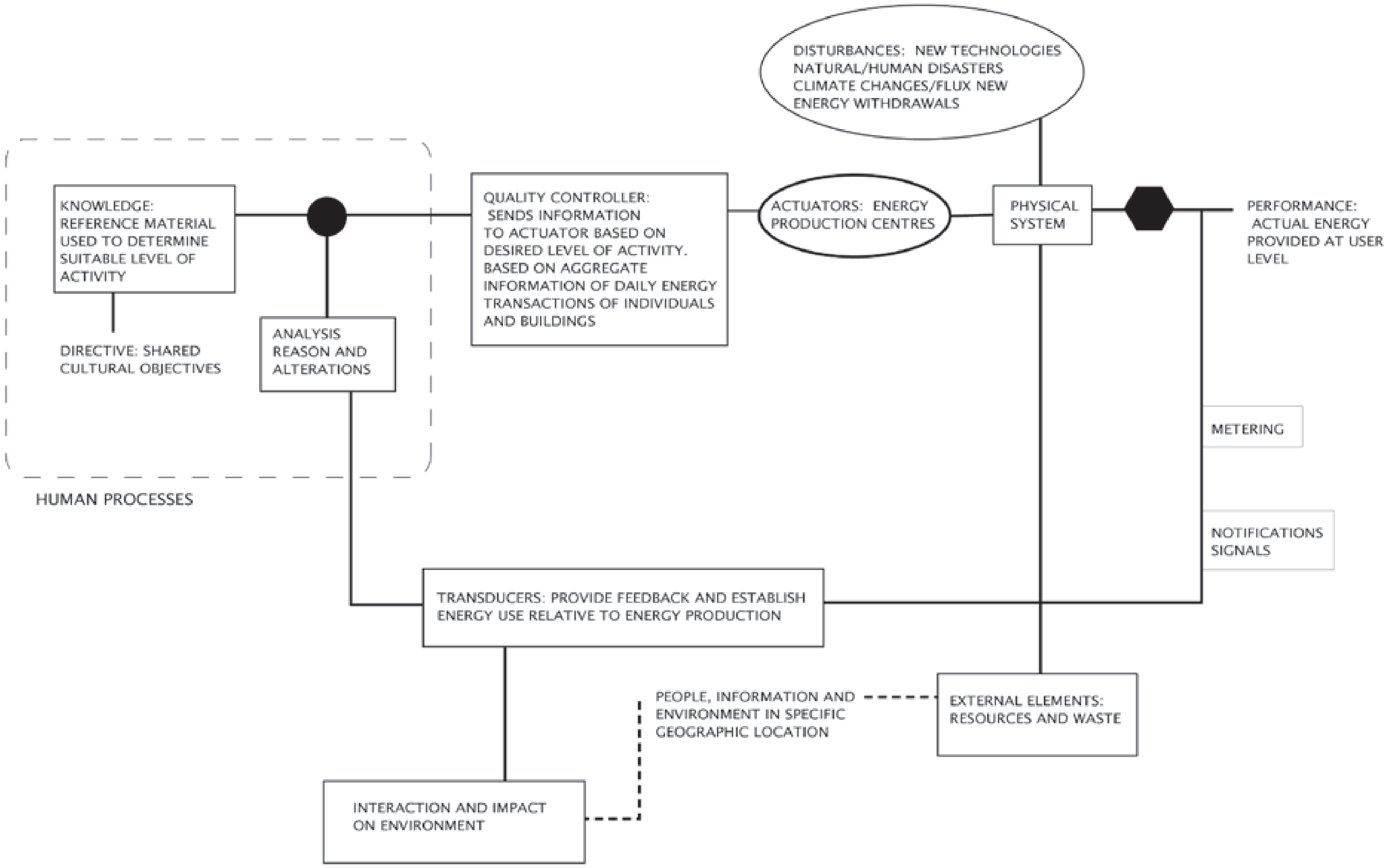


Fig. 2.14 Krumdieck Energy - Environment Systems Model

than solely relying on prediction based schedules.

Responding to disturbances quickly and efficiently is achievable using a migrogrid system. Each microgrid responds to problems internally creating cycles of internal-renewal as a function of regenerative design. This means that while a disturbance is remedied technology can also be upgraded. Regenerative design means that the microgrids have to behave as self reliant regions, each resolving individual disturbances and advances so as not to compromise the integrity of the greater system.

Transportation-energy microgrids operate based on functional strategies of autonomous ecosystems. They harness energy, preferably from renewable and available sources. They store energy. They conserve energy through integration and adaptation to place. They integrate functions of the system and promote functional diversity. They use feedback loops for self-regulation. They operate as a cooperative network, enhanced through processes of co-evolution. By capturing most of their energy internally they become regionally autotrophic. Peter Newman calls this operation strategy panarchy.[11] Panarchy is described as a pattern of nested adaptive rhythms through space and time. Newman and Jennings describe, "the dynamic interplay between processes and structures that sustains relationships on the one hand and accumulates potential on the other."[12] Their theory essentially is that the processes that build greater connectedness go hand in hand with the processes that disturb the system and stimulate it to release potential and to reorganize. Newman and Jennings explain, "these two opposing cycles exist as part of a whole, helping to build system resilience by creating ecological memory ...and renewing the system through the release of stored nutrients."[13] Together processes of connectedness and disruption instigate a system of feedback and memory which can evolve over time through iterations of destruction and restoration.

The city benefits by overlapping regions that are able to consolidate individual resources into a network. Providing greater connectivity in the public transit sector allows for a versatile and egalitarian transportation system. Borrowing strategies from ecosystem networks, reciprocity between energy and transportation services begins to emerge.

Systems Approach to Energy Distribution

A fundamental difference between how cities and ecosystems currently operate is their behavior within an environment. Ecosystems operate symbiotically with their environment. Cities currently alter their environments to suit the demands of inhabitants, but as Susan Krumdeick states:

> The only way to achieve a sustainable society is to have a sustainable energy and environment architecture, where the daily activities of individuals and businesses are carried out within environmental constraints. [14]

Krumdeick's theory is that a sustainable system must be based on systems engineering principles applied to a supply-led economic theory. Predictions of energy patterns by the Energy Information Administration along with sections of the *Post Carbon Reader*[15] establish the

11 Newman and Jennings, *Cities as sustainable ecosystems: Principles and practices*, 103.

12 Newman and Jennings, *Cities as sustainable ecosystems: Principles and practices*, 99.

13 Newman and Jennings, *Cities as sustainable ecosystems: Principles and practices*, 103.

14 Krumdeick, "Systems Approach to Posing Problems and Finding Sustainable Solutions."

15 The Energy Information Administration bases their predictions on assuming we stay on our current course of action where the *Post Carbon Reader* speculates on what would occur if we wean society in North America off pedroleum dependence.

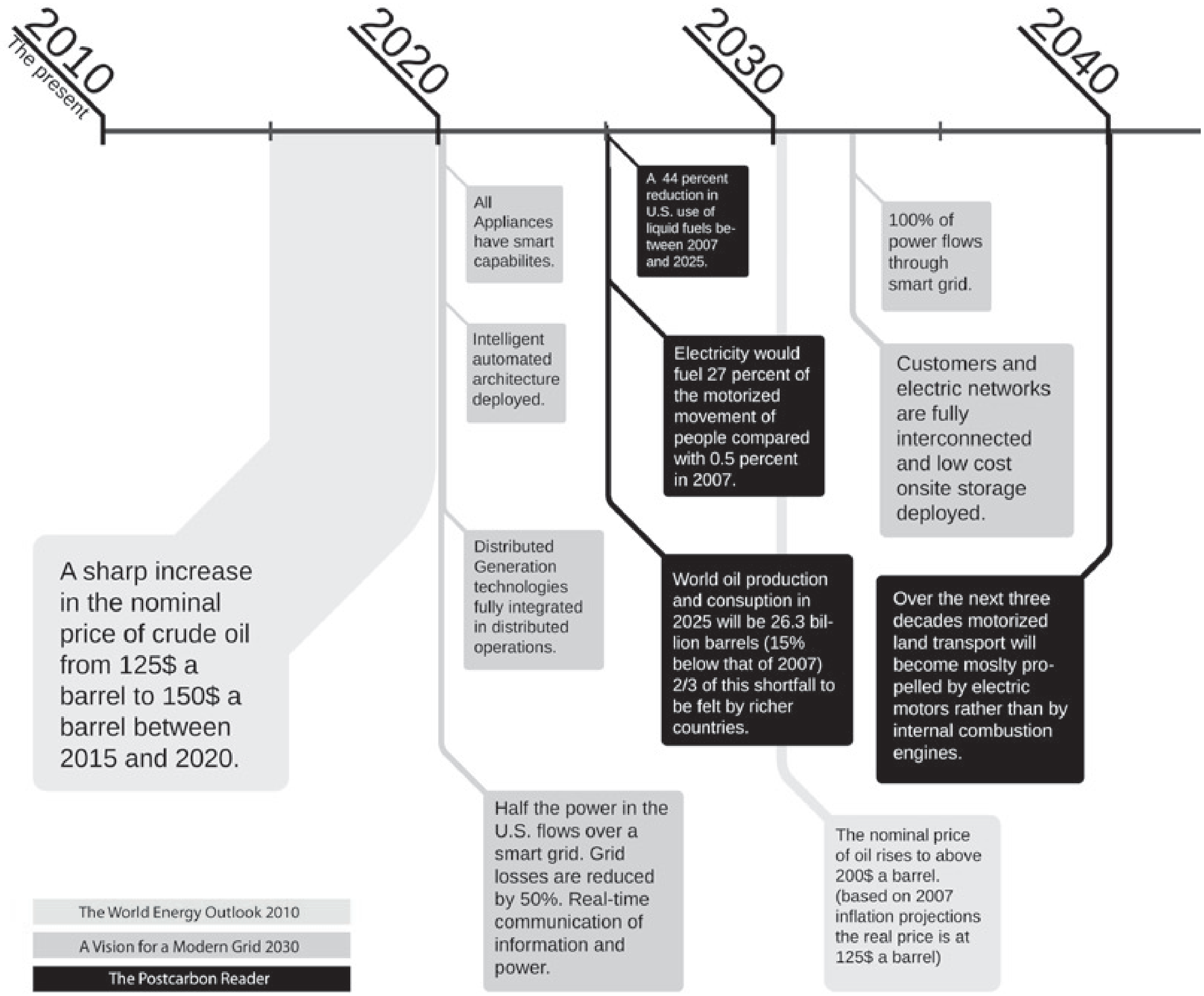


Fig. 2.16 Timeline of Various Predictions

constraints of the proposed local Los Angeles energy facilities. These predictions define what actuators (see Fig. 2.13) will be installed to inform the relationship between consumption and production in Los Angeles. Krumdeick defines actuators as economic relationships that determine how people access electricity and transportation services they require and desire. Siting electricity production facilities in local districts and micro-regions allows actuators and consumers to communicate at local levels. The actuators are key contributors to feedback information relayed back to the user. This information would include the source generator of electricity, peak load times and local consumption patterns.

02-3 Network Design

Symbiotic Networks - Highly Distributed

A decentralized system works with the current centralized energy production system to add energy efficiency, sustainable energy options, security and power quality[1] to the current energy infrastructure.

> Form can be understood as resulting from the joint intervention of energetic capital and profit, hysteresis and homeostasis, inertia and autoregulation, permanence and adaptive change.[2]

Fig. 2.17 Energy-Transit Network

1 Power quality is the required limits of electrical properties for a given electrical system to function without measurable energy losses or degradation of performance and life.

2 Fernandez, *Fire and Memory: On Architecture and Energy*, 99.

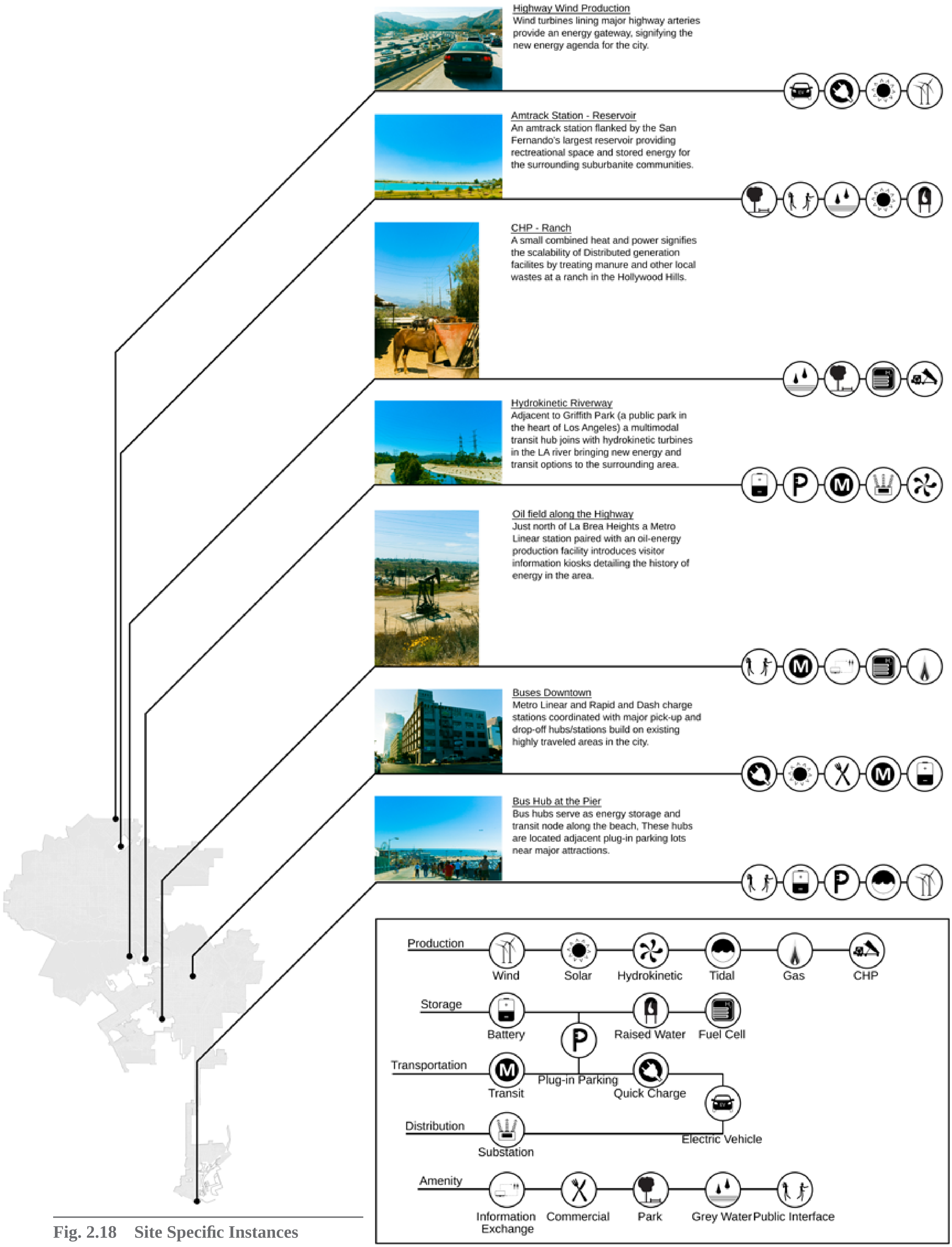


Fig. 2.18 Site Specific Instances

System Objectives

As networks, transportation and electricity have shared objectives. Ultimately each area aims to establish a state of autonomy within the cycle of the greater network. This requires each neighbourhood energy and transportation systems to be coordinated first at a local level and then within the greater system. Each community will be fitted with various electricity-transportation nodes. These nodes serve their immediate population by providing accessible transportation options and access to advanced electrical energy options. In some areas these provisions are directly linked. Examples include: electric plug-in parking lots, quick charge stations, bus-charge stations and electric bus depots.

Each energy facility is equipped with Smart-technologies that communicate with one another. At the center of this network is a central command station. The location of command stations is governed by security, geography, proximity and connectivity.[3] Secure locations and information exchange network is important for the control centers due to the drastic effects of a terrorist assault.

These nodes will integrate within their respective environments by providing public space and public services specific to their local district. Transportation and electric public services should be complemented by public spaces.

3 Los Angeles has a newly introduced fiber-optic information infrastructure that enables high speed information exchanges. This network is faster and more physically secure than cellular or broadband lines because it is underground.

Supply and Delivery

Electricity will be produced within and beyond the city limits. Eventually local electricity production will obviate any imported energy but this is in the distant future. Local production in the electricity market will decrease reliance on long distance transmission and stepped voltage controls. Production will occur at various scales and through a variety of means. Each production facility would be sited with specific consideration for local energy needs and local resources available. This coincides with the energy districts mentioned earlier. Each district is given a role within the greater city energy network. The communities within each district are responsible for their energy consumption, production and storage.

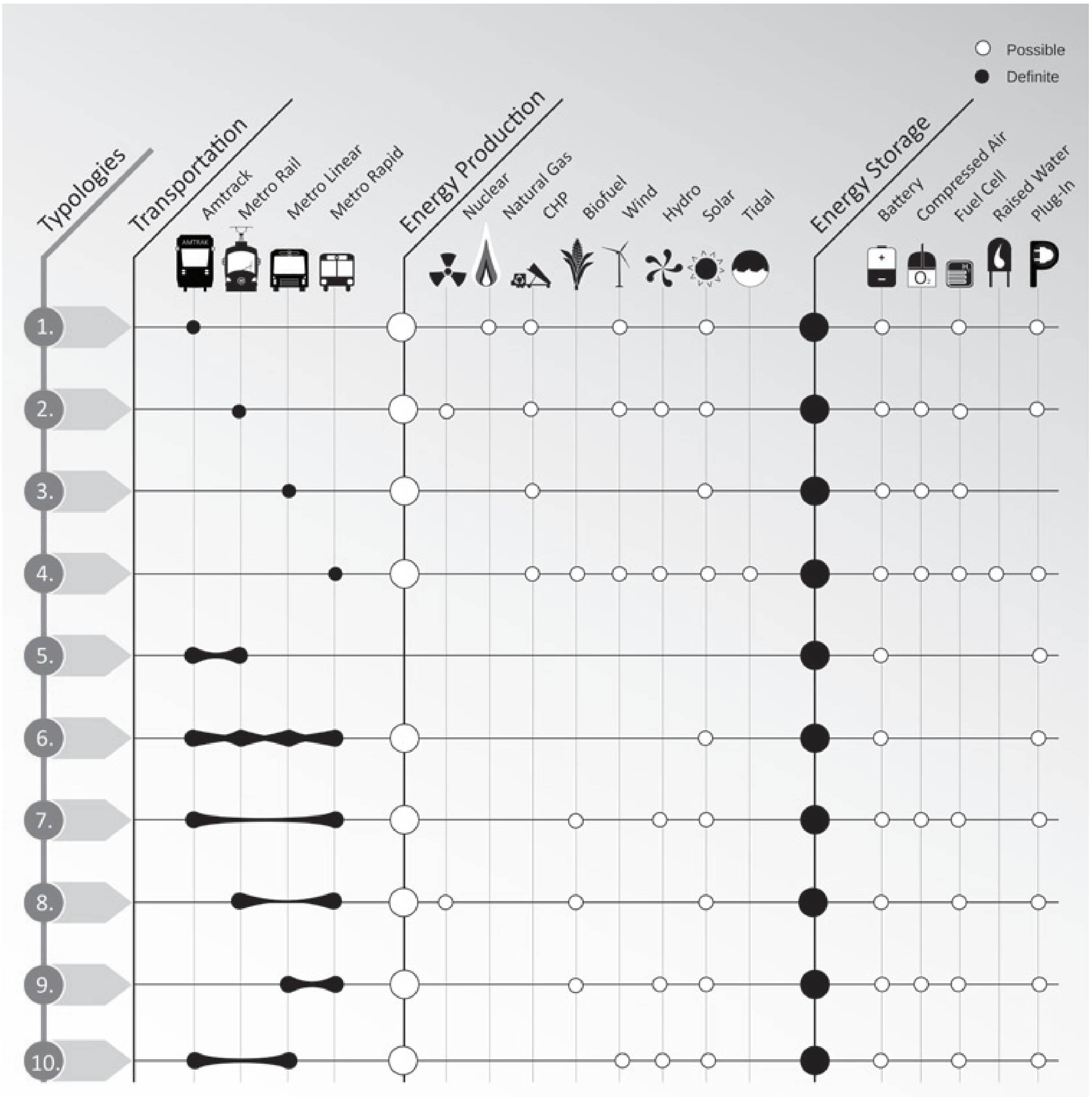


Fig. 2.19 Los Angeles Transportation-Energy Node Typologies

Some coupled facilities have storage dominated energy amenities but all are incorporated so that energy and transportation have mutually beneficial aspects.

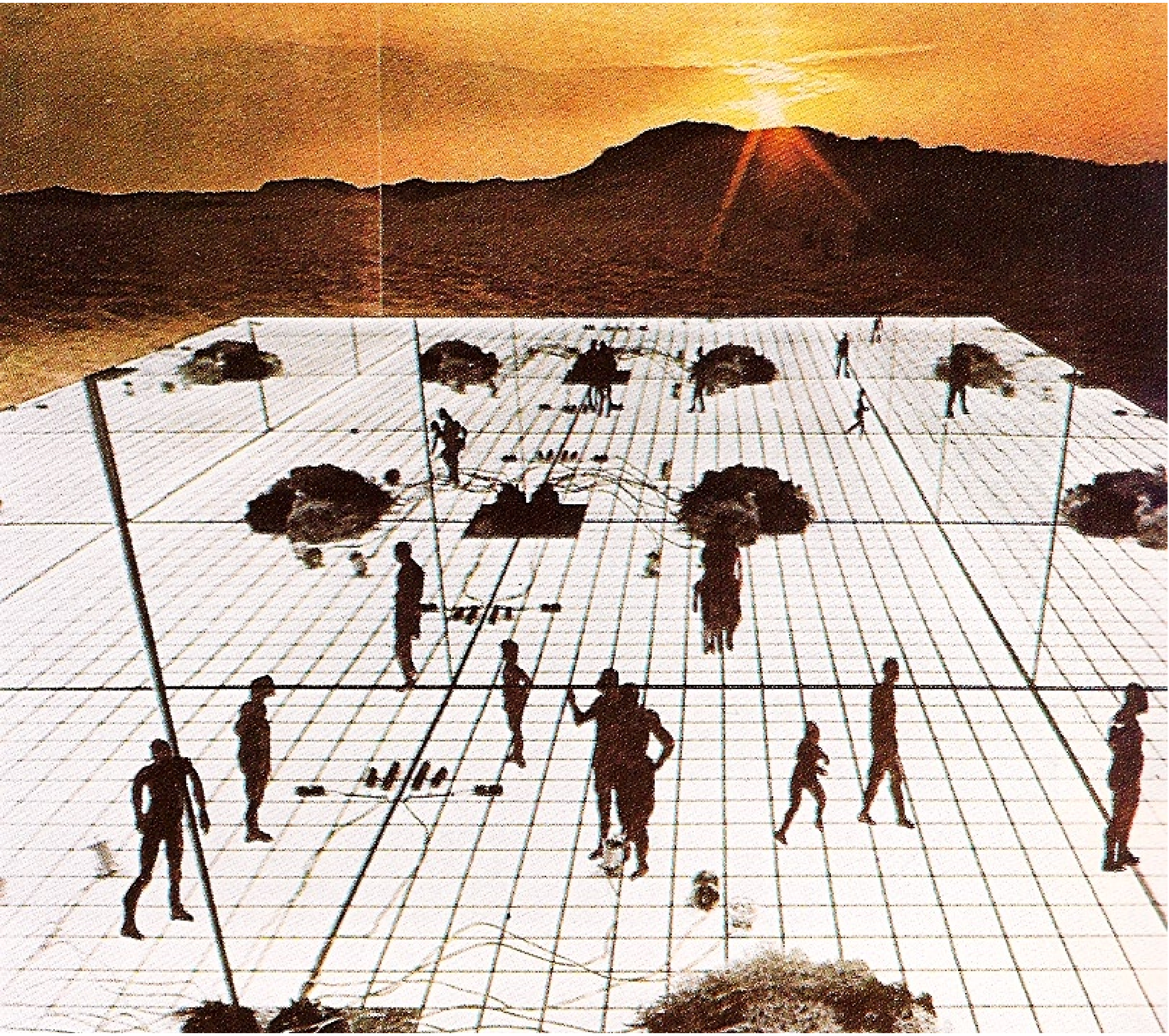
The resulting nodes will constitute a physical foundation of the cooperative electric and transportation systems. Each location has unique challenges as part of its physical characteristics. The flows of energy, people and information are coordinated at each node and presented to the public user through the collocation of architectural and information elements.

Visitors are exposed to indicators of the role of energy and transportation in their community. As Smart technologies permeate the daily lives of users, the performance of the grid will become of utmost importance. The Smart communication between user, device and network will be evident in new building elements. This will include the introduction of interactive, exposed infrastructure. Real-time information of community energy and transit schedules are displayed at each node. Following past examples of "making ecological processes visually apparent,"[4] the design agendas aspire to make city transportation and energy patterns legible. At each node careful consideration is given towards integrating community goals with those of the greater city. In this sense Los Angeles can become a self-healing entity, as Newman explains, "Cities can be both ecologically and socially regenerative through activating their sense of place."[5]

Each community node corresponds to that community's transportation and energy requirements.

4 Newman and Jennings, 147.

5 Newman and Jennings, 155.



03 Proposal

03-1 Future Energy Ecology

Fig. 3.01 Landscape as Motherboard, by Superstudio

One of Superstudio's many iterations of life types. This image illustrates the integration of urban populations with networked infrastructures. This describes a state of City-Network where people are served by electrical and mechanical services.

Supplying a city with its electricity needs from within city boundaries will be a hard task to accomplish. Although complete self-sustainability is the aim of the system, realistically there will be several stages that our urban forms will pass through as they move toward an independent energy network. This thesis situates itself within the transition between: centralized energy production and decentralized energy production, fossil fuel based electricity production and renewable electricity production, individual transportation and mass public transportation. It is assumed that the electricity based transportation will become the dominant power choice in the future. Thus the future state of the following proposal is situated within an Energy Ecology. This title is borrowed from Reyner Banham's *Los Angeles: The Architecture of Four Ecologies.*

Reyner Banham describes Los Angeles by portraying what life is like in a semi-personal manner. His accounts identify four environments or ecologies of Los Angeles: Surfurbia, Foothills, The Plains of Id, and

Fig. 3.02 Long Beach.

Previously oil derricks framed the shoreline (see Fig. 1.26, p 68), now it is accompanied by the rhythm of horizontal wind turbines.

Autopia.[1] Each ecology has an exclusive relationship with Los Angeles that is complemented by a specific architecture. The ecologies are descriptions of unique cultural and historical events that formed each region's particular spirit of place.

The ecologies solve the problem of describing the character of a city with no common urban place. The decentralized network described by this thesis will exist in a hypothetical Los Angeles of 2030. The proposed microgrid communities in Los Angeles are described as an extension of Banham's original ecologies. The following section describes a fifth ecology of energy in the city of Los Angeles. Characteristic neighborhoods of the presumed Los Angeles of 2030 are presented through short descriptions and images.

Ecology V : The Electric City

Energy and public transportation are symbiotic infrastructures. They occupy the same land and appear to operate with parallel rhythms. Both have peaks, jams, disturbances and periods of smooth sailing. They are mobile in the military sense, equipped and prepared to move quickly to any place they are needed. There are distinct energy-transportation communities scattered throughout the city. For example, Sunland and Tijuana are wind laden areas. Their highways and hillsides are lined with horizontal and vertical wind turbines, spinning with the turbulent winds produced by the flow of the day's traffic.

The smaller privately owned gas stations were the first to go. This freed up corner plots of land throughout the extents of urban sprawl and diminished the popularity of roadside commercial areas. After the mandatory soil remediation there was a period of massive reappropriation of corner plots. They had become a useless building type, replaced by at-home or at-work EV charging stations. The electric vehicle took over the streets of Los Angeles in merely ten years.

Once lined by oil derricks the Pacific Coast Highway is now framed by rows of windmills rhythmically sweeping through the air. There is no need for a 'beautification fence' or public art distraction; the white elegant blades are innately beautiful. They symbolize a future Los Angeles, tired of relying on oil and coal for its energy, tired of smog and debris clouding the city streets. The highway is almost silent. Not because it is empty, but because it is electric. The high torque low-noise engines hum almost silently.

The Los Angeles Metro system overcame the roadblocks of its past and pushed forward with a new approach. By consolidating transportation entities and linking payment strategies with monthly energy bills the system is able to function seamlessly and provide transit riders with transportation options beyond the personal vehicle.

Each neighbourhood has a role in the city's energy network and these roles are visible through mobility. As before, the city bus was the provider of the largest portion of public transportation, but now the bus is more than a transportation vessel. Bus depots become icons of energy storage and community responsible energy practices. Their energy storage capacities are what enable the electric and hybrid bus system to run on renewable energy resources. Bus stops provide information on local energy systems as well as routes, schedule times and nearby amenities.

Microgrids are formed by common energy environments, whether production, storage, distribution, or a combination. Each area has a specific role resulting in a unique urban situation.

Walking down a major transportation corridor is not uncommon. The city decreased the amount of road-side parking by 15% every five years since 2020, Which

1 Banham, *Los Angeles: The Architecture of Four Ecologies.*

Fig. 3.03 Charging Stations

Los Angeles many gas stations were the first to feel the ramifications of an electrified transportation system. Between 2025 and 2040 alternative transportation markets brought countless new modes of transportation to Los Angeles. From the electric tricycle to shared electric vehicle services, Los Angeles had not seen this kind of transportation shift since the abandonment of its Red-car system in the 1940s.

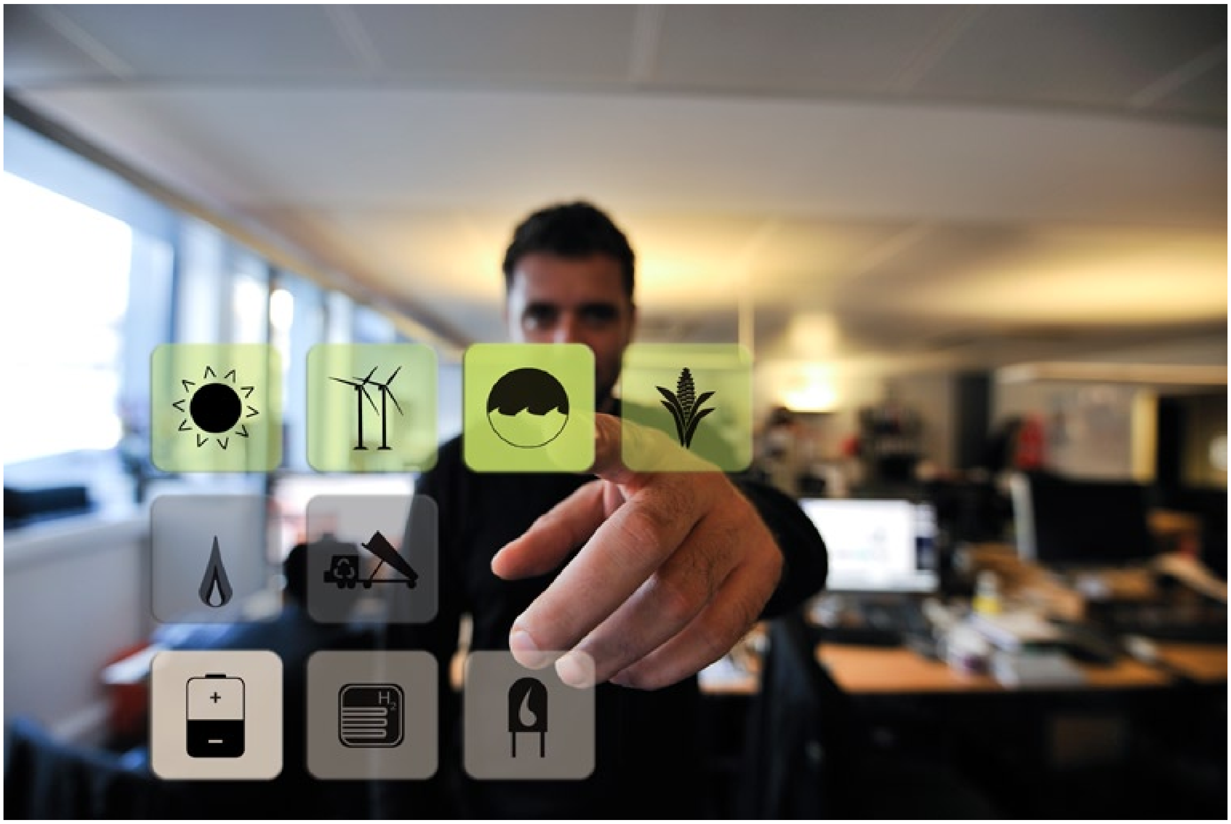


Fig. 3.04 Smart Systems

Storage and production information is communicated to the community with Smart devices and feedback systems. The role of energy in urban quality of life is manifest in the thousands of instruments providing feedback and monitoring. The modern kitchen is equipped with intelligent appliances as energy efficient as the LED lighting on its digital displays.

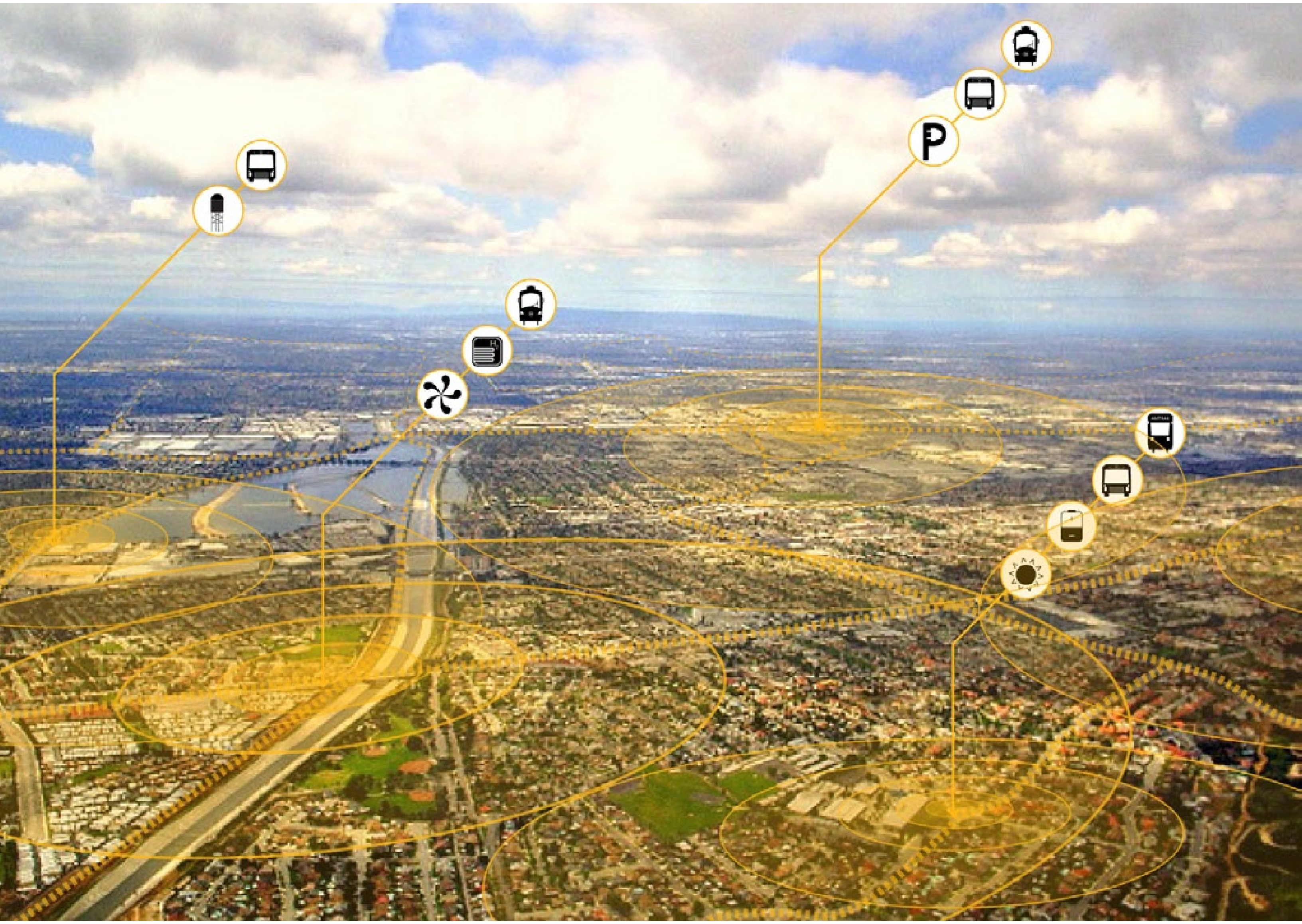
Fig. 3.05 Major Transportation Corridor

Multi-modal transportation hits Los Angeles. Eight lane roadways are a thing of the past. Streets are now lined with designated public transit-ways and bike lanes was one of the many strategies for the implementation of Transit Oriented Development zones. These areas offer a higher quality of life by integrating public services, housing, nature, history, culture and education.

The enormous and dreary parkade of Los Angeles was transformed into a sophisticated machine. Vehicles pour in and out bringing with them megawatts and volts of energy in their batteries. The en-route fuel-up or even fill-up is in the Los Angeles past. Generally people know where they are going on a particular day, and do not need any more energy than required to get there. Batteries and people function together through various periods of flux. The drivers park their vehicle on the second floor, beside the ride-share lot and plug them in. The vehicle's system connects to the greater parkade network and communicates requests. Charge? No, has excess. Release? Yes, battery full from home power source, requires 50 percent for home trip and errands. When the driver returns the vehicle will have given power to the parkades electric storage facility, essentially being paid to park.

Communities have been given centrality in the form of visibility and accessibility from adjacent and distant locations, desirability to customers and business owners, their draw for urban landmarks and social happenings.[2] Transit destinations within each community are positioned in proximity to business, commercial and recreational facilities. Along Wilshire Ave. where towering condominiums and a six lane highway used to command the masses, alternative transportation has throughout the years claimed its territory. Designated bike lanes were the first to appear. The middle class residents of Brentwood, Westwood and Bel-Air surprised the city when health and congestion issues prompted them to advocate for the addition of 1,200 miles of bike paths.

2 Sergio Porta and Vito Latora, "Centrality and Cities: Multiple Centrality Assessment as a Tool for Urban Analysis and Design," in *New Urbanism and Beyond: Designing Cities for the Future*, ed. Tigran Haas, 140 (New York, NY: Rizzoli International Publications, 2008).



03-2 The Electric City: Typologies

The introduction of transportation-energy nodes into the urban fabric of Los Angeles requires the establishment of typologies. The Los Angeles public transit extension was overlaid onto mapped assessments of energy production and storage locations to establish the basic elements of each type. These typologies outline the basic kit-of-parts for how these nodes can cooperate with the communities which they serve.

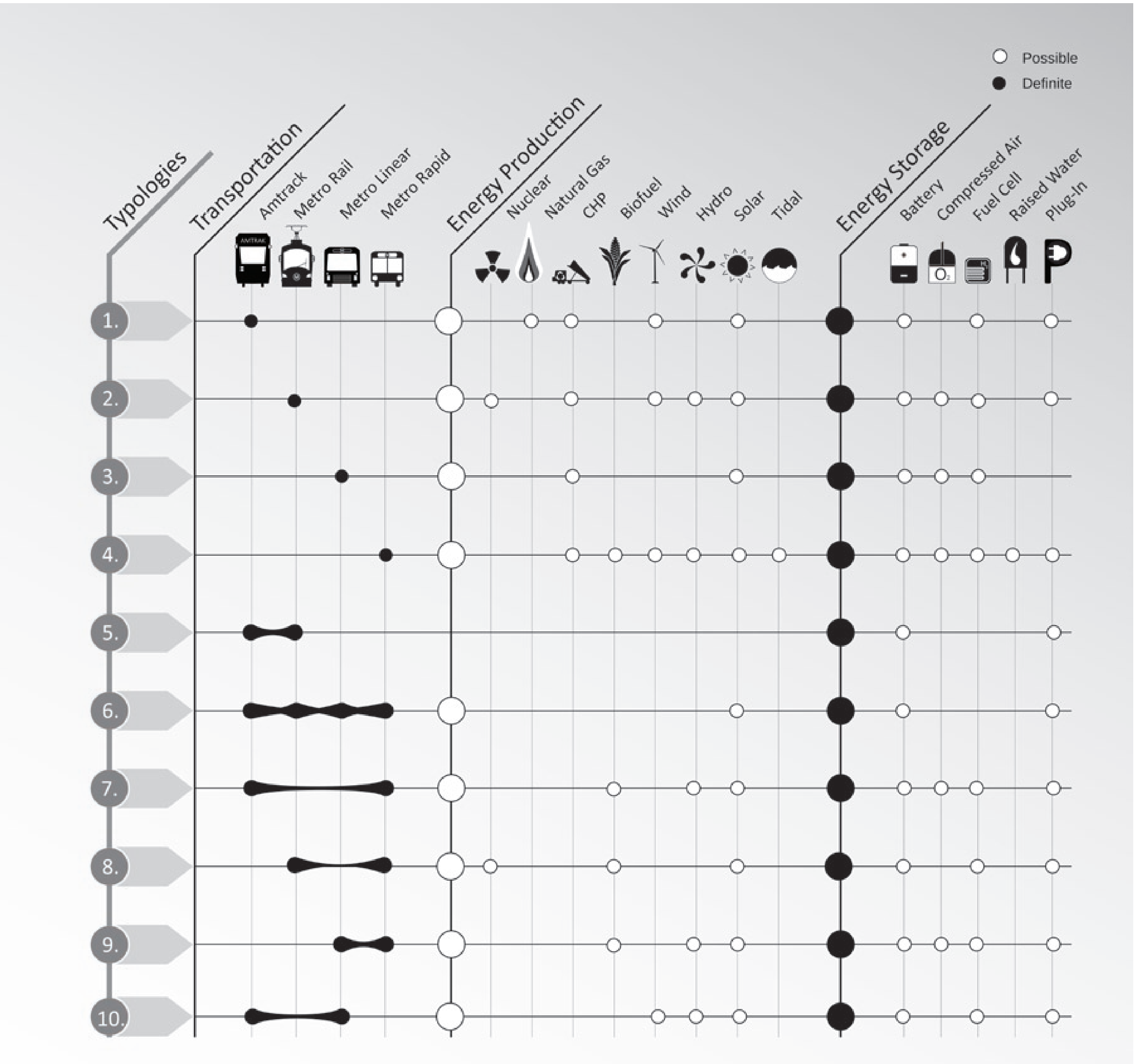
Each typology is an example of a typical site where energy-mobility and people are brought together and exhibit micro aspects of the paired networks offering examples of stations, stops and multi-transit nodes. Each typology offers examples of new moments of interface between the community's energy infrastructure and connectivity. This is accompanied in some cases by added public space and amenities, such as parks, recreational facilities and parking,

Fig. 3.06 Los Angeles -Types

Multi-modal transportation in Los Angeles requires a variety of types to respond to local differences in geographical, demographic, infrastructural and climatic characteristics.

Fig. 3.07 Energy-Transportation Typologies

This diagram classifies each typology 1 through 10 and their respective functions. The relationship between energy and transportation facilities is unique in each type.


Possible
Definite
Typologies
Transportation
Amtrack
Metro Rail
Metro Linear
Metro Rapid
Energy Production
Nuclear
Natural Gas
CHP
Biofuel
Wind
Hydro
Solar
Tidal
Energy Storage
Battery
Compressed Air
Fuel Cell
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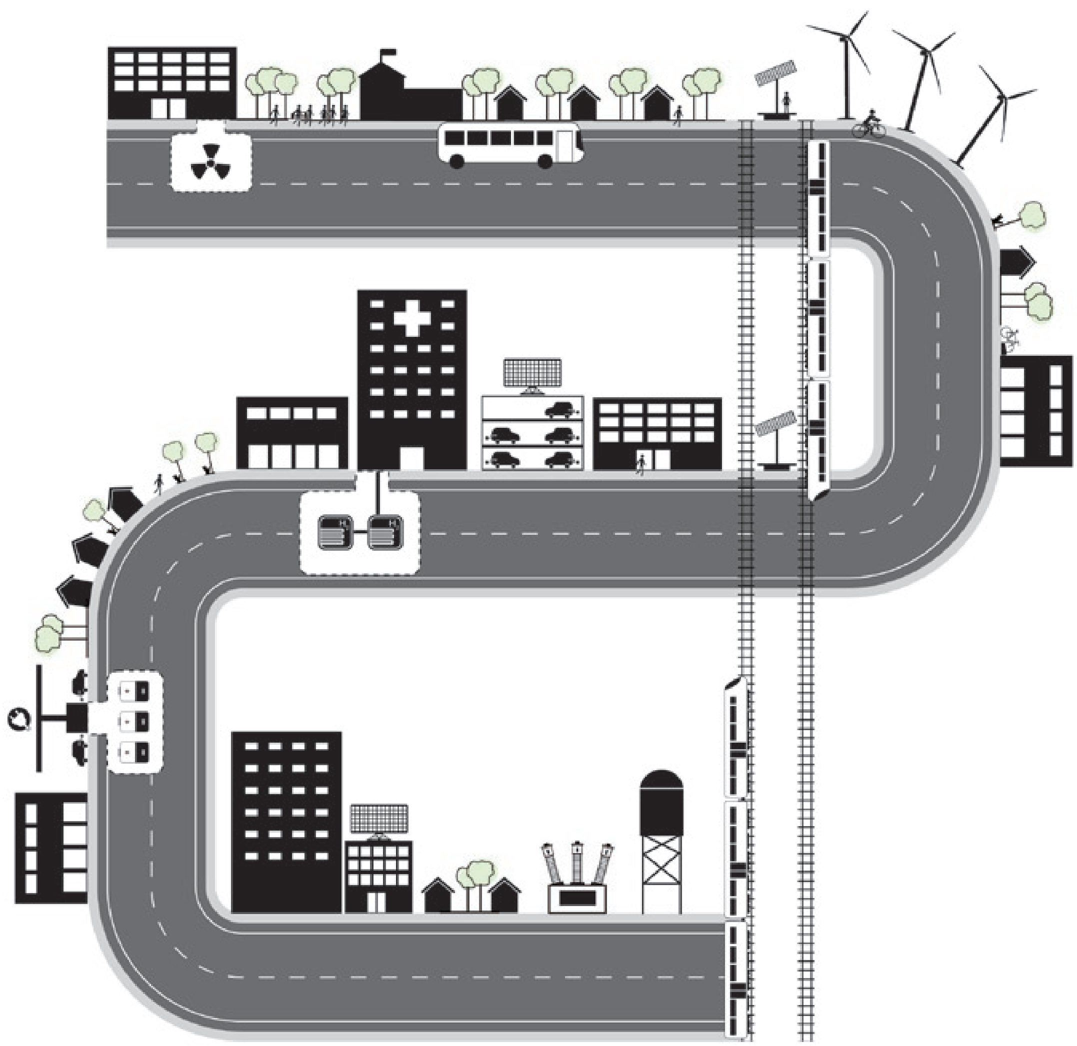


Fig. 3.08 Community Micro-Areas

Energy - Transportation and Community

The introduction of each energy-transit facility activates essential amenities by adding unique characteristics to the area's micro-culture. Each type offers new public areas that directly connect to local needs and aesthetics. Rather than employing an ubiquitous overall solution, the types are able to respond to unique urban characteristics. This in turn creates new experiences of departure and destination for travellers. This is a new vision of Los Angeles from micro to macro exhibiting the local and city-wide alliance between energy and transit networks.

System Components

The following maps and diagrams illustrate the theories and strategies for a localized urban energy production system. Four typologies are examined to formulate responsible ideas of how this system would be expressed tectonically as units of an urban network.

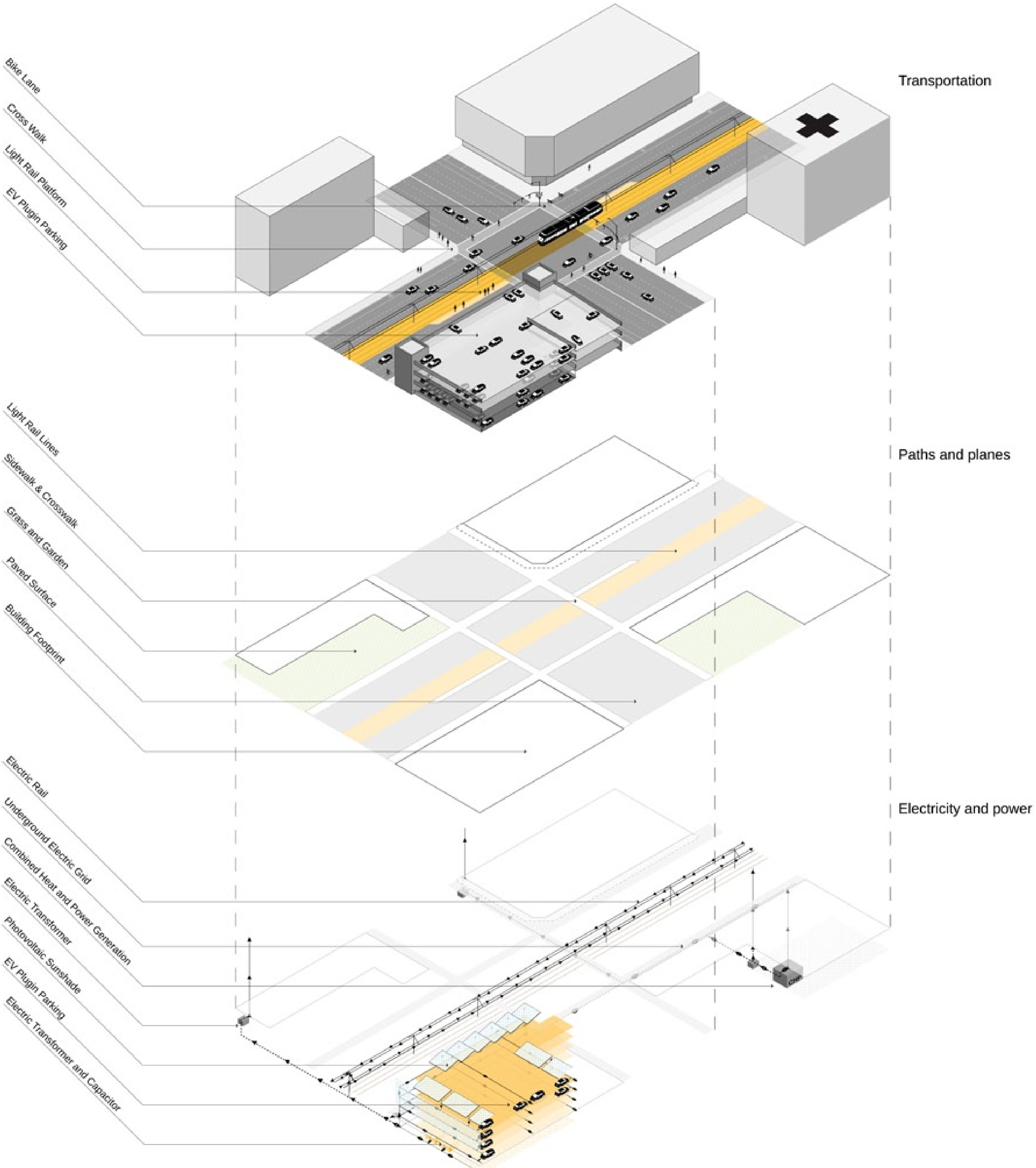


Fig. 3.09 Type 2.

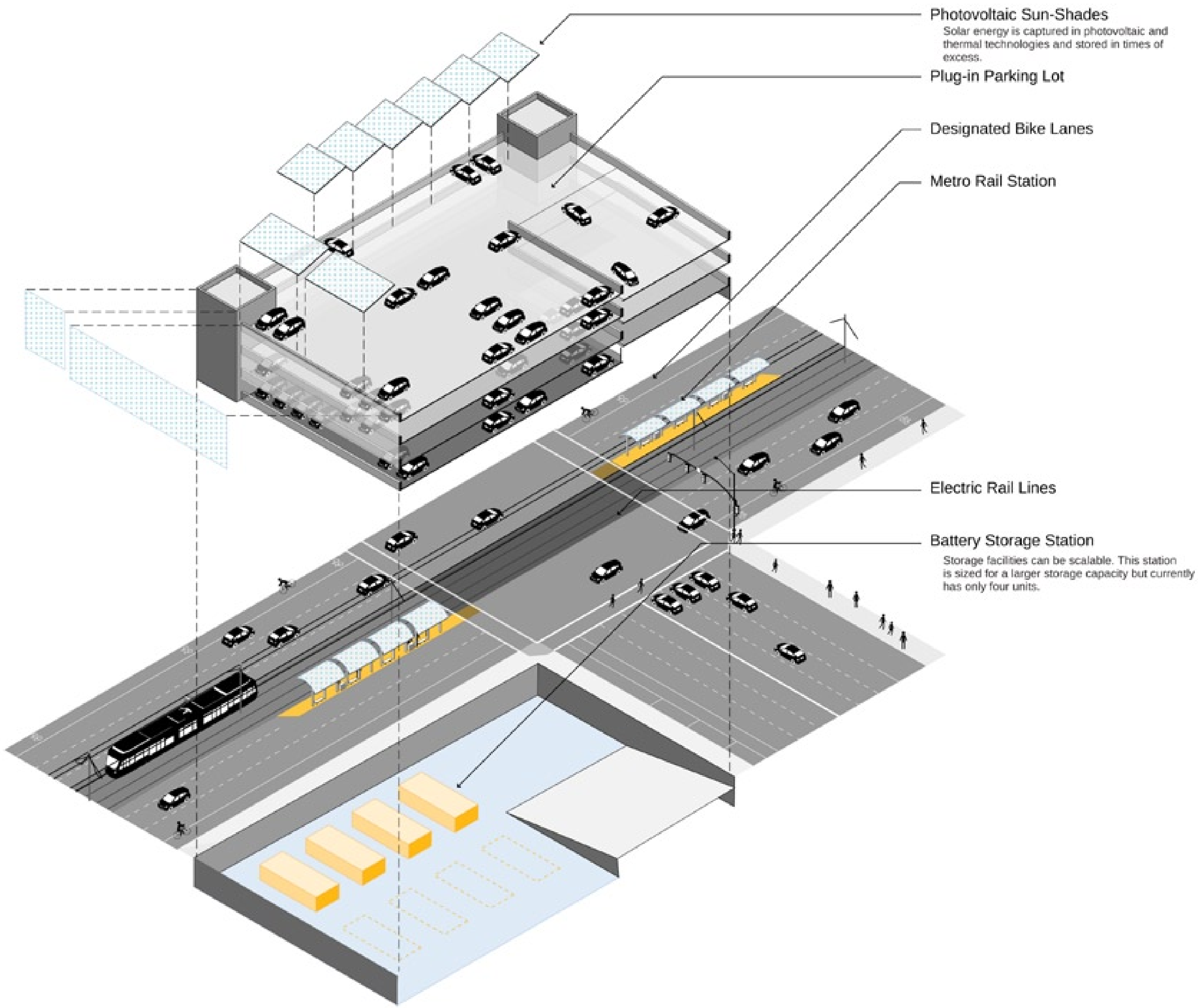


Fig. 3.10 Type 2. Stops

Type 2.

This type attempts to take advantage of the ubiquitous parking garages throughout Los Angeles. This type was based on an introduction of Light Rail along major roadways such as Wilshire Blvd. This station does not function necessarily as one solid unit of transit and energy storage. Rather, the facility functions with a transit and energy facility in close proximity. The Light Rail lines connect to energy technologies like flywheels, batteries and ultracapacitors stored in the basement of the parking garage. The electric cars plugged into this parking garage are able to function as a giant battery. By using these parked cars to store energy for the urban area parking structure is then activated with a dual purpose.

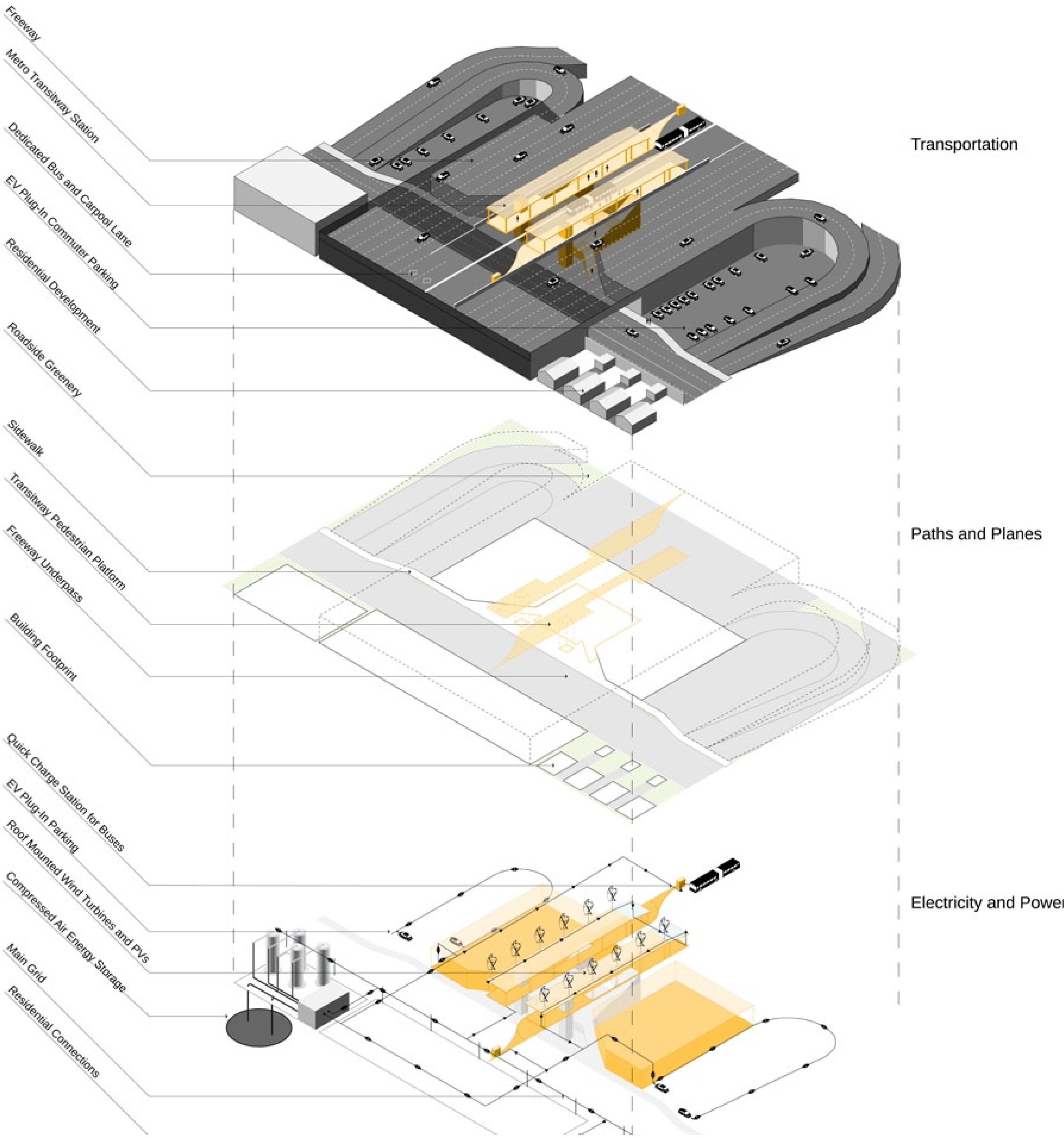


Fig. 3.11 Type 3.

Acting like Lightrail Transit a Metro Linear node connects expresses bus services with local bus services. In this area people are more inclined to use bus services than rail. This is part of a prejudice many Angelenos have against rail transit services.

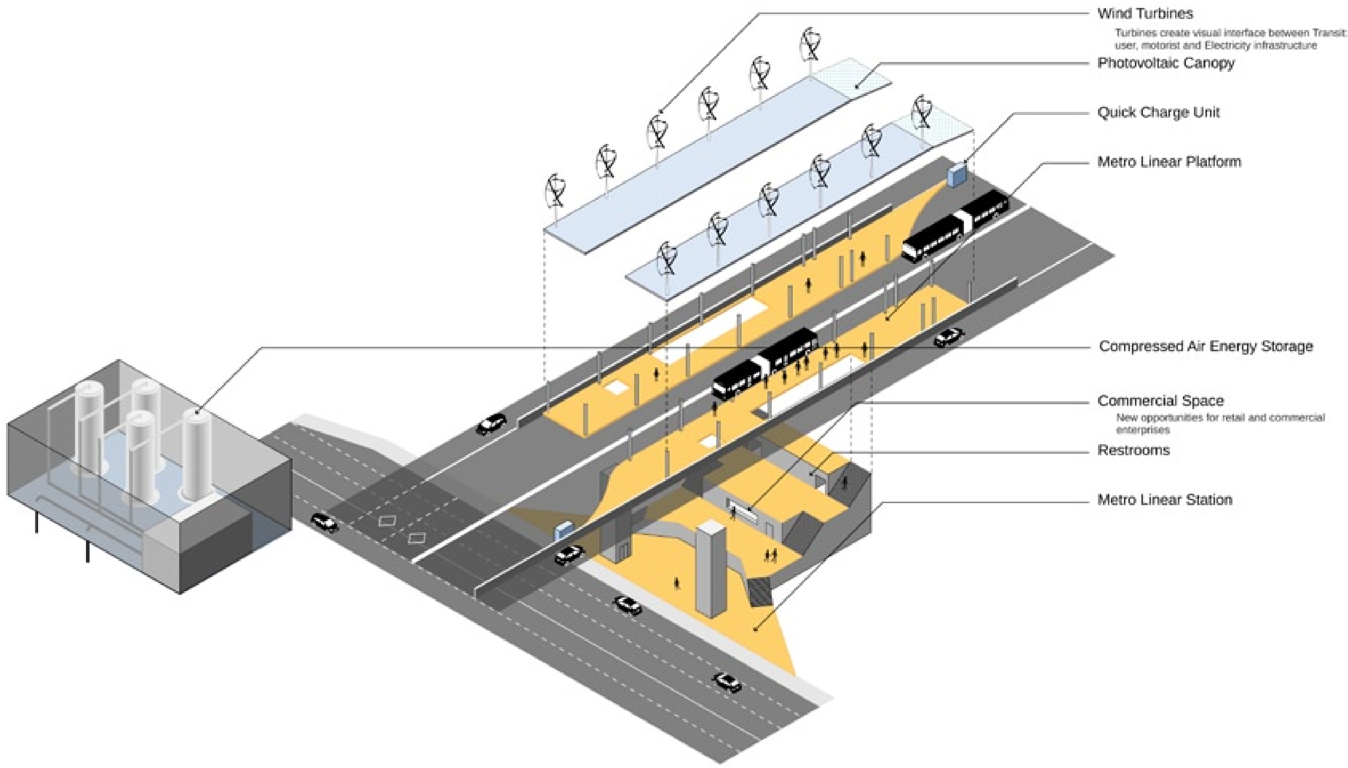


Fig. 3.12 Type 3: Station and Storage

Type 3.

Type 3 acts as a light rail station but only accommodates Metro Linear vehicles. This station operates on one of Los Angeles many freeways, along a designated transit/ carpool lane. This station offers charge facilities for the electric buses made possible by the large fuel cell energy storage facility below.

As with Type 4 this station takes advantage of local parking provisions by retrofitting and introducing new plug-in parking to the area. These parking lots would be designated to commuter parking for transit users.

Each bus drop off area is equipped with quick charge technologies to facilitate sporadic recharging of electric buses. The quick charge stations are provided with proper voltage by a Hydrogen fuel cell storage station. This storage station stores power from the wind and photovoltaic energy sources on the transit platforms as well from any power generated from the surrounding area. The fuel cells are housed in a protective facility below the concrete freeway. Access to the equipment is through large maintenance doors at both adjacent parking lots.

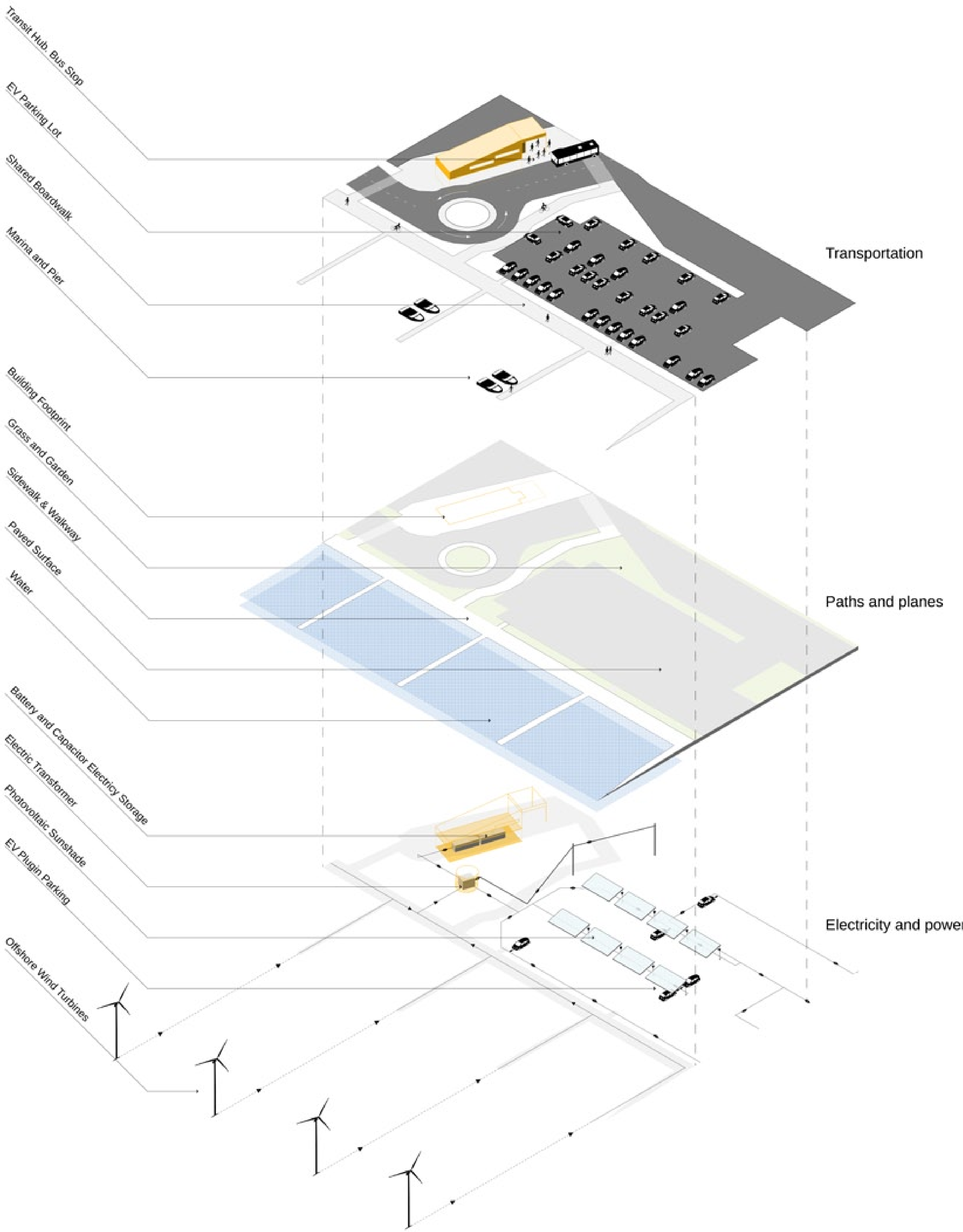


Fig. 3.13 Type 4.

This node functions as a transit station by providing shelter and information to riders and as an electricity center by housing valuable battery storage equipment in its basement.

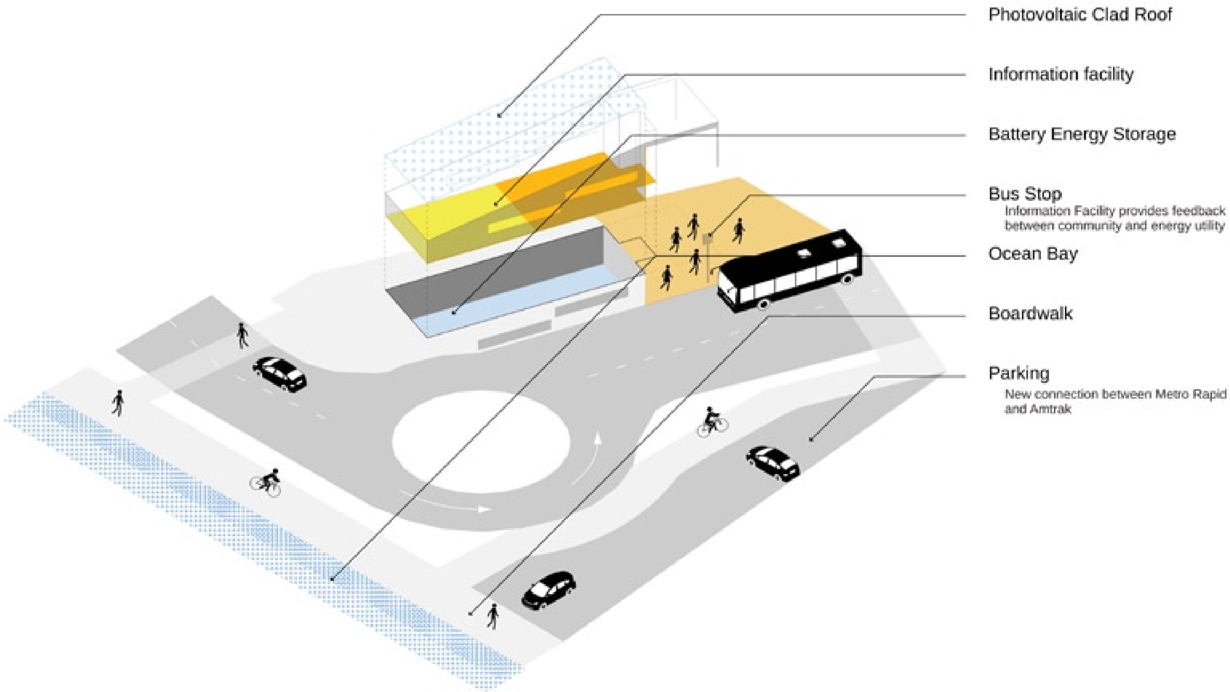


Fig. 3.14 Type 4: Facility

Type 4.

This type consists of a bus stop, possible energy production and energy storage. This specific instance is located along the boardwalk near a harbour. The station provides a designated waiting area for transit users as well as an amenity and information center. Designated pedestrian walkways and crosswalks provide a safer environment for transit-users. Energy is brought to the storage center from offshore wind turbines distributed throughout the local microgrid. This area has an abundance of public parking because of adjacent tourist attractions and marinas. The implementation of plug-in EV parking mutually benefits the microgrid storage requirements as well as parking lot users.

The design strategy for all of the types is centered around the goal of making energy infrastructure, or more specifically electric energy infrastructure more legible. For this facility energy infrastructure is highlighted by lit pathways shared by pedestrians and electricity. These pathways extend towards energy production conduits leading to the station.

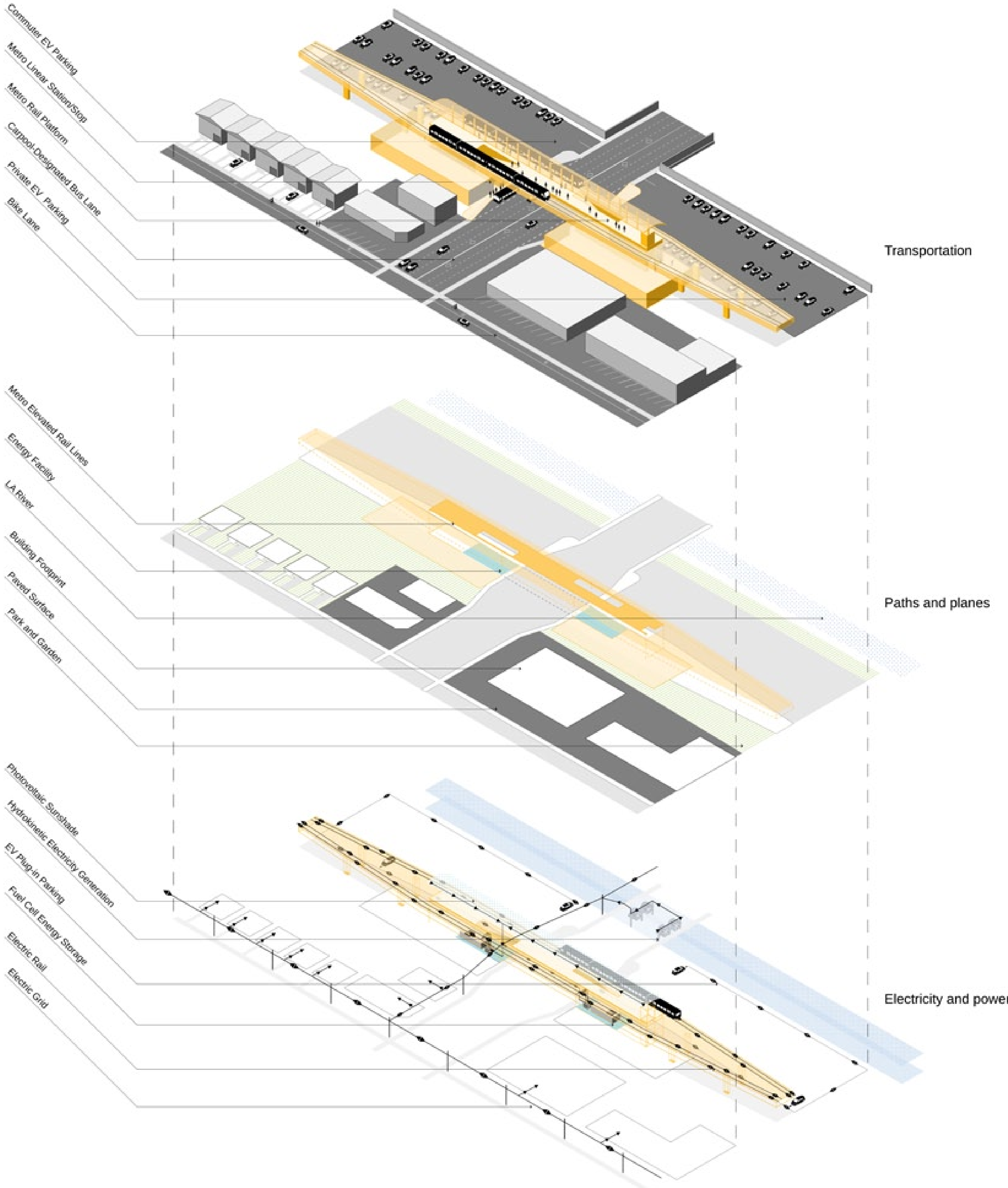


Fig. 3.15 Type 7.

This is an example of a Metro Rail station with a connected Metro Linear station below. This facility is an example of how energy can be stored on site with fuel cell technologies

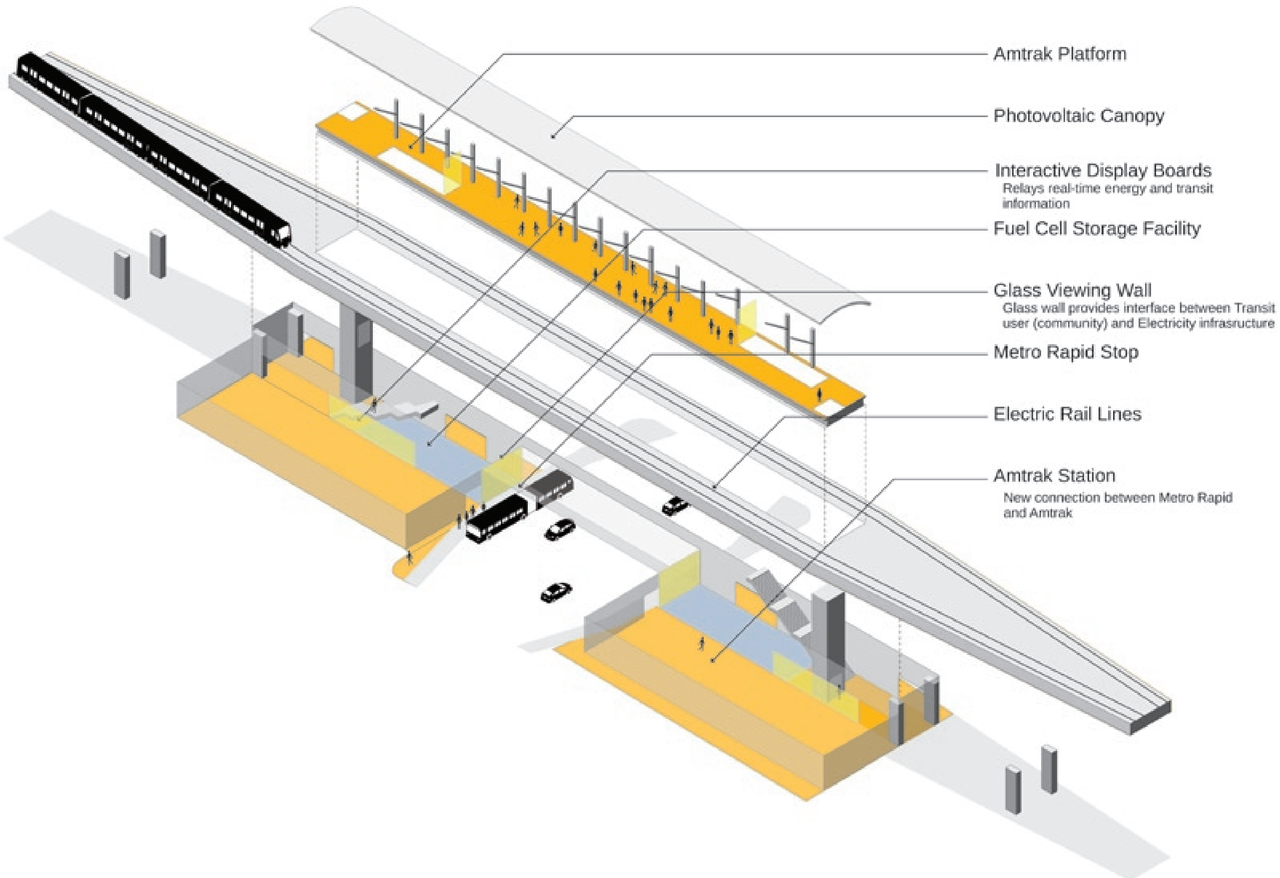
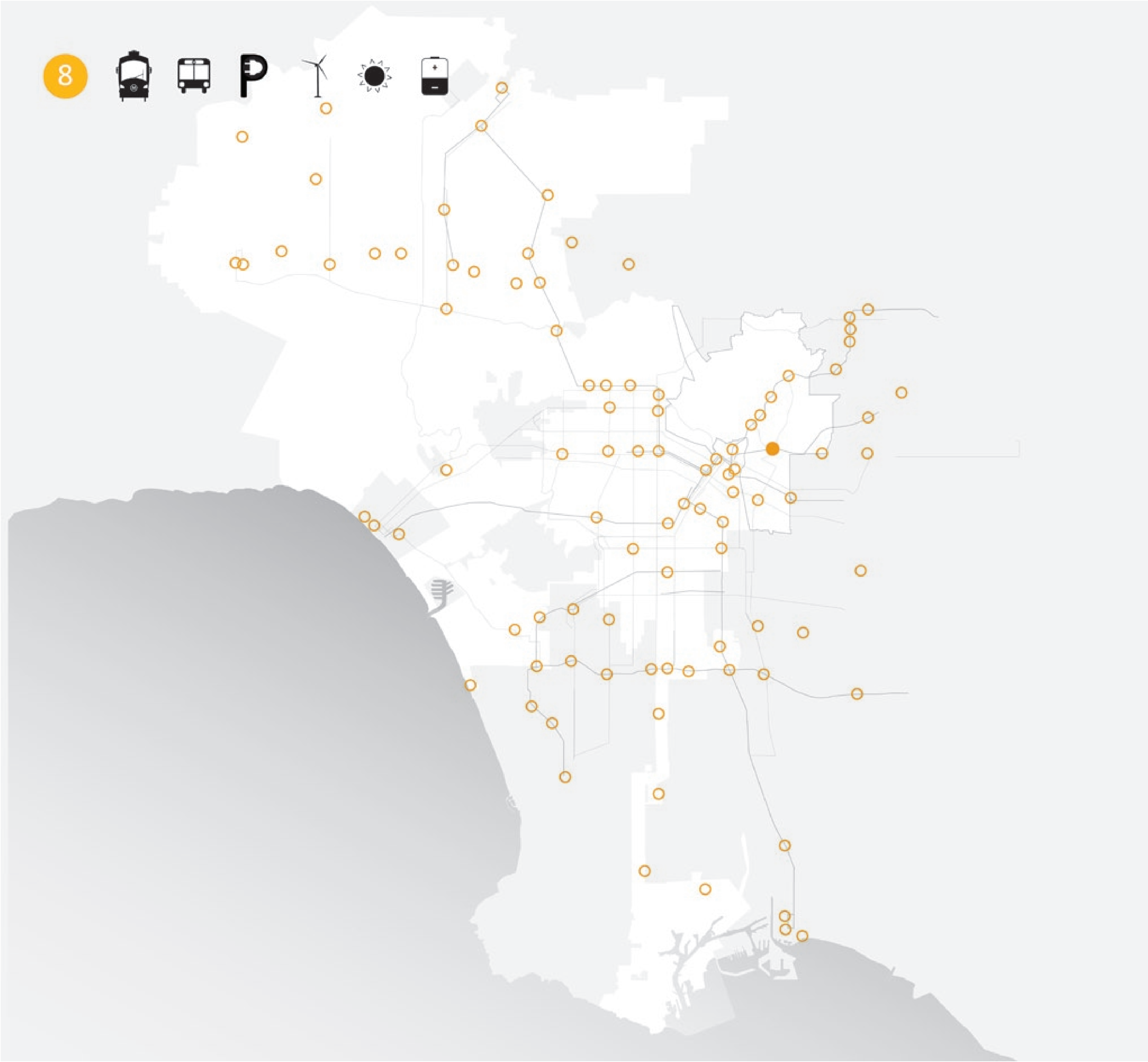


Fig. 3.16 Type 7: Facility

Type 7.

Type 7 encompasses the combination of two types of rapid transit available in Los Angeles, Metro Rail and Metro Linear. This station operates on two levels. The upper level is designated to rail transit and the lower to Metro Linear pick-up and drop-off. As with Type 4 this station takes advantage of local parking provisions by retrofitting and introducing new plug-in parking to the area. One of these parking lots would be designated to commuter parking for transit users.

Metro rail, like many other rail systems, has regenerative breaking technology in the breaking system of its rail cars. This energy along with other energy production in the area can be stored in electriciy storage devices. For this example hydrogen fuel cells are used along with support devices such as flywheels and transformers. Energy from the surrounding area such as from a photovoltaic canopy and hydrokinetic turbines, as noted in the diagram, can be stored here for future use. The fuel cells are housed in the concrete walls of the station. Access to the energy storage equipment would be provided via the adjacent parking lots for maintenance procedures and upgrading equipment.


8

03-3 Type 8: Expanded

The following section is an exploration of the possible architectural elements that would arise due to the pairing of electric and transportation infrastructures. After exploring a few possible types of urban hubs connecting energy and transportation infrastructures, Type 8 from the previous section is expanded upon and given context within a specific community. The Type 8 base model consists of Metro Rail and Metro Rapid services along with plug-in parking facilities, wind and PV energy production, and battery storage. The expansion of this type will include additional program as a result of an analysis of the chosen location's context.

Fig. 3.17 Type 8-Location.

The chosen Type 8 location is in East Los Angeles

Fig. 3.18 Site Satellite

1. The Golden Sate Freeway
2. San Bernadino Freeway
3. Lincoln Park
4. Hazard Park
5. USC Health Sciences Campus

03-4 Facility: Interface

The design of Type 8: Expanded builds on the kit-of-parts provided in the typologies. The design images illustrate new architectural opportunities presented at the community and facility scale. Sections and axnonometric drawings outline the function and flows through the facility while a series of ideal vignettes offer a glimpse of the possible outcome when combining the unique circumstance of a paired energy and transportation infrastructure.

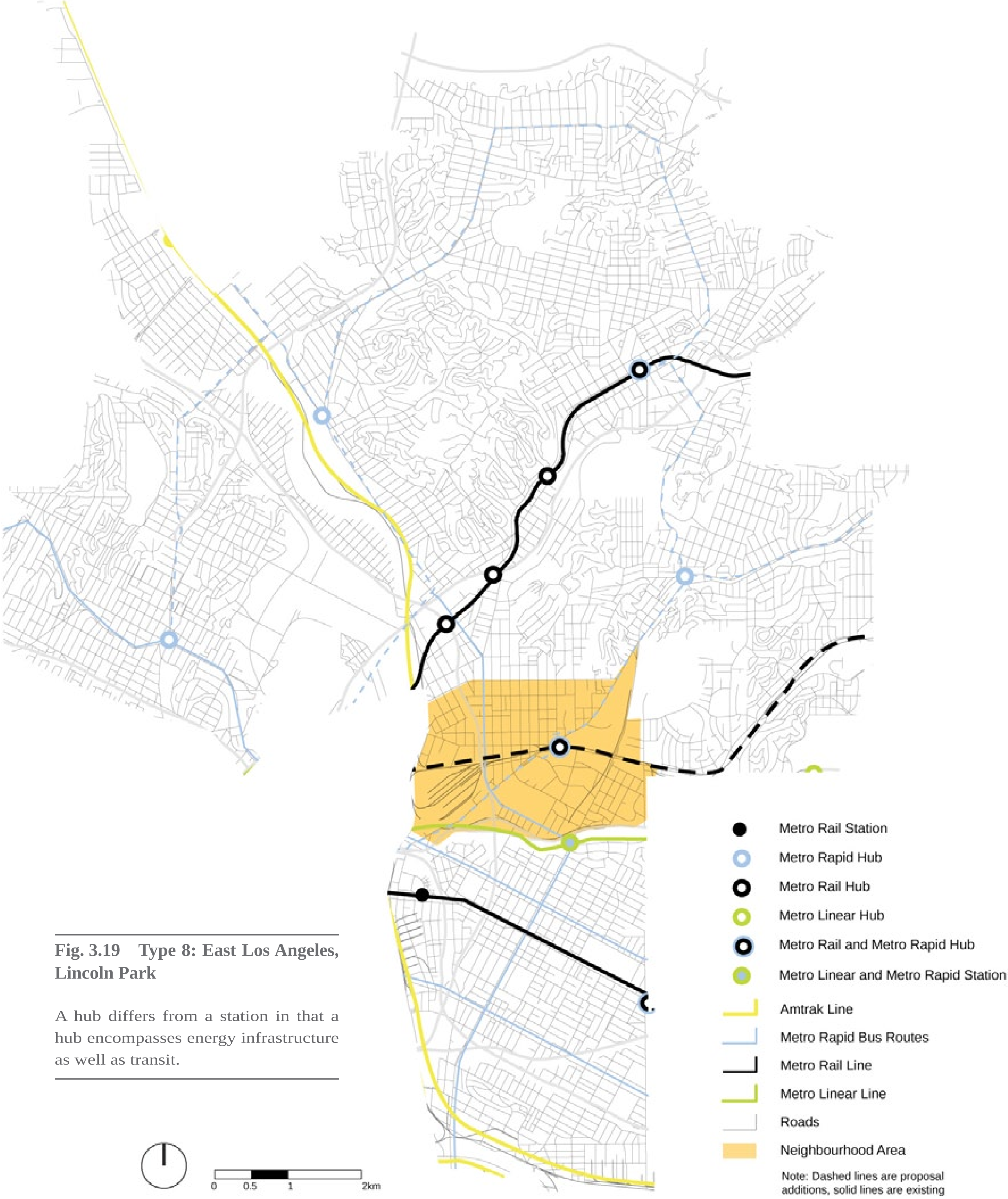


Fig. 3.19 Type 8: East Los Angeles, Lincoln Park

A hub differs from a station in that a hub encompasses energy infrastructure as well as transit.

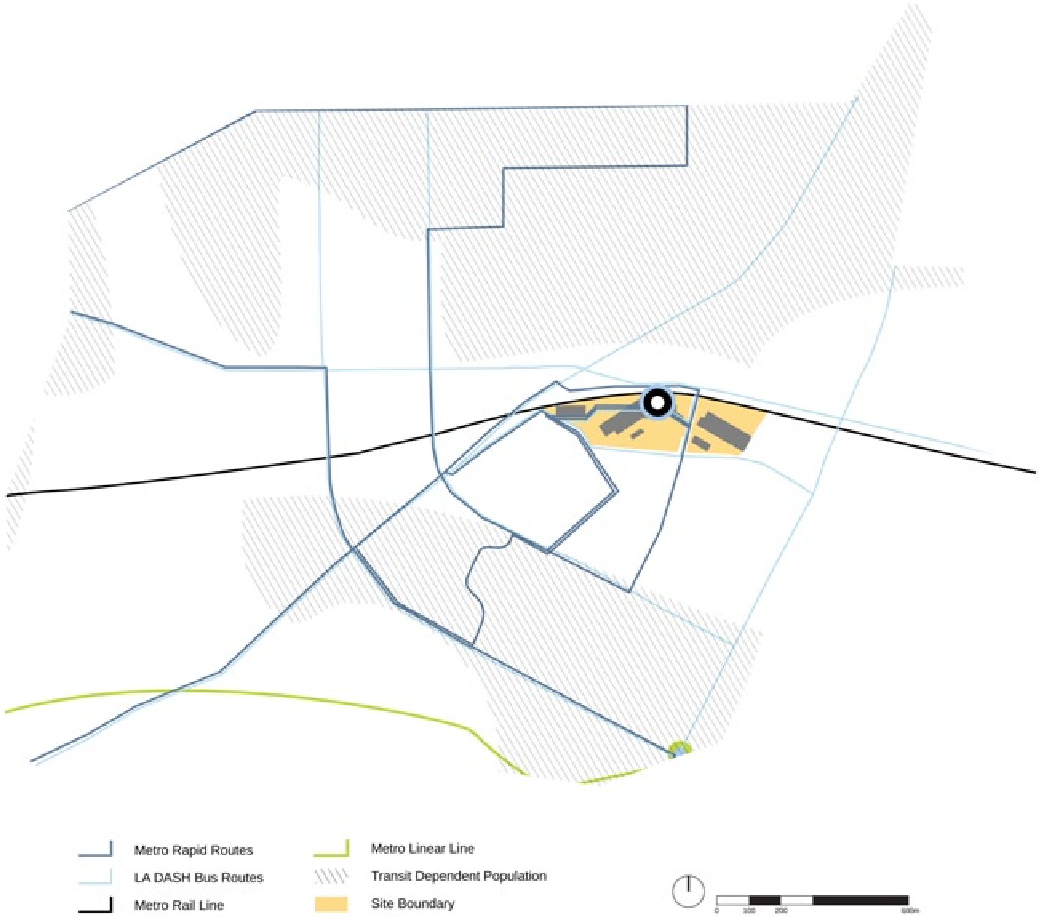


Fig. 3.20 Neighbourhood Area: Transit

A map of the transit dependent population and transit routes in the urban area around the case study facility building footprint.

Site

Lincoln Park in East Lost Angeles was chosen as a site for the Type 8 expansion. This site is situated between a residential, predominantly Latino community and the University of Southern California's Medical Campus (Fig. 3.16). To the west of the site is the Los Angeles County Detention Center and Juvenile Courts. The area is characterized by a highly transit dependent population as well as new transportation needs introduced by the growing university campus. Currently there are only two bus routes operating in the area, one along Valley Blvd. and one along North Mission Rd. There is one Metro Rapid service which serves the University to the far south, beyond walking distance for the residence north west of Lincoln Park (Fig. 3.20).

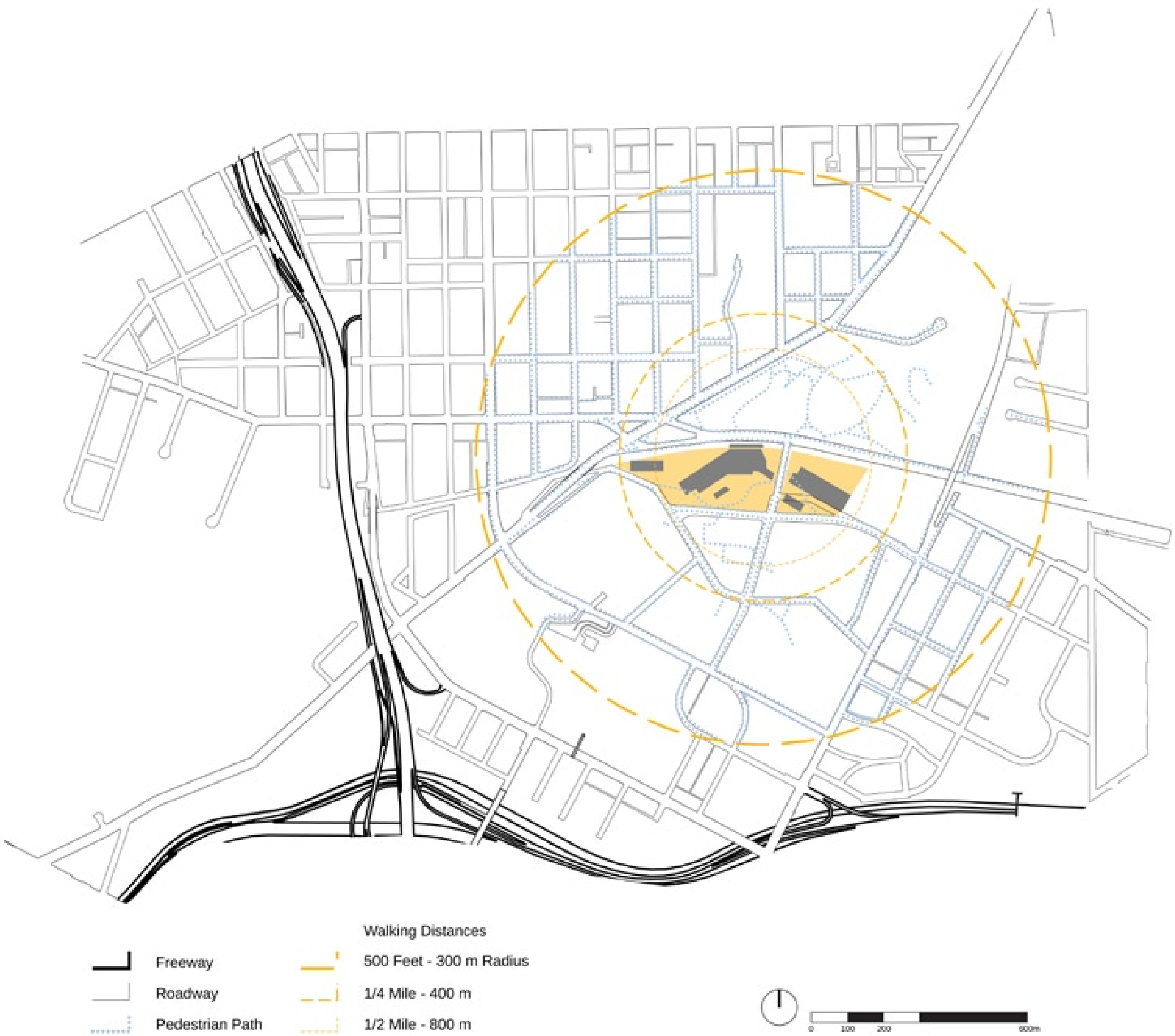


Fig. 3.21 Mobility

This map illustrates walking distances (orange circles) from the site as well as general pedestrian and vehicular pathways.

Fig. 3.22 Land Use

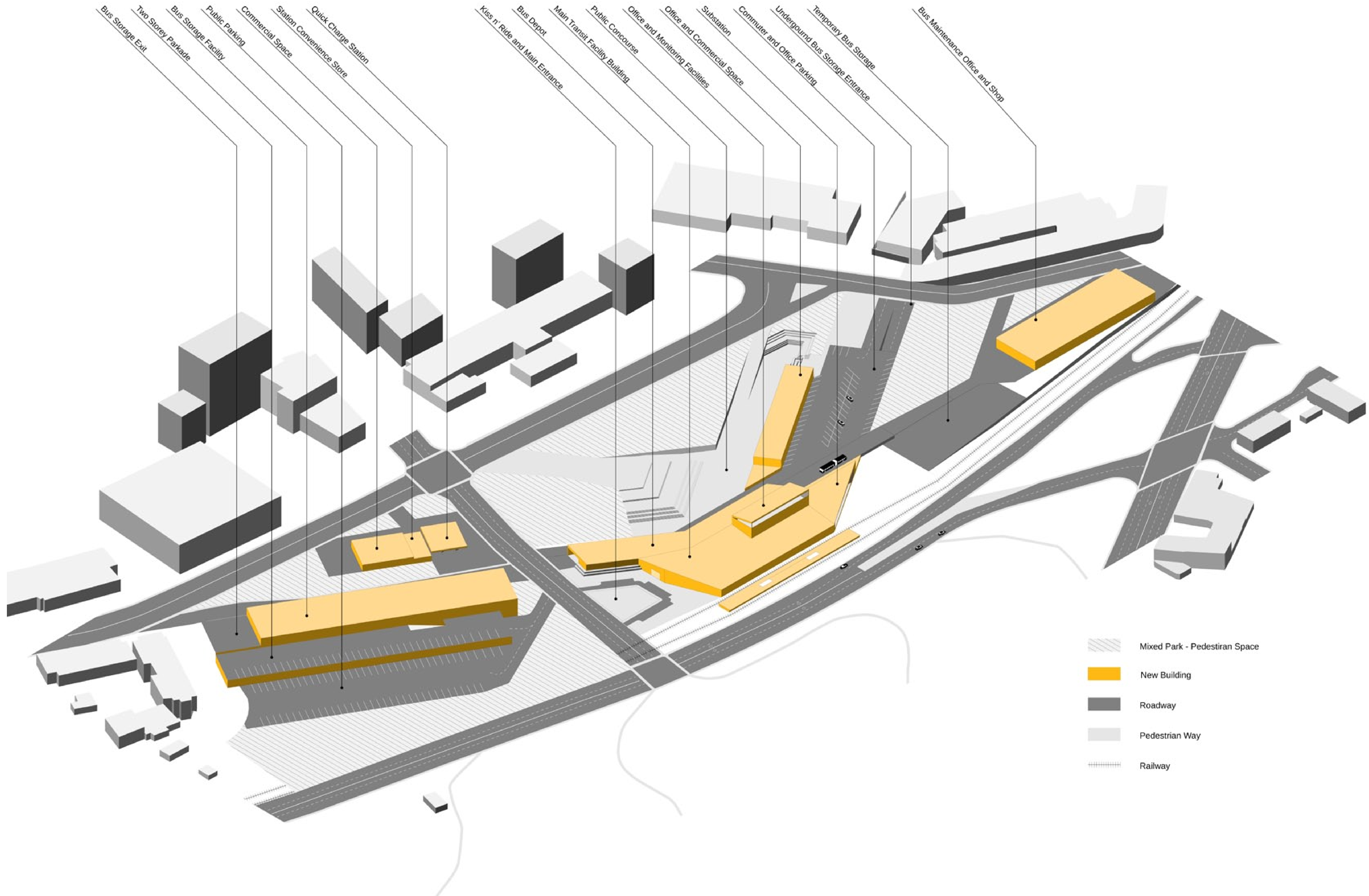
Note on this map that there are three major landuses surrounding the site: park, government and educational.

Fig. 3.23 Energy

Energy use is displayed in a gradient denoting high and low energy uses.

Fig. 3.24 Urban Features

The topography in the area gradually slopes upwards toward the east and south east.


Bus Storage Exit
Two Storey Parkade
Bus Storage Facility
Public Parking
Commercial Space
Station Convenience Store
Quick Charge Station
Kiss n' Ride and Main Entrance
Bus Depot
Main Transit Facility Building
Public Concourse
Office and Monitoring Facilities
Office and Commercial Space
Substation
Commuter and Office Parking
Undergound Bus Storage Entrance
Temporary Bus Storage
Bus Maintenance Office and Shop
Mixed Park - Pedestiran Space
New Building
Roadway
Pedestrian Way
Railway

Program

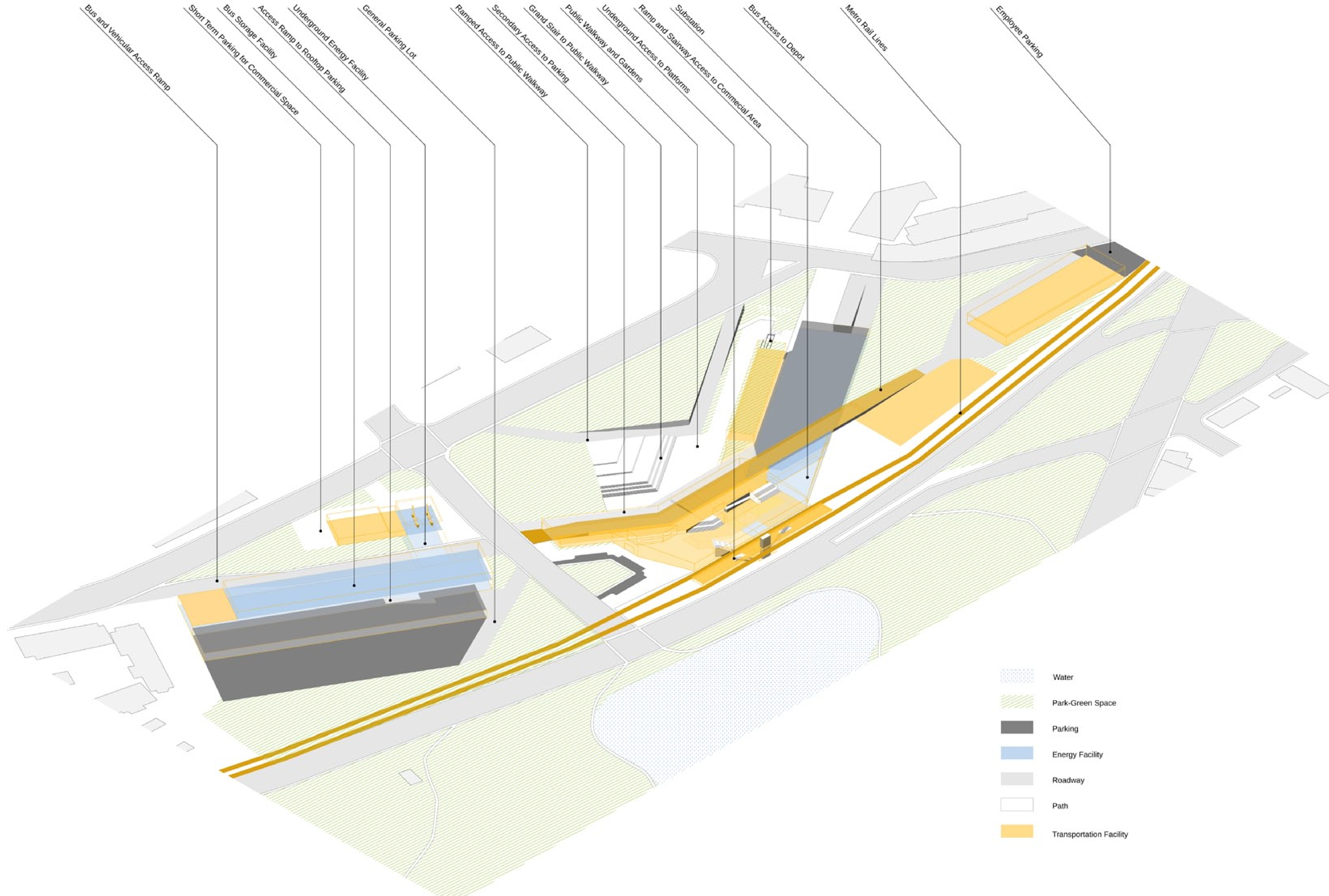
Splitting up into three major structures the transit-electric facility combines electric and transportation infrastructure throughout its site. The 7,600 square-meter three storey energy-transit center houses a public transit concourse (with cafés and retail space throughout), bus and rail transit platforms, office space, parking, a neighbourhood sized substation, an energy storage center water treatment center, and an energy command center.

The 4,560 square-meter, two storey service facility encompasses a bus maintenance area and battery storage center on the sunken first floor. Office space, a restaurant and retail space. The third section is the 9,000 square meter, two storey charge and discharge depot. This depot incorporates a supplementary battery storage center, bus storage, a quick charge station and parking, with park terraces above.

These facilities are flanked by park space that includes seating areas, various water features and some gardens. Dispersed throughout the site there is also 16,200 square meters of parking and 3,200 square meters of additional commercial/ office space.

Fig. 3.25 Facility Program

The facility's shape and layout within the site stemmed from creating a building organized on the basis of the principles of the greater system, as a distributed but networked facility.



Bus and Vehicular Access Ramp
Short Term Parking for Commercial Space
Bus Storage Facility
Access Ramp to Rooftop Parking
Underground Energy Facility
General Parking Lot
Ramped Access to Public Walkway
Secondary Access to Parking
Grand Stair to Public Walkway
Public Walkway and Gardens
Underground Access to Platforms
Ramp and Stairway Access to Commercial Area
Substation
Bus Access to Depot
Metro Rail Lines
Employee Parking
Water
Park-Green Space
Parking
Energy Facility
Roadway
Path
Transportation Facility

The design of the Type 8 expansion transit-electricity project was created in an effort to exhibit the positive effect to the urban community in combining electricity and (electric) transit infrastructure. The design is predicated on the idea that urban areas will one day be weaning themselves off petroleum. Thus the design incorporates specific instances of energy efficiency, space efficiency and incorporates new transportation technologies.

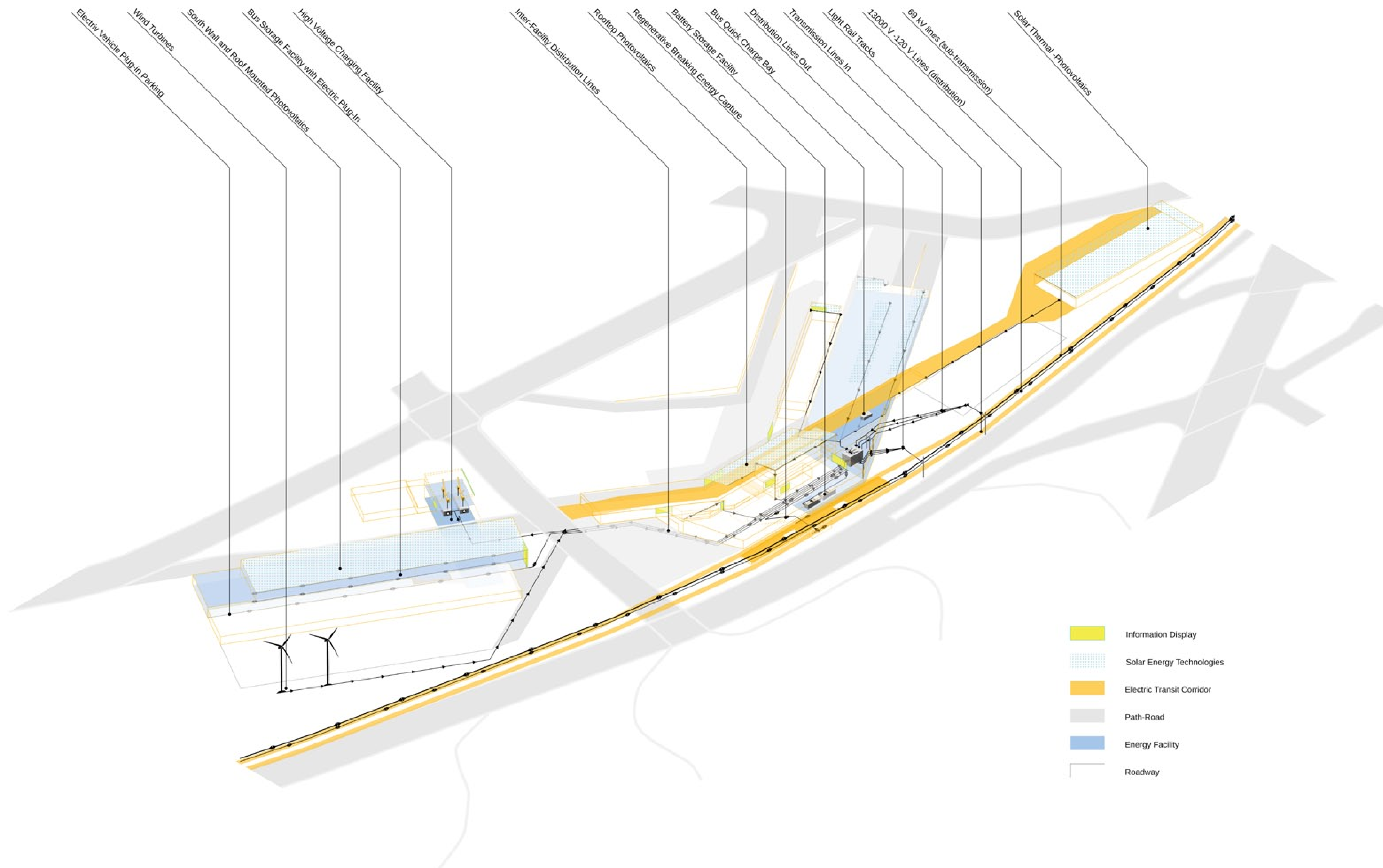
The Lincoln Park area has a large transit dependent population (Fig. 3.18) as well as a frequently visited destination of the University of Southern California's Medical Campus (USC), including three hospitals and various educational facilities. The proposed station is situated on the boundary between these two populations. The station aims to alleviate transportation issues for the transit dependent population while offering an alternative transportation option to those traveling to the medical campus.

The area is also due for the introduction of a local energy substation (to handle the introduced demand from the newly developed medical campus) The project encompasses this electricity infrastructure by including energy storage and energy transformers (a substation). The station is organized to follow the existing relationship between energy and transportation in the city. Electricity conduits follow the paths of transportation networks. Similarly, the paths of people, transit and automobiles run parallel to those of electricity. Energy conduits and points can thus be used as tools for way-finding throughout the site. This creates an dialog between system, building and user by the juxtaposition of energy program elements with circulation.

The design aims to stimulate the use of alternative transportation methods such as rail, bus, and bike by improving the accessibility of transportation amenities.

Fig. 3.26 Facility Paths and Planes

To complement the large public park to the north this facility adds several areas of greenspace throughout the site. Metro Rail and Rapid (bus) stations are located in the central area of the site to the north. This location enables the station to take advantage of existing rail divides as well as adjacency to a major intersection. Buses are routed through Eastlake Ave.



Electriv Vehicle Plug-in Parking
Wind Turbines
South Wall and Roof Mounted Photovoltaics
Bus Storage Facility with Electric Plug-In
High Voltage Charging Facility
Inter-Facility Distribution Lines
Rooftop Photovoltaics
Regenerative Breaking Energy Capture
Battery Storage Facility
Bus Quick Charge Bay
Distribution Lines Out
Transmission Lines In
Light Rail Tracks
13000 V -120 V Lines (distribution)
69 kV lines (sub-transmission)
Solar Thermal -Photovoltaics
Information Display
Solar Energy Technologies
Electric Transit Corridor
Path-Road
Energy Facility
Roadway

This is accomplished by introducing multi-modal nodes of transportation as well as incorporating personal vehicle infrastructure.

Electricity - Transit

Energy produced on site from photovolatic and wind technologies is brought through transformers to the energy storage facility, or one of the bus/car storage parking lots. Energy is stored here until required for use. Energy produced in the surrounding community is brought to the station through the local electricity grid. After passing through the transformers in the substation it is stored in one of the energy storage options on site. These energy levels and patterns are relayed to the facility's users through a series of interactive display boards. These boards indicate the station's capacity, current level etc.

Paths of electricity and transportation are complemented by the building's corridors, pathways and roadways. The form of the building follows a pattern similar to that of lines on a circuit. Destination points throughout the site are connected by pathways for people, cars, buses and electricity. To emphasize how electrical pathways follow those of pedestrians the conduit paths are traced on the floor, wall and ceiling surfaces to act as guides and informative cues as to what is occurring in the energy station. This creates transit and energy corridors within the site creating moments of interface between pedestrian, transportation and energy network infrastructures.

Fig. 3.27 Energy Movement, Production and Storage

Several areas for on-site energy storage provide enough stored energy to power the surrounding neighbourhood for one day. These storage devices are linked through a series of electricity conduits.

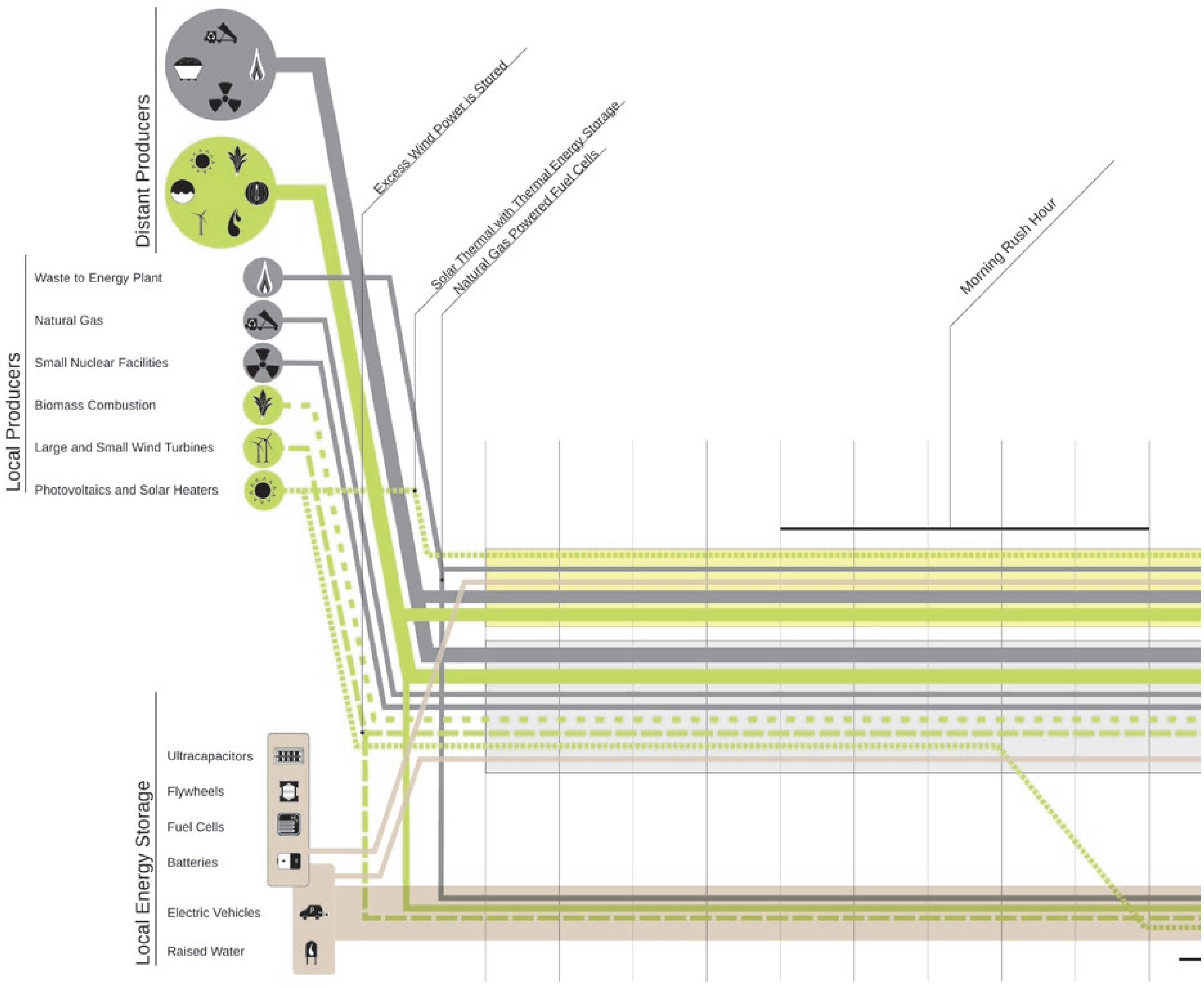
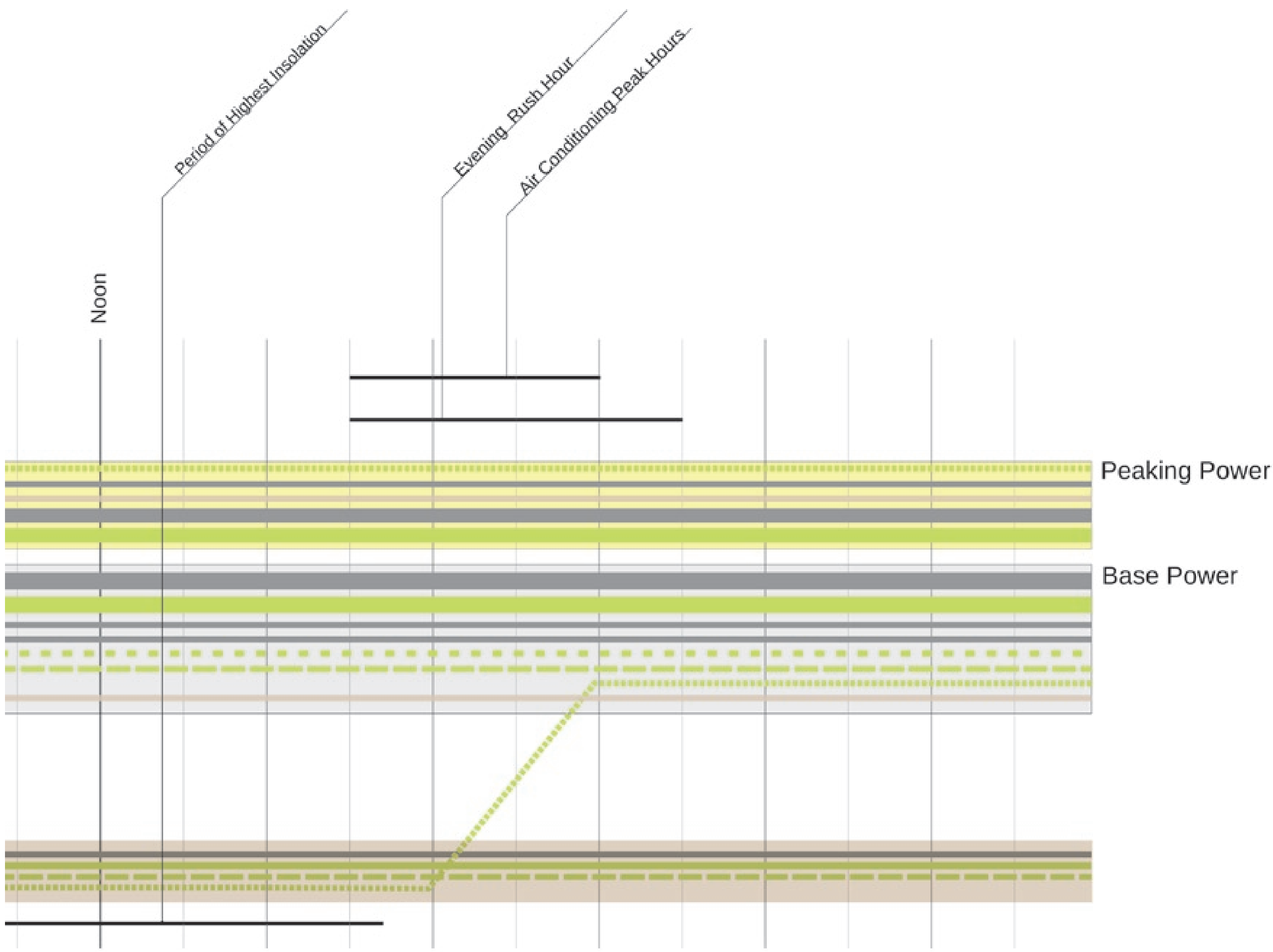


Fig. 3.28 Typical Neighbourhood Production Time-line

This is a hypothetical future daily energy flow for one particular neighbourhood, Lincoln Park. Electricity is still imported from outside the neighbourhood limits but the area has a substantial amount of storage opportunities that can accommodate excess from adjacent production districts.


Period of Highest Insolation
Evening Rush Hour
Air Conditioning Peak Hours
Noon
Peaking Power
Base Power

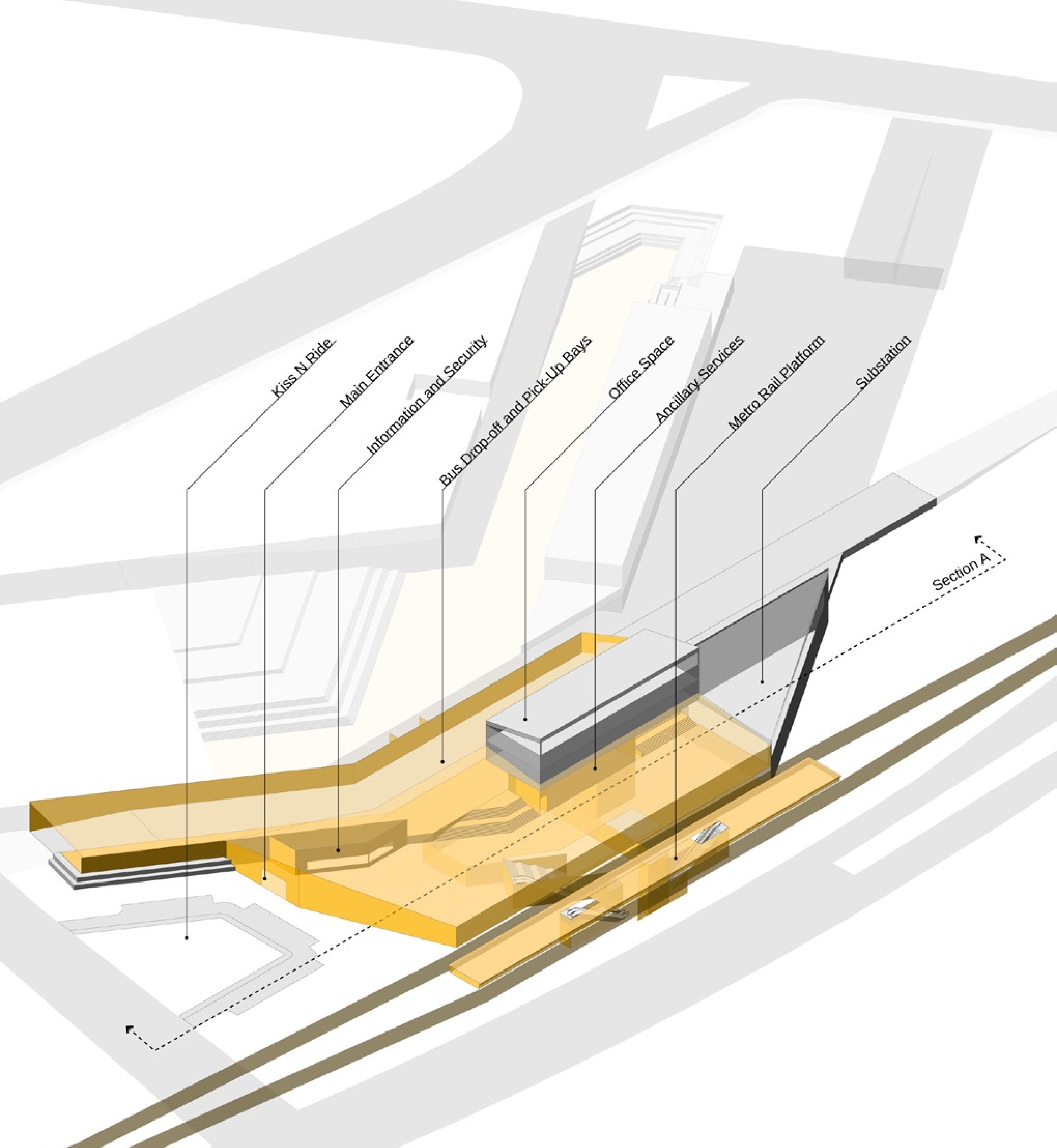

Kiss N Ride
Main Entrance
Information and Security
Bus Drop-off and Pick-Up Bays
Office Space
Ancillary Services
Metro Rail Platform
Substation
Section A

Fig. 3.29 Section A Locator

A longitudinal section, Section A through the main circulation area of the transit facility illustrates the moments where transit users are visually and physically accompanied by electrical infrastructure.

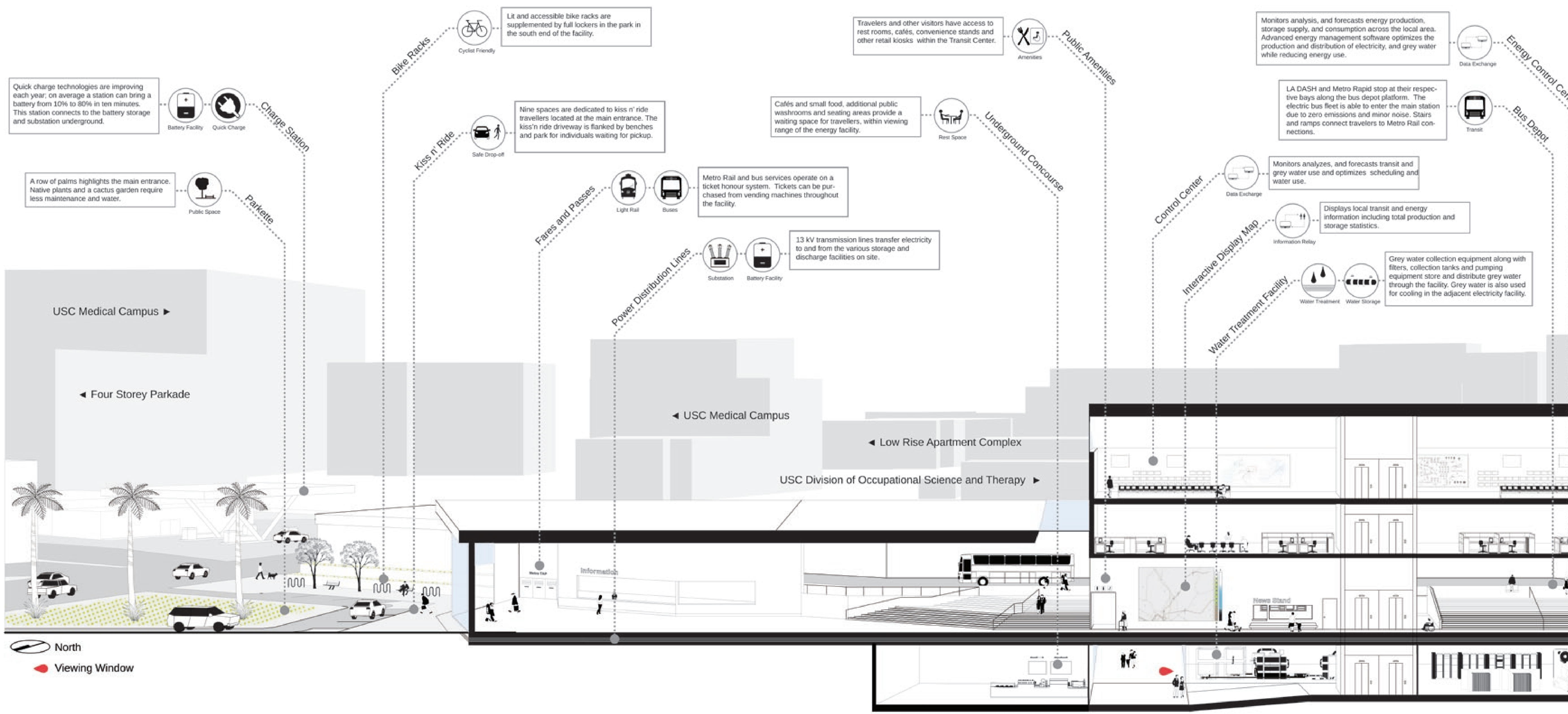
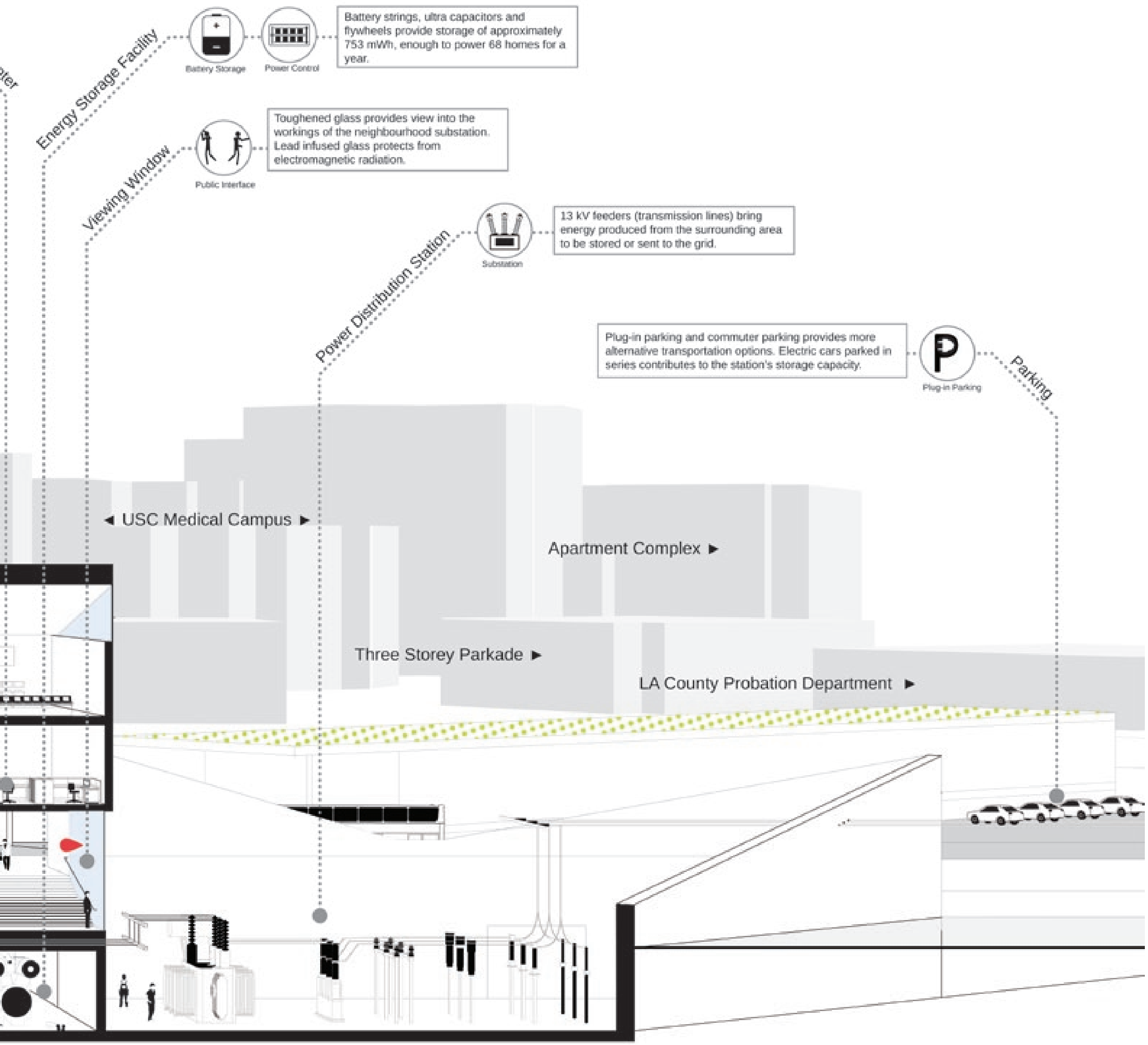


Fig. 3.31 Section A

A longitudinal through the the transit facility, adjacent substation, offices, battery storage facility and water treatment facility. Enormous glass viewing windows allow for a transparency of neighbourhood energy infrastructure for the community transit users.


Energy Storage Facility
Battery Storage
Power Control
Battery strings, ultra capacitors and flywheels provide storage of approximately 753 mWh, enough to power 68 homes for a year.
Viewing Window
Public Interface
Toughened glass provides view into the workings of the neighbourhood substation. Lead infused glass protects from electromagnetic radiation.
Power Distribution Station
Substation
13 kV feeders (transmission lines) bring energy produced from the surrounding area to be stored or sent to the grid.
Plug-in parking and commuter parking provides more alternative transportation options. Electric cars parked in series contributes to the station's storage capacity.
Plug-in Parking
Parking
◄ USC Medical Campus ►
Apartment Complex ►
Three Storey Parkade ►
LA County Probation Department ►

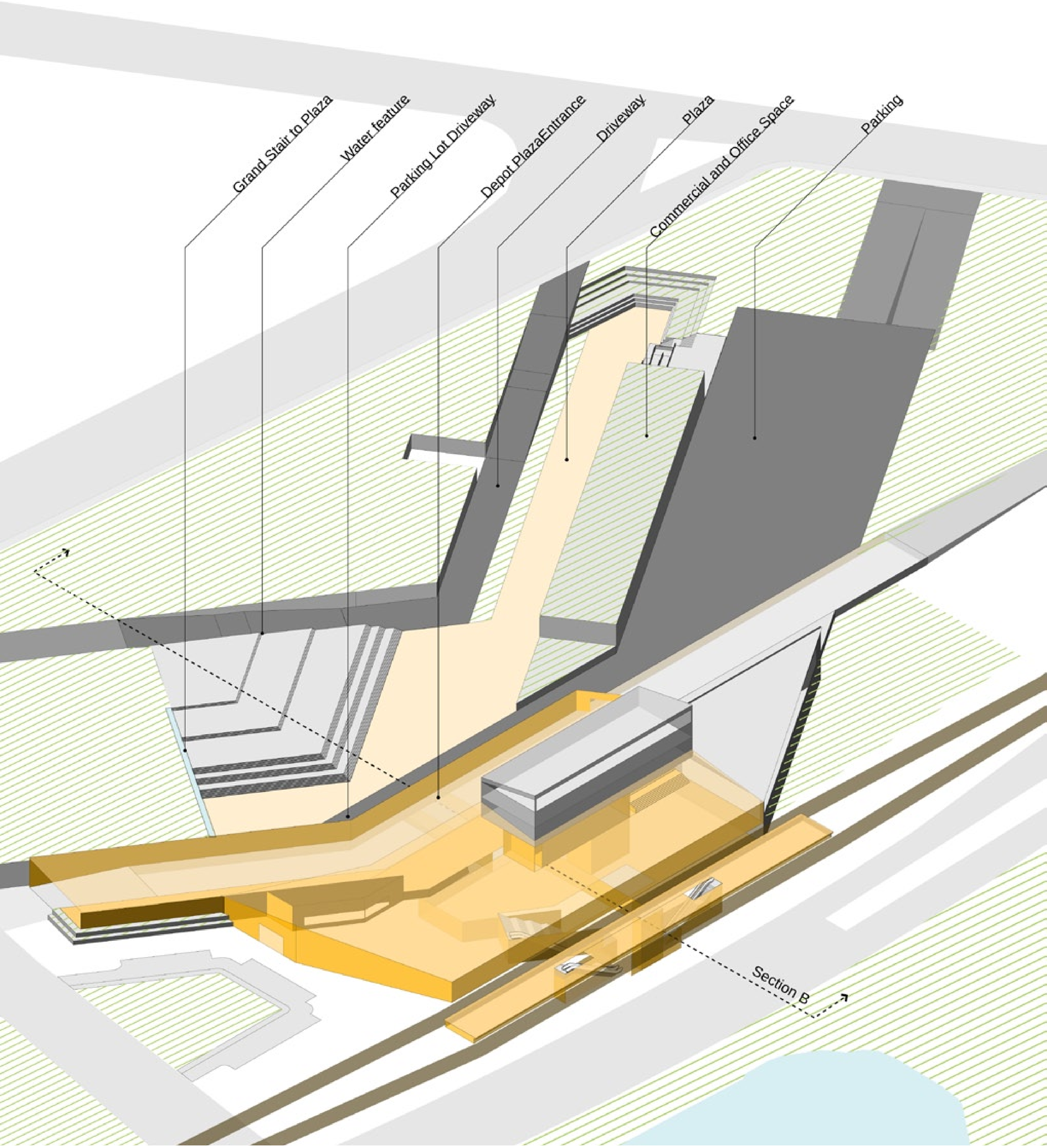

Grand Stair to Plaza
Water feature
Parking Lot Driveway
Depot PlazaEntrance
Driveway
Plaza
Commercial and Office Space
Parking
Section B

Fig. 3.31 Section B Locator

A section perpendicular to section A through the main circulation area of the transit facility exhibits the pedestrian and vehicular flows through the facility and its amenity spaces.

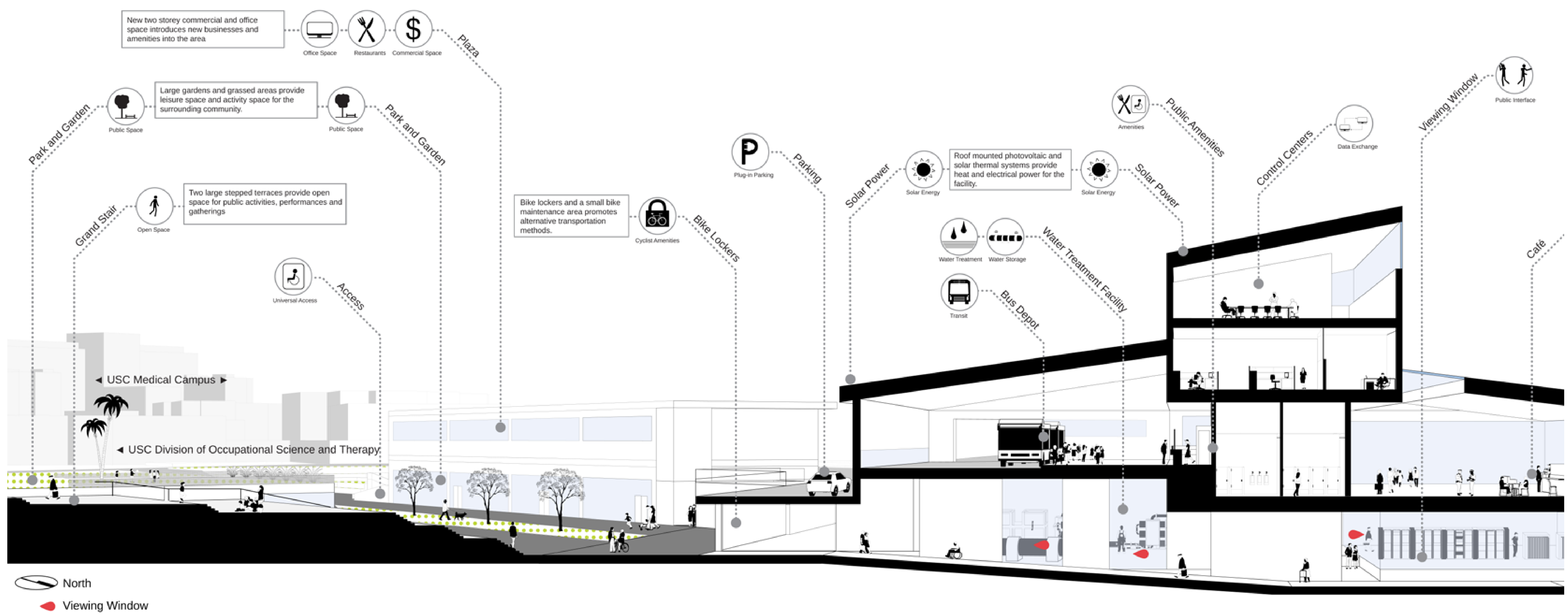
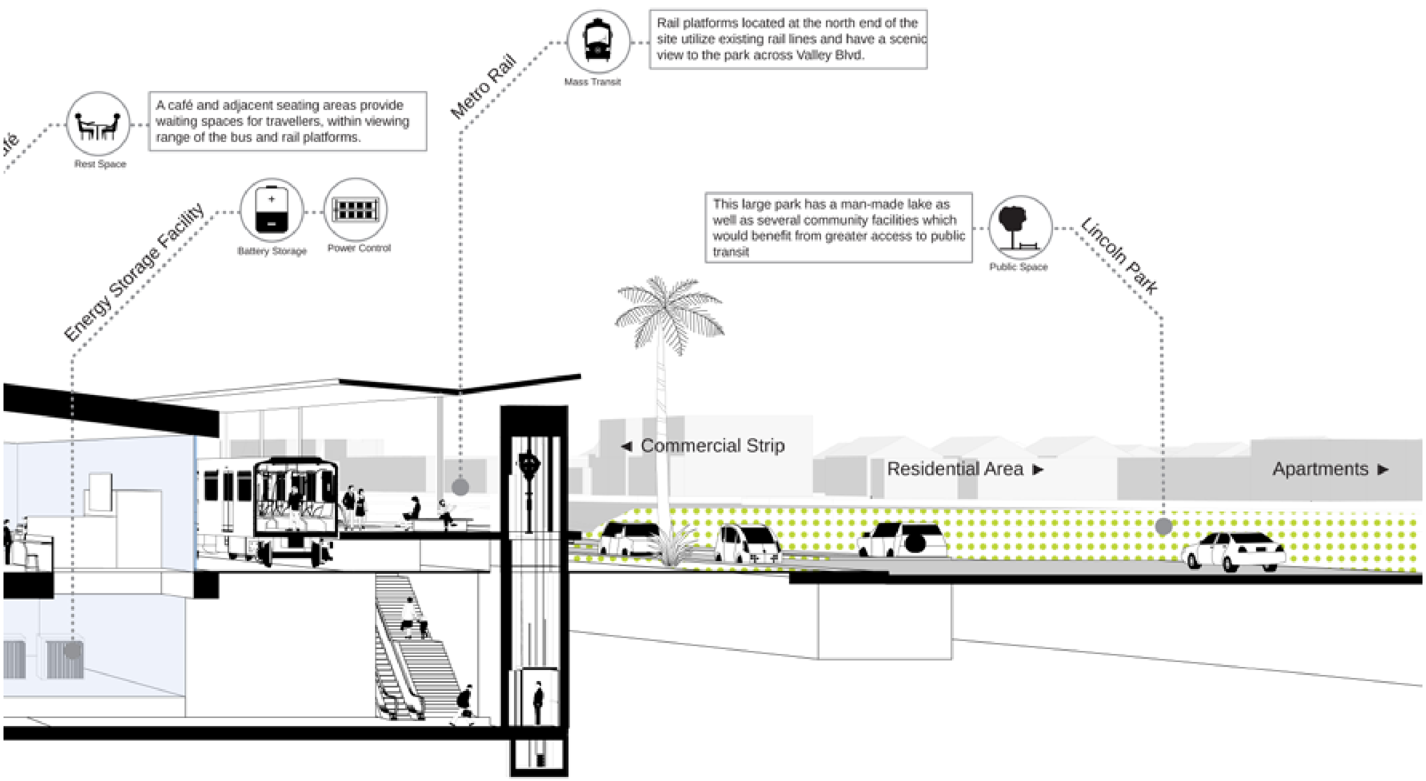


Fig. 3.33 Section B

A longitudinal through the the transit facility, adjacent substation, offices, battery storage facility and water treatment facility. Enormous glass viewing windows allow for a transparency of neighbourhood energy infrastructure for the community transit users.


A café and adjacent seating areas provide waiting spaces for travellers, within viewing range of the bus and rail platforms.
Rest Space
Metro Rail
Mass Transit
Rail platforms located at the north end of the site utilize existing rail lines and have a scenic view to the park across Valley Blvd.
Energy Storage Facility
Battery Storage
Power Control
This large park has a man-made lake as well as several community facilities which would benefit from greater access to public transit
Public Space
Lincoln Park
◄ Commercial Strip
Residential Area ►
Apartments ►

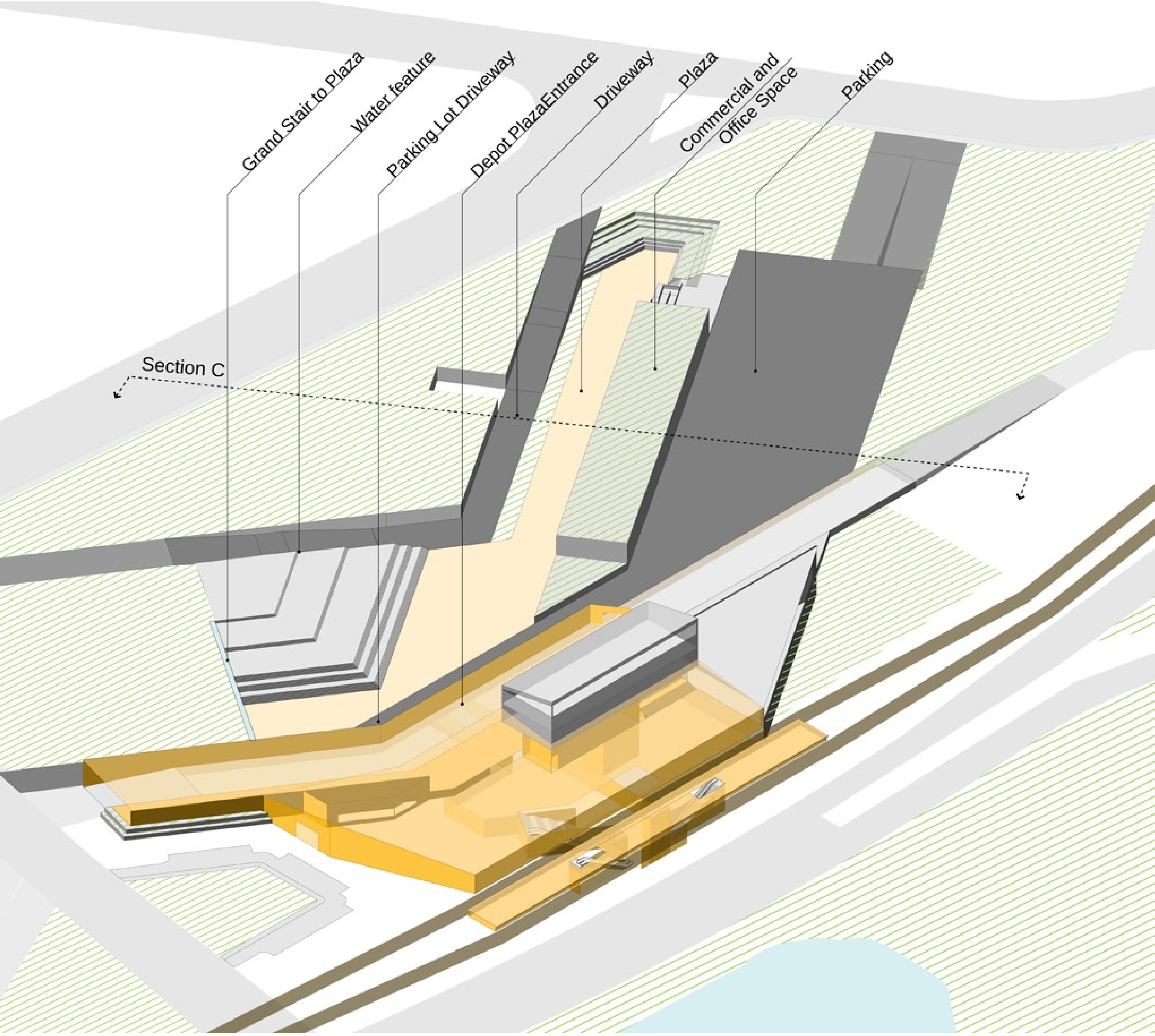

Grand Stair to Plaza
Water feature
Parking Lot Driveway
Depot PlazaEntrance
Driveway
Plaza
Commercial and
Office Space
Parking
Section C

Fig. 3.33 Section C Locator

A section perpendicular to the main circulation area of the sunken plaza. This section shows the entrance to the facility through a basement-level while exhibiting the pedestrian and multi-vehicular flows through the facility and its amenity spaces.

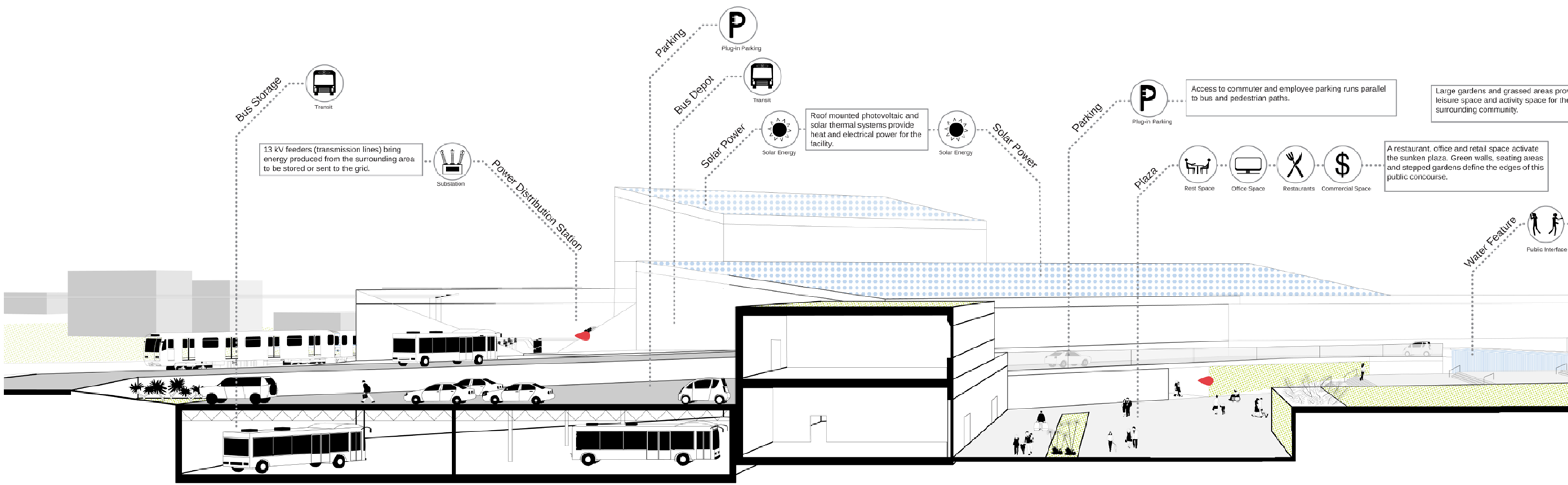
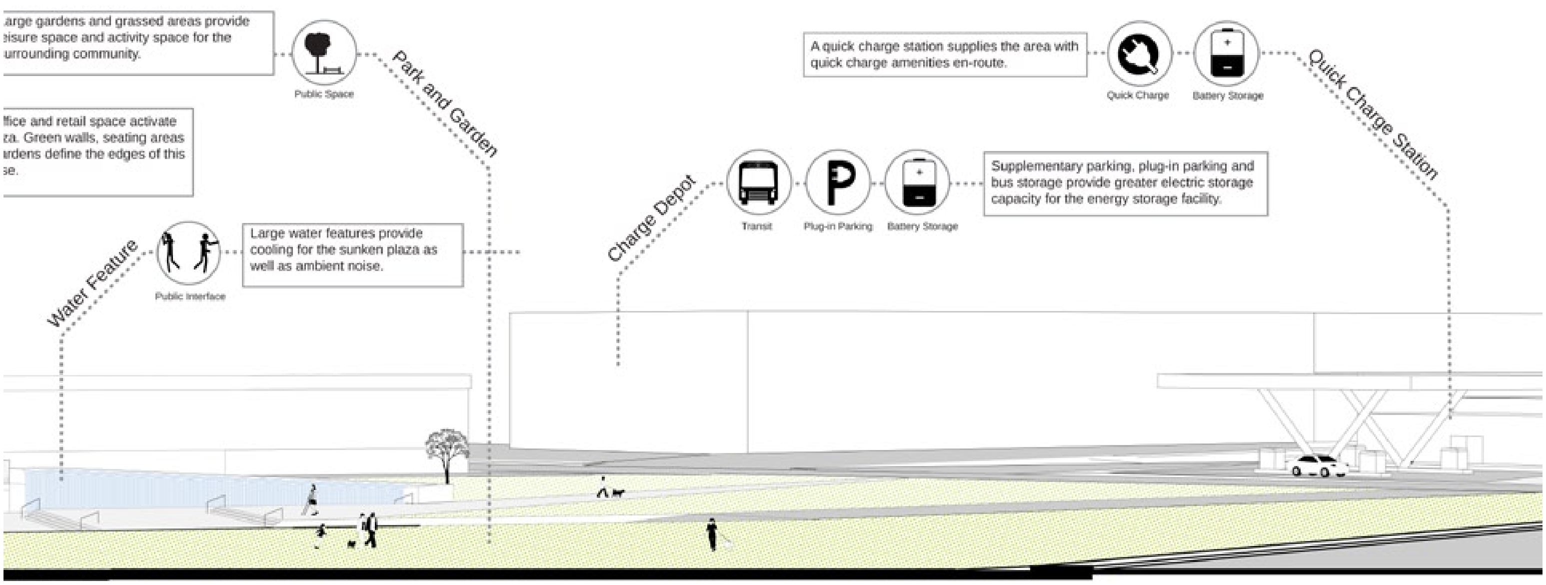


Fig. 3.35 Section C

A section through the sunken plaza offers a view into the various trajectories of travellers on the site. There is also areas for recreation and leisure supported by basic amenities in the transit facility.



.arge gardens and grassed areas provide
eisure space and activity space for the
urrounding community.
Public Space
Park and Garden
ffice and retail space activate
za. Green walls, seating areas
ardens define the edges of this
se.
Water Feature
Public Interface
Large water features provide
cooling for the sunken plaza as
well as ambient noise.
Charge Depot
Transit
Plug-in Parking
Battery Storage
Supplementary parking, plug-in parking and
bus storage provide greater electric storage
capacity for the energy storage facility.
A quick charge station supplies the area with
quick charge amenities en-route.
Quick Charge
Battery Storage
Quick Charge Station

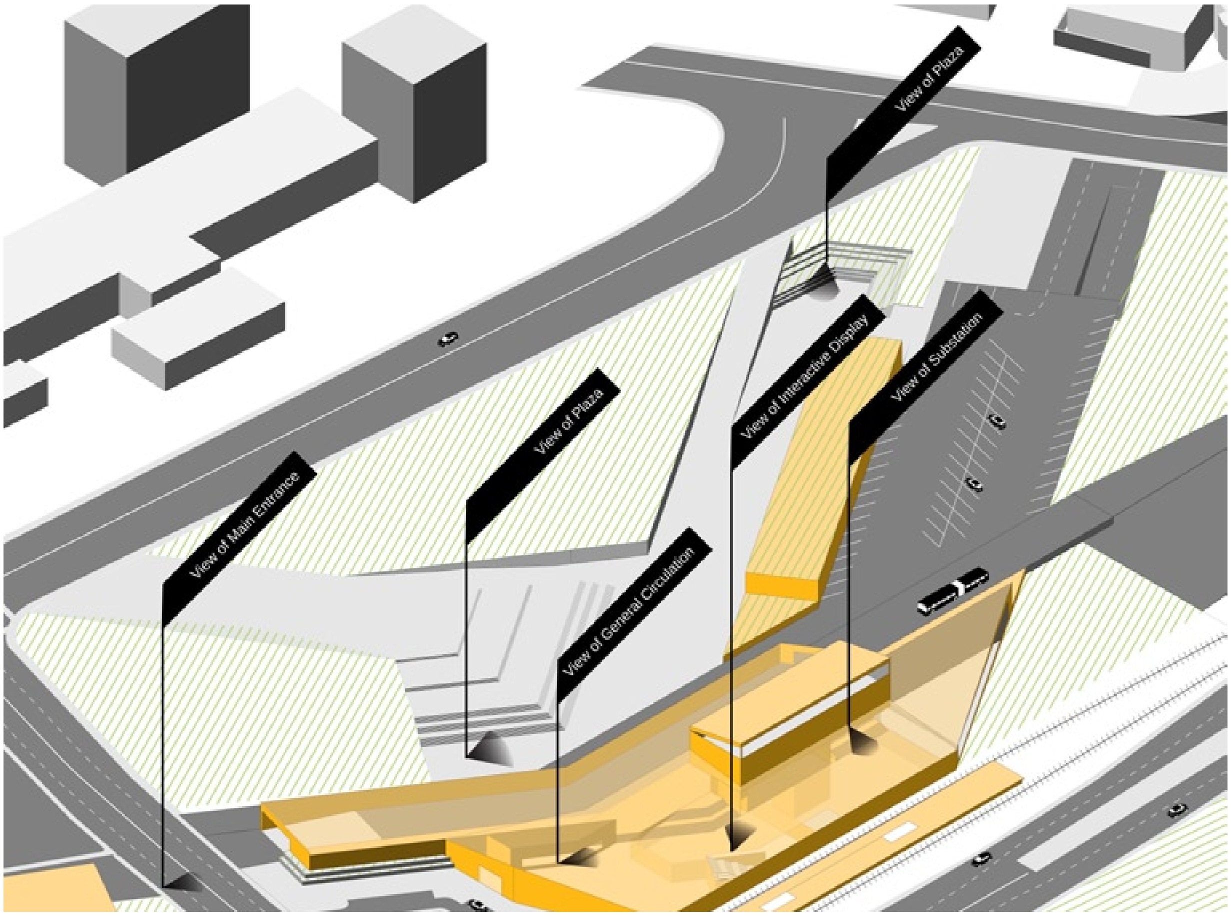


Fig. 3.36 Perspective Vignettes Locator

The following diagrams intend to exhibit how the networks governing principles are manifest in the urban fabric of a specific neighbourhood in Los Angeles, Lincoln Park. This design project aims to stimulate existing places while refining community energy and transportation patterns with sustainable ones.

Liaison/Infrastructure and Community

Every complex living system must coordinate the transfer of mass, energy, and information. The energy and transportation systems proposed encourage communities to have responsible and conscious energy and transportation practices. As this proposal requires a stepped energy and transportation plan from macro (city) to micro (neighbourhood) it is exhibiting characteristics of Glocalisation. Glocalization was first coined as a term for altering universal farming techniques to suit local conditions. The introduced energy and transportation infrastructure will operate similarly to the original definition of Glocalisation. The communities in Los Angeles would be individually organized and coordinated based on local energy and transportation trends. Each neighbourhood would then be organized as an individual that is coordinated within the greater framework. Michael Hough's comment on distanced food production parallels that of energy:

> Separated as we are from the sources and processes of our food supply, and the culture that goes with it, we carry around a burden of expectations and ignorance that may often be as destructive as it may be well meaning[1]

Previous ignorance of energy and transportation systems will henceforth be active and cooperative with community governing principles.

1 Hough, *Cities and natural process*, 18.

Fig. 3.36 Main Entrance on a Weekday Morning

Fig. 3.37 The sunken plaza

The plaza is essentially a large open public space that is pedestrian and bike friendly and flanked by commercial and park spaces. This plaza has multiple entries and exits connecting to parking transit and the surrounding community's amenities.

Fig. 3.38 The Fard End of the Plaza

Fig. 3.39 General Circulation


Cafe

Fig. 3.40 Substation Interface

Energy infrastructure such as the substation coordinating flows of people, transportation and energy around it this enables it to serve as an anchor within the site. Rather than lacking a sense of place like the other Los Angeles substations this one has a unique character provided by the programmatic pairing of energy, transit and commercial facilities.

Fig. 3.41 Interactive Display Board


Weekly Summary of local Energy Production
Mon
Tues
Wed
Thurs
Fr
Sat
Sun
Next Train in: 00h:08m
Bus Schedule
Battery Status
News Stand

Fig. 3.42 Energy Interface

Conclusions

Our energy and building resources are finite. Distributed energy generation coupled with energy efficiency is necessary for the new sustainable city. The thesis investigated the role of architecture in this future scenario using the city of Los Angeles. The resulting proposal articulates a city where community and infrastructure act as cooperative mechanisms that support the city. The aspects of distributed energy production and energy storage were studied at an urban scale. Once this energy network was established it exhibited unique situations that, when paired with transit infrastructures, created mutually beneficial conditions. Building on strategies of distributed generation (DG) and Smart energy technologies coupled with transit oriented development (TOD), a new energy network emerged. This network functions on principles of zero entropy and autonomous ecosystems. The proposed infrastructure is contingent upon the cooperation between energy and transit infrastructures, which enables the system to act as a network. This network works with new and existing transit and electricity infrastructure. Site specific energy production, storage and distribution are paired with transit nodes throughout the city forming energy-transit districts. This leads to an urban situation that emphasizes the existing polycentric organization and strengthens the autonomy of each community. With sensitive energy and transit planning each neighbourhood allows local energy

and transit practices to suit regional supply and demand.

A case study facility is created to investigate the future vision of this urban initiative at a local scale. A substation, energy storage and transit hub are amalgamated into one energy-transit facility. The schematic design focuses on areas of energy/user interface to make energy infrastructure more legible within an energy conscious community. Flows of energy, people, and vehicles in the facility are studied and choreographed to suit the regional mobile population.

The future scenario of the thesis is characterized by typologies and narrative images developed as an extension of Reyner Banham's four ecologies of Los Angeles. The fifth ecology "Electric City" describes a new Los Angeles, free from the burdens of a centralized energy network and heightened by the implementation of feedback systems. The new everyday lifestyle of the future Angeleno is multi-modal. Each citizen is able to contribute to a new economy of energy within their community and as a result each local energy and transportation infrastructure is unique. The proposed facility offers a glimpse into one of these unique instances of the "Electric City." This station creates instances where people and energy infrastructure can converge to create new relationships between energy user and energy system.

This thesis does not address the complex phasing and reorganization that would need to be resolved if this proposal was brought to fruition. The creation of a cooperative system would require the collaboration of various disciplines over decades. A national plan supported by governing bodies would be the catalyst if this plan was adopted. Government agencies would be required to work cooperatively to create suitable taxes, incentives and subsidies in order to attract public interest and investors. New regulations, codes and standards would need to be introduced into engineering and architectural disciplines as well as the transportation and energy industries. Programs of regional and urban public transit services would be essential to accommodating a larger mobile population with an energy conscious agenda. The most important and uncontrollable aspect of this proposal would be the pivotal culture shift. Currently there are no serious repercussions for being irresponsible energy consumers. For a sustainable future the public body would need to alter daily activities and take ownership for their energy consumption and production.

Sustainable design should add value to its surroundings and influence the local community to take ownership for its actions. If this thesis was expanded a test site would be imperative to examine how architecture and design can influence its users. Architects typically use new technologies and systems as appendages to architecture. Future architectural thought should be focused towards integrating energy efficient technologies and systems with the design schematic. This would require new partnerships between architects and a wide spectrum of technology experts but also present new opportunities for architecture to participate in a sustainable world.

Appendix

A1. Energy Resource Comparison

Resource	Petroleum (Distillate fuel oil, residual fuel oil, jet fuel, kerosene, and waste oil.) Worlds primary energy source	Coal (Anthracite, bituminous, subbituminous, lignite, waste coal, and coal synfuel.)	Nuclear Power
General Pros	Highly transportable, can be easily stored (at room temperature). Energy dense, historically cheep to produce, transport and use.	Cheap, reliable, easily stored	Reliable and relatively cheap, increased efficiency and reliability in reactors in recent years, emits much less co2 than coal to produce an equal amount of energy
General Cons	Significant environmental impacts, extraction is damaging in poorer nations, non-renewable and many oil fields are already depleted thus increase in competition for resources. Declining eroei and limits to global production constrain future growth.	Long distance transport only economical for high quality coals, non-renewable resource, worst environmental impacts (in both mining and energy release), primary source of green house gas emissions, some nations have already used up most of their original reserves (global disputes), declining eroei, expected to peak at 2025, 2030	Uranium is a non-renewable resource, the peak of production is likely to occur between 2040 and 2050, average grade is already declining. Recycling of fuel and alternative nuclear fuel are possible but undeveloped, plants are costly to build, substantial environmental impacts,
Water Use	1.3m^3/GWh Consumptive	3.5m^3/GWh Consumptive	1.6 m^3/GWh Consumptive to non consumptive
Area Energy Density	115 ha/1000GWh	Surface mining 400 M^2/GWh Underground mining 200 M^2/GWh Power plant operations 9.1 M^2/GWh	48 ha/1000GWh
EROEI	In production 19, new discoveries 8 and declining	3-14	4-18
Average Life Span	20 Years	50 Years	40 Years

	Natural Gas	Shale Oil	Tar Sands	Hydrogen
	Least carbon intensive of the fossil fuels, energy dense, easily transported through established infrastructure	Large quantity of the resource in place, the us has an amount almost twice the remaining conventional oil resources	Large amounts remain to be extracted, the place where the resource exists in greatest quantity is Canada, close and politically friendly to the U.S.A.	
	Burning it still releases co_2, non-renewable and depleting. Environmental impacts are similar to that of oil. Increasing geopolitical competition for access	Low energy density, high environmental impacts, non-renewable, greenhouse gas contributor, use for heat is far more polluting than coal	Requires substantial processing or upgrading for a usable finished product, non-renewable, polluting and climate changing, fastest growing source of Canada's greenhouse gas emissions, production and use of one barrel of syncrude doubles that of conventional petroleum, extensive environmental damage, costly	Biomass production of hydrogen requires a substantial amount of land to grow the crops used as feedstocks. Coal-based hydrogen production requires coal resources and their inherent cons. There would also be a rise in demand for metals and other materials for fuel cells and related infrastructure.
	1.1 M^3/gWh consumptive,		4.5 Barrels of water for each barrel of syncrude	
	115 Ha/1000gwh			
	3-16 Note: new extraction technologies is more energy intensive and wells deplete quickly thus eroie is expected to rise dramatically	1.7-2.1	3.5 (noted as optimistic)	
	25 Years			

Resource	Hydroelectric	Geothermal	Wind	
General Pros	Most energy and financial investment occurs during project construction, very little extra required for maintenance and operation, cheaper, renewable energy source	Little to no environmental impact. Technologies are very efficient and plants have low emissions. Low cost after initial investment	Renewable energy source, enormous capacity for growth, low cost of electricity and declining,	
General Cons	Environmental impacts (magnitude depends on size of dam etc), destruction of habitat, relocating people in case of dam failure.	Sites are found in few areas worldwide, not a universal solution. Expensive start-up.	Uncontrolled and intermittent resource, some environmental impacts due to migration routes, habitat. Major resources are in remote locations means increased transmission infrastructure	
Water Use				
Area Energy Density	3,700 m^2/GWh		233 ha/1000GWh	
EROEI	40-200+ Very site specific	4-13	6-80	
Average Life Span	60+ Years	40 Years	20 Years	

Solar Thermal	Biomass	Hydrokinetic	Photovoltaic
Non-polluting, Most abundant energy source available. Scalable	There is an abundant supply and it is inexpensive to grow and extract. Reliable source capable of scaling up. Can be used in diesel engines	No emissions, Reliable.	Non-polluting, Most abundant energy source available. Scalable
High initial investment. Weather dependent. Requires unobstructed path for sunlight.	Plant must be near end use to cut transportation costs. Contributes to pollution and greenhouse gas emissions. Still reliant on fossil fuels for conversion process.	Environmental impacts due to changing the aquatic environment.	High initial investment. Dependence on scarce resources. Weather dependent. Requires unobstructed path for sunlight.
	11.8 m^3/GWh		
1 m^2/mWh			10 watts per square foot
10	1-6	15	3-12
15-30 Years	20-40 Years	15-30 Years	30 Years

A2. Los Angeles Electricity

Some Background Information

Power generated miles from Los Angeles is carried to the city through an interconnected network of high-voltage electricity transmission lines.[1] Once the power reaches the city it is solely managed by the LADWP. The Department maintains more than 9,656 kilometers of overhead distribution lines and 9,978 kilometers of underground distribution lines. The average Los Angeles residence receives its annual 6120 kWh of alternating current (AC) through common power transformers. This figure is substantially less than the electricity consumption of an average U.S. home: 11,040 kWh.

The Los Angeles Department of Water and Power (LADWP) supplies almost 22 billion kilowatt hours of electric power per year. Los Angelones are provided with a diverse (but not evenly weighted) portfolio of energy generation made up of coal 44%, natural gas 32%, large hydroelectric 7%, nuclear 9%, and renewable power sources 8%. The city has a total generating capacity of about 7,266 megawatts to serve Los Angeles peak demand of about 6,006 megawatts.

1 The Owens Gorge Transmission Line transports 110,000 kW from three hydro-electric generating plants in the Owens River Gorge. This line combined with the 1,362 kilometer long Pacific Intertie, the Intermountain Power Agency 500-kV direct current transmission line, and various lines of Path 46 deliver Los Angeles its electricity.

Fig 1.16 Various electricity infrastructure around Los Angeles

From top to bottom: Substation 36, Receiving Station E. At Chahuenga Blvd, Receiving Station near Griffith Park, and Substation accross from the Art College of Design.

A3. Los Angeles A History of Rail and Public Transit

As trade and the transport of goods increased in Los Angeles so did the presence of transport vehicles along the city's rail and trucking corridors. This in turn caused an increase in the economy and pollution of the city. The Pacific Electric Railway Company (PE) operated freight and passenger services extending along the San Gabriel and Santa Monica Mountains and towards the Pacific Ocean. Lines of the PE railway influenced the positioning of new developments. These generated the initial formation of the city's sprawled condition. Almost every suburb of the Bay Area was connected by inter-urban rail lines of the PE red-car. 1898 through 1927, the Los Angeles Railway "LARy" ran yellow streetcar services in central Los Angeles. While PE's red-car system offered longer distance connections, the LARy[1] provided ever greater connectivity with inner city trips. LARy's ridership was almost three times that of the Pacific Electric red-car but together they provided Los Angeles with the most extensive public transportation system in the United States until the 1940's.

Los Angeles' municipal infrastructures are not unfamiliar with the abuse of power and corruption at the corporate level. Hollywood films and documentaries have been produced predicated on many shocking incidents in the battles for public infrastructure in Los Angeles. *Chinatown* portrays the manipulation of water provisions by government figures for financial gain. *The Smartest Guys In The Room* documents Enron's participation in a state-wide energy scandal over California's electricity market, labeled by many Californians as 'the energy crisis of 2001.' Who Framed Roger Rabbit? is a parody of the corporate derailment of Pacific Electric's red-car system. Roger saves toon-town from being demolished for a personal automobile highway and defeats the manipulative villain, unlike the reality of Los Angeles' public transportation. In actuality, the maturation of a public transportation system in Los Angeles was suppressed by entities concerned with investments in automobile-based markets.

As early as 1915 the personal automobile began to reach the streets of Los Angeles. Middle-class support for public amenities diminished and Los Angeles began to lose touch with its public transportation system. The ultimate downfall of the red-car system was coordinated through a well organized auto-freeway lobby that effectively opposed public subsidies for public transportation. At the wheel of these lobbies were several car and bus focused corporations including General Motors, Standard Oil, Firestone Tire, Phillips Petroleum, and Mack Truck Manufacturing Company. United under a false corporation National City Lines these companies were able to purchase and dismantle county transit lines.[2] Since the National City Lines scandal, several attempts to provide improvements to public rail in Los Angles were defected by highway initiatives and errors in ridership planning. Massive transit suffered in Los Angeles until 1980, when voters passed Proposition A. This reduced bus fares by increasing local sales tax by one-half cent and enabled the city to establish funds for the construction of a new urban-rail system. Since then the LA Metro has added four light rail (or designated bus lane) lines (the blue, green, gold and purple). PE was already seeing a decline in ridership due to automobile increases, outdated equipment, and Angelenos general distrust of its corrupt governments and fears as to its ability to control and operate a publicly owned massive transit system. Until the introduction of the private auto, the most profitable and exploitable areas were

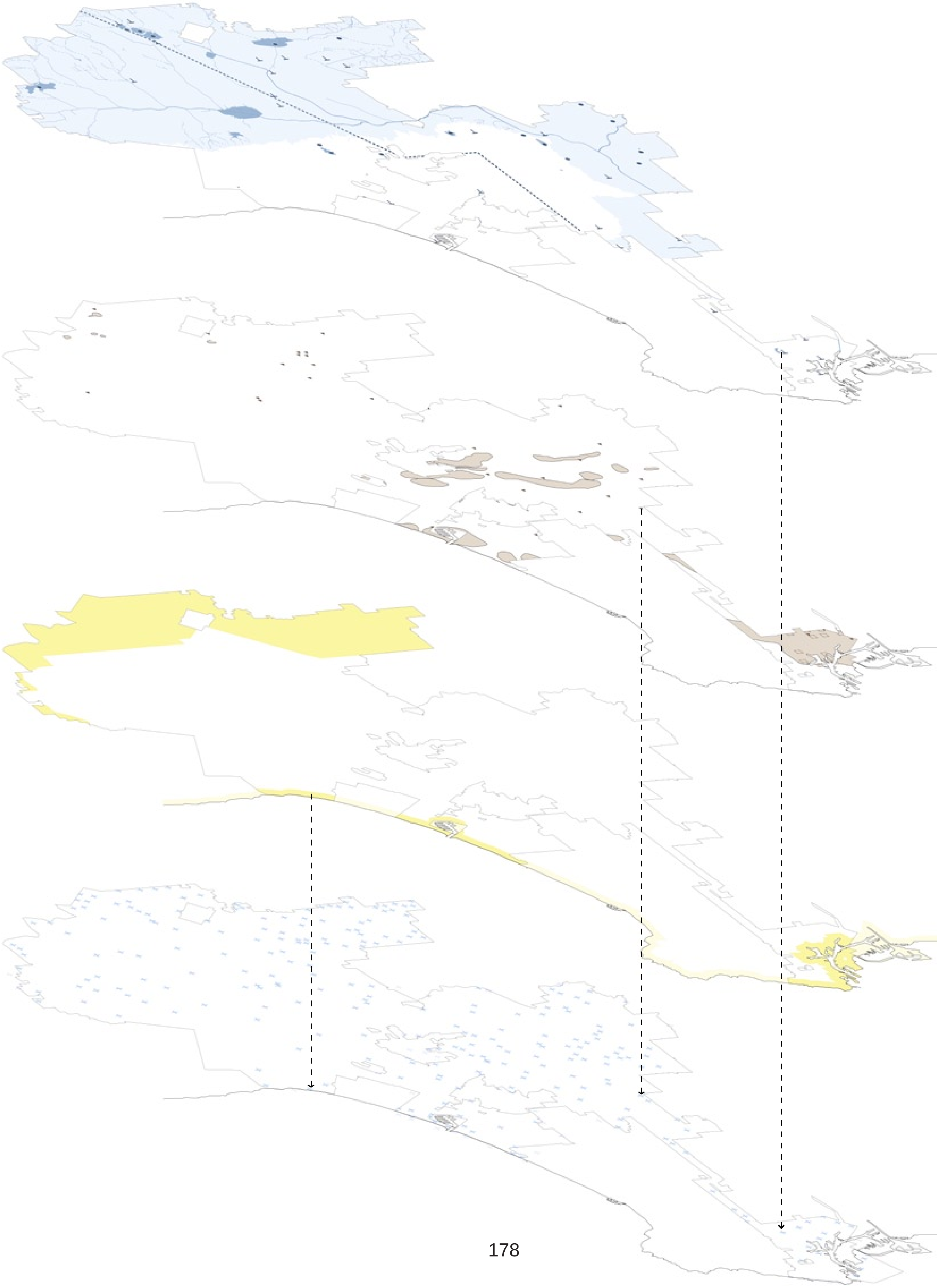
1 Despite LARy's connected infrastructure the rail service had a poor reputation due to overcrowding and poor working conditions for support staff

2 In 1949 a federal court convicted the entities associated with *National City Lines* and fined them $37,007

Fig 1.17 Metro Red Line Tunnel During Construction

those along the mass transportation network, the Pacific Electric Rail. It was not until 1980 that Los Angeles saw its first subway the Metro Red Line. Originally this line was intended to extend from Hollywood, through the San Fernando Valley and over to East Los Angeles. With 70 stations and over 79.1 miles (127.3 km) of rail, Metro Rail can connect you to just about anywhere in Los Angeles County. During the heavy peak travel times, there are as many as 250 trains operating throughout the system. There were 304,459 daily weekday boardings as of March 2010.[3]

3 according to www.metro.net.



A4. LA: Siting Future Electricity Production

Fig 1.18 Los Angeles Energy Production Sites

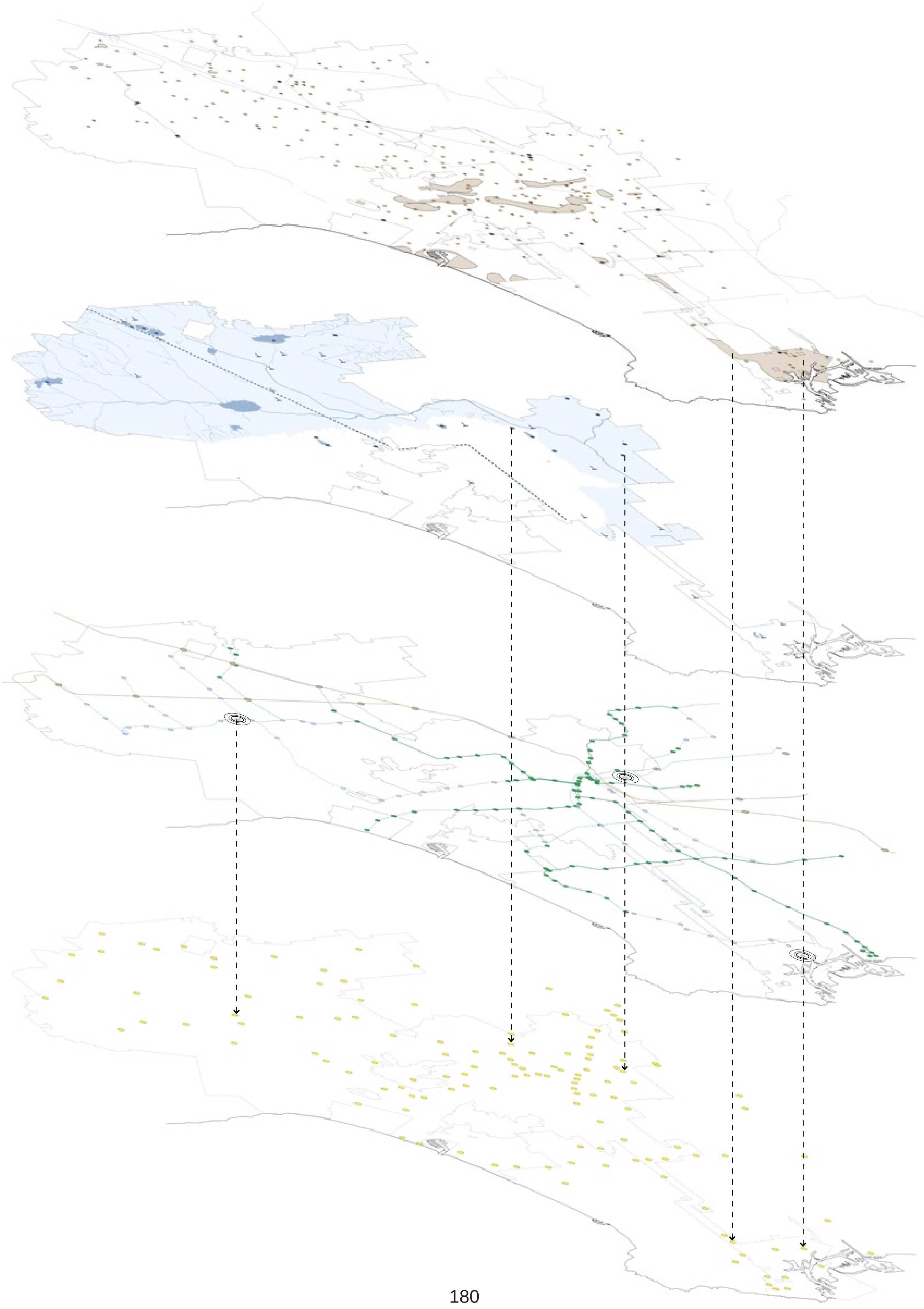
Left: The features considered in the appraisal city areas for storage facilities included: existing water pumping stations, water bodies with significant current, existing oil production sites, landfills (for landfill gas CHP plants), high wind areas, and existing production sites that included three natural gas plants.

LA River Watershed
Pumping Station
River
Los Angeles Aqueduct

Oil Well Boundary
Landfill Site

High Wind Area

Energy Production Site



A5. LA: Siting Future Energy Storage

Fig 1.19 Los Angeles Energy Storage Sites

Various characteristics were considered in the appraisal city areas for storage facilities, these included: areas where pumped air or raised water energy storage were feasible as new or retrofit projects, places with existing or proposed Metro stations, and at existing power receiving stations.

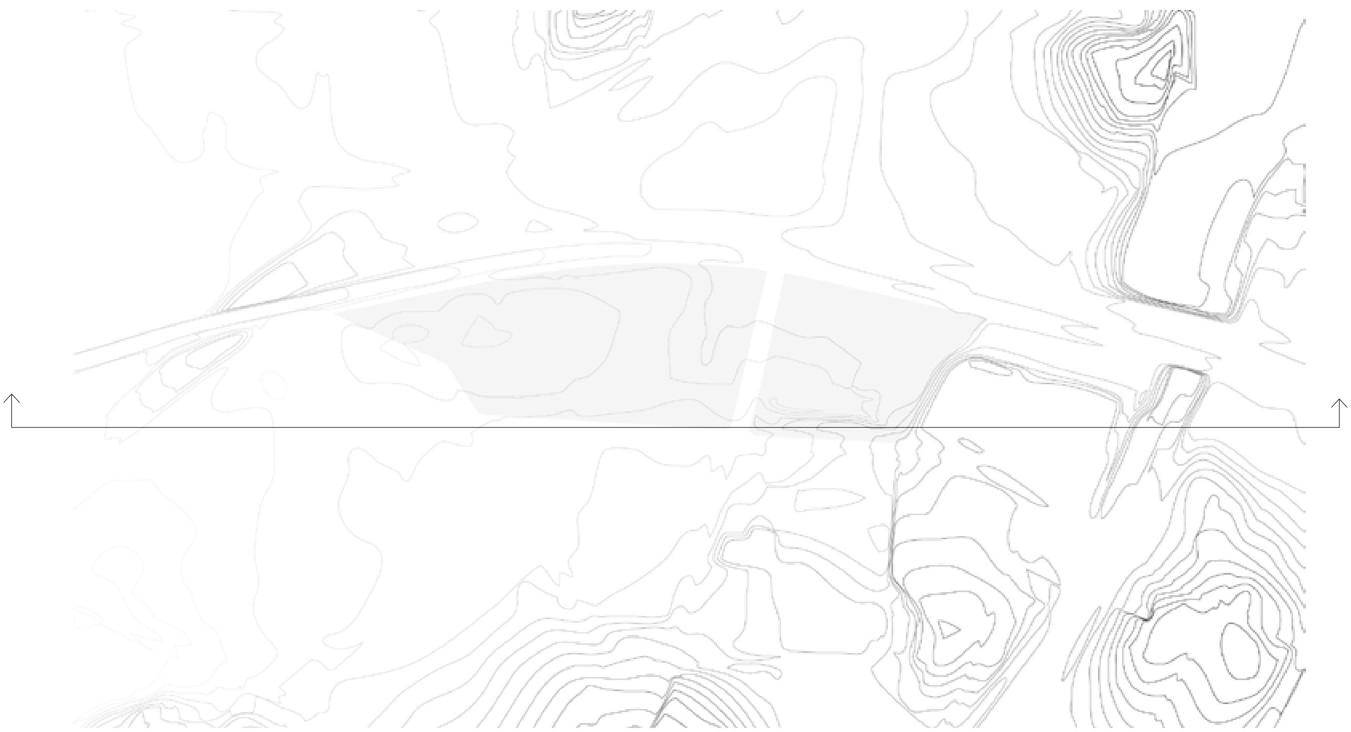
Oil Well Boundary
High Voltage Transmission Lines
Power Receiving Station
Power Distribution Station

LA River Watershed
Reservoir

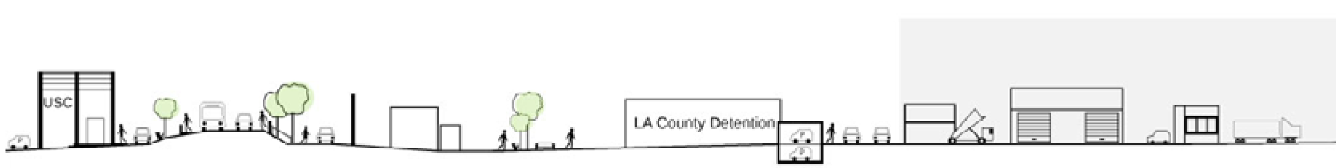
Metrolink Station
Metro Rail Station
Metrolinear Station
Metro Rail Lines
Metro Linear Transitway
Metrolink Commuter Rail
(Proposed Metro lines are dashed)

Energy Storage Site

Structures and Properties



Elevation

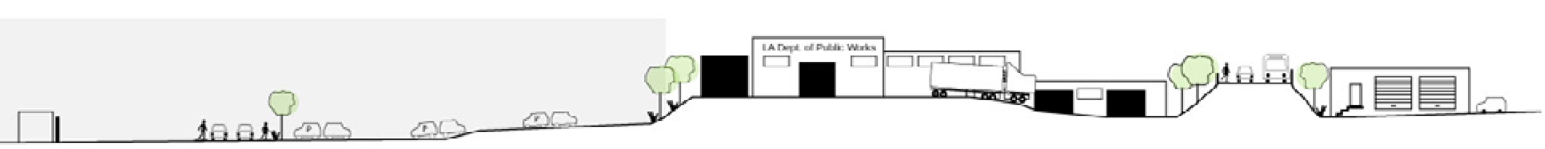


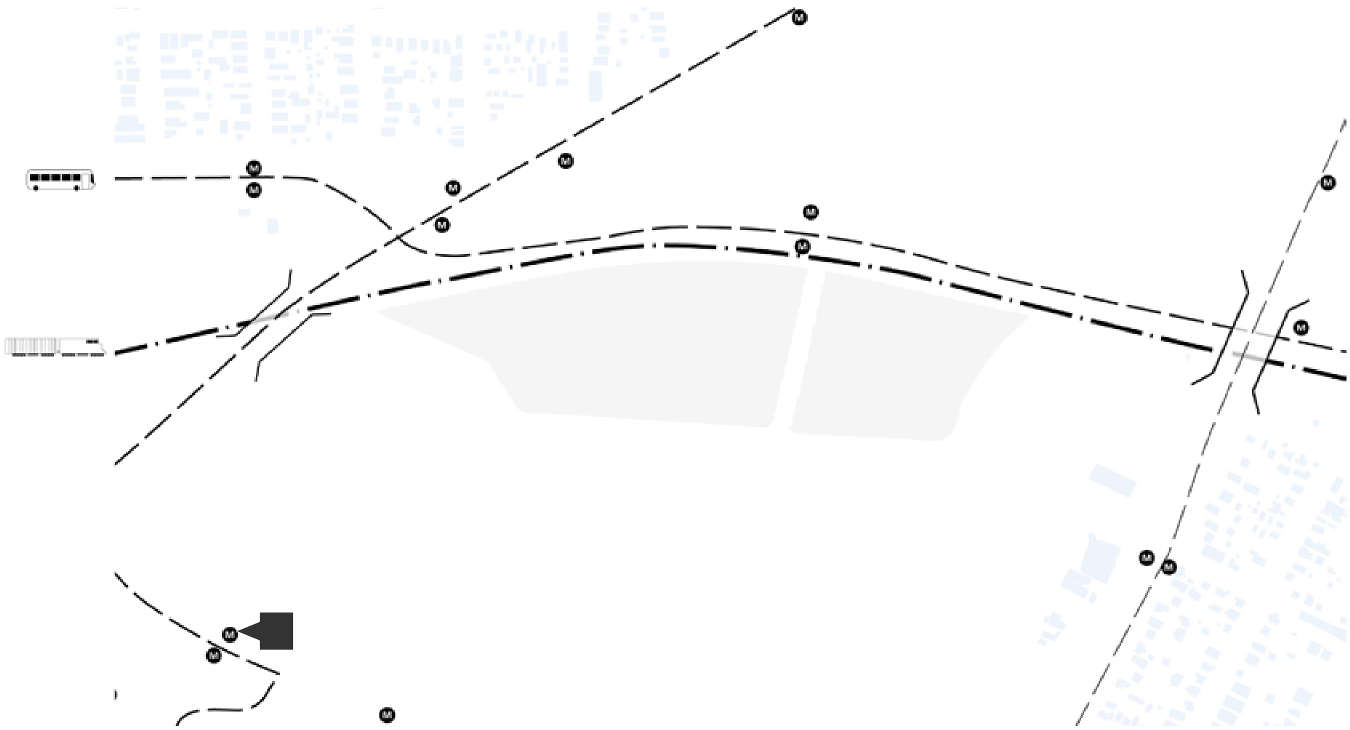
Site Section A

A6. Lincoln Park Mapping

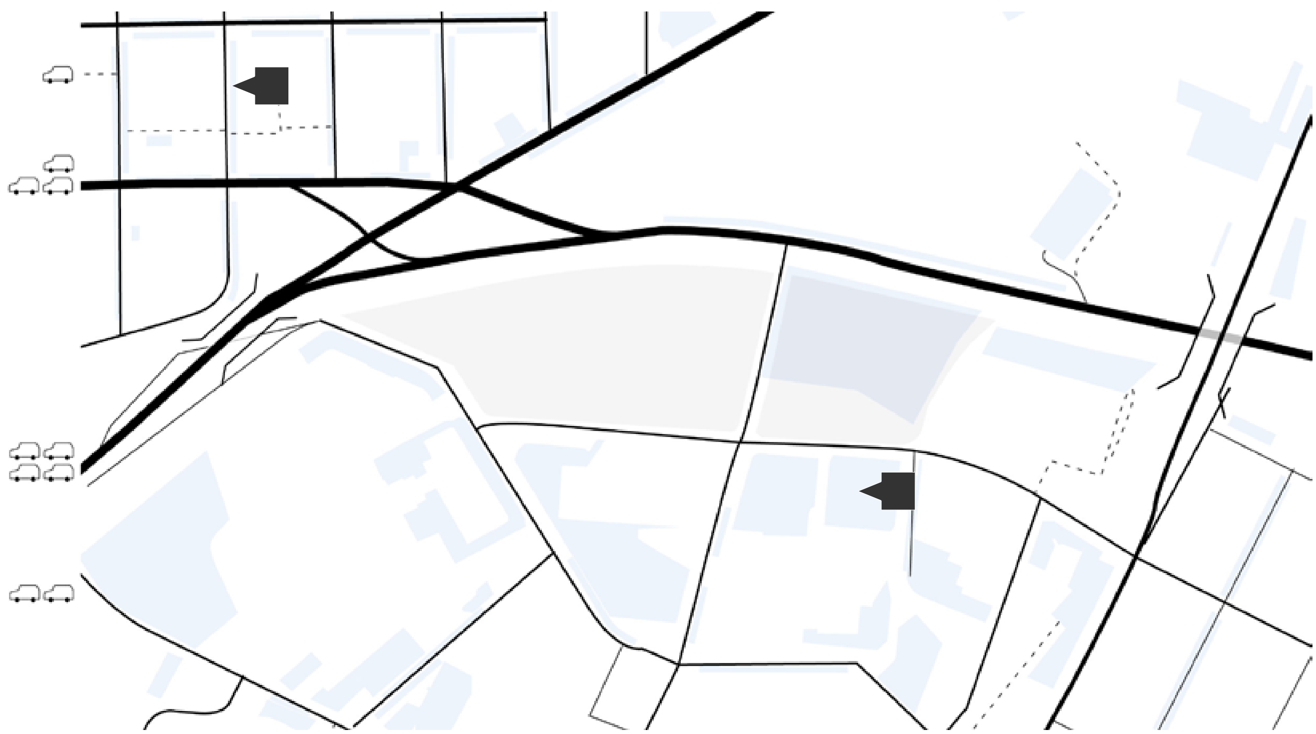
Current Site Features

1. Residentail Area Parkades for USC range in sizes from 2 to 6 stories
2. Latino Cultural Arts Center
3. Community Center
4. Los Angeles Department of Public Works Scrap Yard
5. Los Angeles County Detention and Los Angeles County Juvenile Court
6. University of Southern California Medical Campus
7. Residential Area





Metro Buses, Railway and Transit Dependant Population



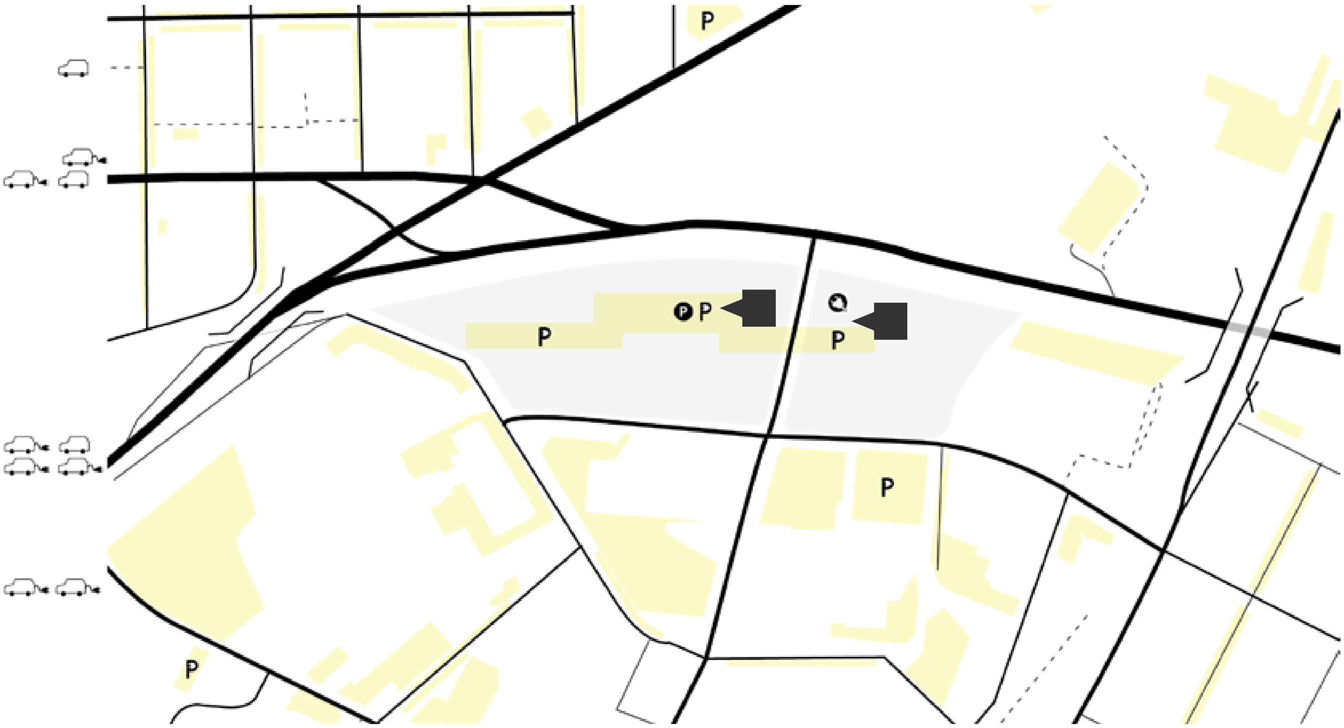
Personal Vehicle Corridors and Parking

Walkways, Bicycle Paths and Park

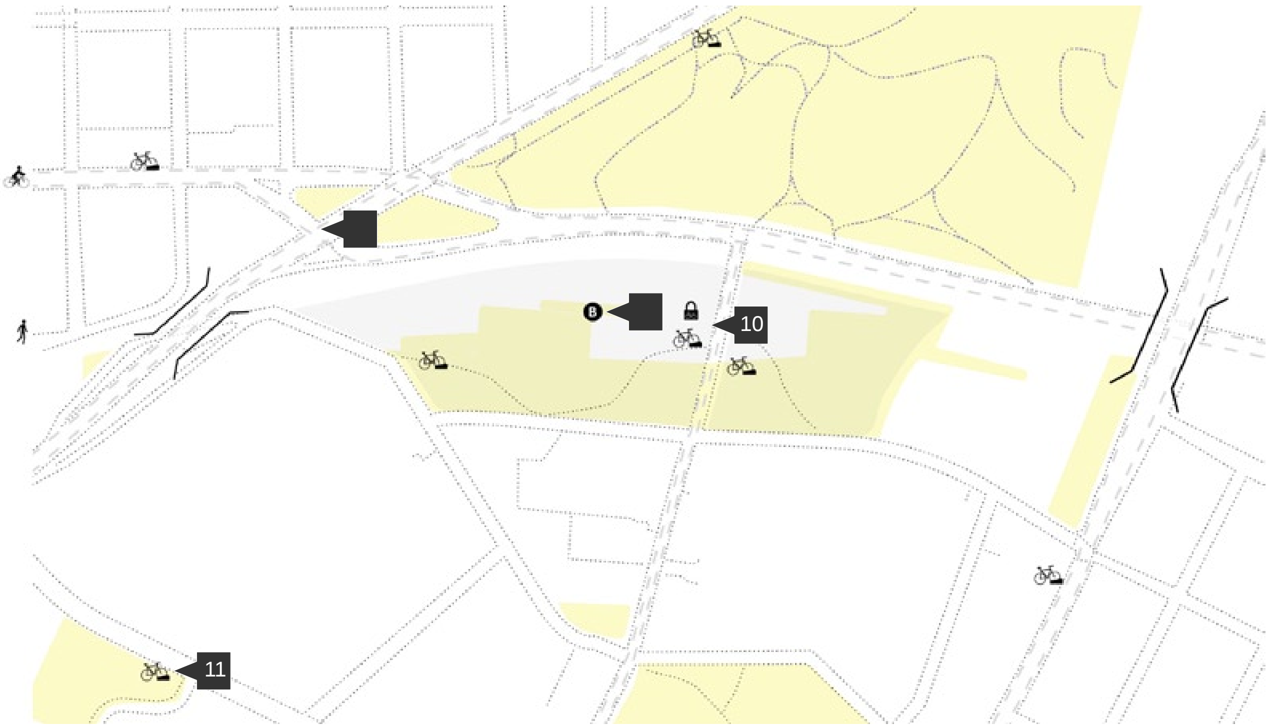
Current Movement Corridors

1. Express bus services for the University of Southern California (USC)
2. Street parking is common in the area
3. Parkades for USC range in sizes from 2 to 6 stories
4. Lincoln Park
5. Controlled intersection allows pedestrians to cross Valley Blvd
6. Hazard Park
7. Pedestrian ramp allows access to Mission Road

Metro Buses, Railway and Transit Dependant Population



Personal Vehicle Corridors and Parking



Walkways, Bicycle Paths and Park

Future Movement Corridors

(30 Year Projection)

1. The transit dependent population has grown considerably
2. An extension of the Metro Red line reaches out to East Los Angeles, serving a greater population of transit dependent citizens.
3. Bus maintenance Facility
4. Bus Depot connects to the Metro station, forming a transit center/hub for the area
5. Bus storage facility
6. Commuter and ‘plug-in’ parking is on site at the transit hub
7. A quick charge station services other vehicles not taking advantage of ‘plug-in’ parking
8. Designated bike lanes takeover previous street-parking lanes.
9. Bicycle commuter hub provides easy transport and access of cyclists through transit facilities
10. Bike lockers and bike racks are located on site
11. Previous dead-space or abandoned lots are designated into park space and pedestrian-bicycle friendly areas.

Glossary

Alternative Energy: The definition of alternative energy varies in relation to categories of energy sources accepted. For this thesis the definition will include the following:

1. Replacement energy resource for existing petroleum liquids generated from biomass and fossil feedstock resources.
2. Electric power generated from wind, solar, photovoltaic, solar thermal, tidal, biomass, and power storage technologies.

Autonomous: able to make decisions and act on them as a free and independent moral agent, existing, reacting, or developing as an independent self regulating organism.

Base Load: is generally the minimum amount of power to meet customer demand based on resonable expectations. Base load values shift hourly in high energy consumption areas like commercial and industrial sectors.

Capacity Factor: the ratio of the actual power output over a period of time and the power producer's ideal output at full capacity over the same time. These factors will vary with type of fuel, power plant design, and power plant age.

Combined Heat and Power: CHP, aka cogeneration, is the use of an electric generator to simultaneously generate electricity and useful heat.

Distributed Generation: also called onsite power generation, dispersed generation, or decentralized energy. Distributed Generation is a range of smaller-scale and modular devices designed to provide electricity, and sometimes also thermal energy, in locations close to consumers. They include fossil and renewable energy technologies.[1]

Distribution: electricity distribution is the last stage after power transmission in a power delivery system. Typically this system transfers power through power lines of less than 50kV to substations, pole-mounted transformers, and distribution wiring to consumers of less than 1kV.

Energy Returned on Energy Invested: EROEI, is the ratio between the amount of usable energy acquired from a given energy resource and the amount of energy expended to obtain that usable energy resource. In general the higher the number the better.

Generating Capacity: typically refers to what a power plant can deliver on a 24 hour, seven day a week basis. This quantity is difficult to apply to wind power plants due to the intermittent characteristic of wind resources.

Generator: an electric generator is a mechanical device that converts mechanical energy into electrical energy. This conversion is usually performed by a motor. The most famous generator is probably the dynamo. The dynamo is a device that uses electromagnetic laws to convert mechanical movement into a direct electric current.

Glocalisation: "glocalization serves as a means of combining the idea of globalisation with that of local considerations." [2]

Hubbert's Curve: is a theory developed by M. King Hubbert in 1956 about the peak of the production rate for a given resource. This peak is denoted as a symmetric logistic distribution curve. Based on Hubbert's calculations he accurately predicted the peak of United

1 Energy .Gov "Distributed Energy," http://www.oe.energy.gov/de.htm (accessed February 3, 2011).

2 Wikipedia, "Glocalisation," http://en.wikipedia.org/wiki/Glocalization#cite_note-1 (accessed February 3, 2011).

States oil production in 1970.

Intermittent Energy Source (IES): a resource of renewable energy that is uncontrollable and unpredictable making it more intermittent than traditional electricity generating sources. IES's are often linked to issues of dispatchability (meaning the ability of an energy producer to handle electricity demands with actual supply).

Net Energy: Like EROEI Net Energy measures the quality of an energy source. This is the difference between the energy used to obtain and energy source and the amount of energy gained from that investment.

Peak Oil: is the climax of global petroleum extraction. After this climax the rate of production will enter terminal decline. This peak is based on observed production rates, the rate of new oil well discoveries as well as predictive modeling developed by M. King Hubbert.

Peak Load: denotes "the maximum power required to supply customers at times when need is greatest. They can refer either to the load at a given moment... or to averaged load over a given period of time."[3]

Reactive Power: is the power delivered to the system with the specific purpose of maintaining continuous and steady voltage conditions on transmission networks. This portion of the power in a transmission line returns to the source each cycle.

Real Power: is the portion of power in transmission that results in net transfer of energy in one direction.

Rolling Blackout: (load shedding) an intentionally-performed electrical power outage instigated as a last resort measure to avoid a total blackout of the power system; usually in response to a situation where the demand for electricity exceeds the power supply capability of the network.

Transit Oriented Development: is an urbanized development designed explicitly to maximize public access to transit infrastructures. This type of development is often associated with mixed-use residential and commercial areas organized around a center transit station or stop.

Transmission: electric power transmission is high voltage electricity transfer, which accounts for the majority of electrical energy transferred from power plants. Transmission lines generally use three phase alternating current at voltages about 110kV to reduce energy lost from transmission over vast distances.

Watt: is a unit of power that measures the rate of energy conversion. One watt is the equivalent of one joule per second.

Kilowatt Hour: (kWh) is a unit of electrical energy equal to 1000 watt hours. This unit is the most common billing unit for delivered electrical energy from utilities.

3 Energy Dictionary. "Peak load, Peak Demand," http://www.energyvortex.com/energydictionary/peak_load__peak_demand.html (accessed February 4, 2011)

Bibliography

Books

Baer, Steve. Sunspots: *Collected Facts and Solar Fiction*. Albuquerque, NM: Zomeworks Corporation, 1977.

Banham, Reyner. *Los Angeles: The Architecture of Four Ecologies.* London: The Penguin Press, 1971.

Bainbridge, David., Judy Corbett, and John Hofacre. *Village Homes' Solar House Designs*. Emmaus, PA: Rodale Press, 1979.

Bolchover, Joshua and Jonathan D. Solomon, eds. Vol. 13, *306090 Books*. New York, NY: Princeton Architectural Press, 2009.

Brune, Michael. *Coming Clean: Breaking America's Addiction to Oil and Coal*. San Fransisco: Sierra Club Books, 2008.

Caudill, William Wane., Frank D. Lawyer, and Thomas A. Bullock. *A Bucket of Oil*. Boston, MA: Cahners Books, 1974.

Daniels, Klaus. *Low-Tech Light-Tech High-Tech: Building in the Information Age.* Elizabeth Schwaiger, trans. Boston: Birkhäuser Publishers, 1998.

Davis, Mike. *City of quartz : Excavating the future in Los Angeles.* London: Verso, 1990.

Davis, Mike. *Dead Cities: And Other Tales.* New York: The New Press, 2002.

Fernandez-Galiano, Luis. *Fire and Memory: On Architecture and Energy*. trans, Gina Carino (Cambridge, MA: The MIT Press, 2000), 79.

Flink, James J. *The Car Culture.* Cambridge, MA: The MIT Press, 1975.

Friedlander, Amy. *Power and Light: Electricity in the U.S Energy Infrastructure 1870-1940.* Virginia: Corporation for National Research Initiatives, 1996.

Fuller, Buckminster. *4D Time Lock*. N.M, Albuquerque: Biotechnic Press., 1972.

Gissen, David., ed. *Big and Green: Toward Sustainable Architecture in the 21st Century.* New York: Princeton Architectural Press, 2002.

Grube, Hans Achim, ed. *Power and Energy: Power Plant Rummelsburg – Berlin.* Berlin: Jovis, 2005.

Haas, Tigran, ed. *New Urbanism and Beyond: Designing Cities for the Future.* New York, NY: Rizzoli International Publications, 2008).

Hackleman, Michael A. *Wind and Windspinners: A 'Nuts and Bolts' Approach to Wind/Electric Systems.* Culver City, CA: Peace Press. 1974.

Hegger, Manfred., Matthias Fuchs, Thomas Stark and Martin Zeumer, eds. *Energy Manual: Sustainable Architecture.* Boston: Birkhäuser Publishers, 2008.

Hermannsdorfer, Ingrid., and Christine Rub. *Solar Design: Photovoltaics for Old Buildings, Urban space, Landsacapes.* Berlin: Jovis, 2005.

Hough, Michael. *Cities and Natural Process.* New York, NY: Routledge, 1995.

Jakob, Michael. "Architecture and Energy of the History of an Invisible Presence," 2G:International Architecture Review. no. 18. 2001.

Judge, Emma, comp. *Hands on Energy, Infrastructure and Recycling.* London: ITDG Publishing, 2002.

Knowles, Ralph L. *Sun Rythm Form*. London: The MIT Press, 1981.

Kultermann, Udo. *Architecture in the Seventies.* New York: Architectural Book Publishing Company, 1980.

Macaulay, David R., and Jason F. McLennan. *The Ecological Engineer Volume One: KEEN Engineering.* Kansas City, MO: Ecotone LLC Publication, 2006.

Marks, Robert., and R. Buckminster Fuller. *The Dymaxion World of Buckminster Fuller.* New York: Anchor Books, 1960.

Mitchell, William J. *E-Topia: Urban Life, Jim- But Not As We Know It.* Cambridge, MA: The Mit Press, 1999.

Moughtin, Cliff., and Peter Shirley. *Urban Design: Green Dimensions.* 2nd ed. Boston: Architectural Press, 2005.

Newman, Peter and Jeffrey R. Kenworthy, *Sustainability and Cities: Overcoming Automobile Dependence*. Washington, D.C. : Island Press, 1999.

Newman, Peter., and Isabella Jennings. Cities as Sustainable Ecosystems: Principles and Practices. Washington: Island Press, 2008.

Pettena, Gianni. Radicals: Design and Architecture: 1960-75. Il Ventilabro: Venice, 1996

Pfeiffer, Dale Allen. *The End of the Oil Age.* From The Wildreness, 2004.

Prasad, Deo., and Mark Snow, eds. *Designing With Solar Power: A Source Book for Building Integrated Photovoltaics.* Sterling ,VA: Images Publishing, 2005.

Rose, Mark H. *Cities of Light and Heat: Domesticating Gas and Electricity in Urban America.* University Park, PA: The Pennsylvania State University Press, 1995.

Schumacher, E.F. *Small is Beautiful: Economics as if People Mattered*. San Bernardino, CA: The Borgo Press, 1989

Skurka, Norma., and Jon Naar. *Design For a Limited Planet: Living With Natural Energy.* New York: Ballantine Books, 1976.

Soja, Edward W. *Postmodern Geographies: The Reassertion of Space in Critical Social Theory.* New York: Verso, 1989.

Stobaugh, Robert., and Daniel Yergin, eds. *Energy Future: Report of the Energy Project at the Harvard Business School.* New York: Random House, 1979.

Todd, Nancy Jack, ed. *The Book of the New Alchemists.* New York: E.P. Dutton, 1977.

Watts, Jennifer A., and Claudia Bohnn-Spector. *This Side of Paradise: Body Landscape in Los Angeles Photographs.* New York: Merrell Publishers Limited, 2008.

Williams, James C. *Energy and the Making of Modern California.* Akron, OH: The University of Akron: 1997.

Yergin, Daniel. *The Prize.* Toronto: Simon & Schuster, 1991.

Zardini, Mirko., and Giovanna Borasi, eds. *Sorry Out of Gas: Architecture's Response to the 1973 Oil Crisis.* Montreal: Canadian Centre for Architecture, 2007.

Journals and Articles

Alexandre, Ariel, & De Michelis, Nicola. (1994). "The energy-efficient city. Organisation for Economic Cooperation and Development." The OECD Observer,(187), 26. *Questia*. 1994, http://www.questia.com/googleScholar.qst?docId=98677236 (accessed February 3, 2010).

"6,650 Beacon Wind Turbines Proposed for London." *Yes2Wind: For a Clean Energy Future*. 20 June, 2007, http://www.yes2wind.com/news2007/20_06_07_news_story.html (accessed October 29, 2008).

Ahn, Jiwoon., Gicheol Jeong, and Yeonbae Kim. "A Forecast Of Household Ownership And Use Of Alternative Vehicles: A Multiple Discrete-Continuous Choice Approach." *Science Direct: Energy Economics*. October 22, 2007 www.sciencedirect.com (accessed October 24, 2008).

Alexander, Lamar. "A New Manhattan Project for Clean Energy Independance." *Science and Technology.* 2008: 39-44. Wilson Web, http://www.hwwilson.com/ (accessed October 20, 2008).

Biello, David. "Tilting at Windmills: Is Small-Scale Turbine Power Viable--Or Just an Illusion?" *Scientific American*. October 28, 2008, http://www.sciam.com/article.cfm?id=small-scale-wind-power& (accessed October 31, 2008).

Blankinship, Steve. ed. "World's Largest Battery Storage System Marks Second Year of Operation." *Power Engineering.* January, 2006, http://pepei.pennnet.com/display_article/246701/6/ARTCL/none/none/1/World%E2%80%99s-Largest-Battery-Storage-System-Marks-Second-Year-of-Operation/ (accessed November 2, 2008).

Buttonwood. "Fuel For Thought." *The Economist.* August 7, 2008, http://www.economist.com/research/articlesbysubject/displaystory.cfm?subjectid=2512631&story_id=11896992 (accessed October 20, 2008).

California Energy Comission "Transportation Energy Forecasts For The 2007 Integrated Energy Policy Report." *Energy Council of Canada.* 2008, http://www.energy.ca.gov/2007publications/CEC-600-2007-009/CEC-600-2007-009-SF.PDF (accessed October, 2008).

Heinberg, Richard, and Daniel Lerch, eds. "The Post Carbon Reader." *Post Carbon Institute.* University of California Press, 2010. http://www.postcarbon.org/reader (accessed. November 28, 2010).

Hodgson, P. E. "The Energy Crisis." Modern Age. Corpus Christi College, Oxford. 140- 147. 2008. *Wilson Web.* November 4, 2008, http://www.hwwilson.com/ (accessed October 20, 2008).

"Hydro-Net by IwamotoScott." *de zeen: Design Magazine*. February 8, 2008, http://www.dezeen.com/2008/02/08/hydro-net-by-iwamotoscott/ (accessed October 20, 2008).

"I want a Mobile Future: 2009 Long Range Transportation Plan," *Metro - Los Angeles County Metropolitan Transportation Authority.* 2010, http://www.metro.net/projects_studies/images/final-2009-LRTP.pdf (accessed. December 20, 2010).

Khan, N., Z. Saleem and A. Wahid. "Review of Natural Energy Sources and Global Power Needs." *Science Direct: Renewable and Sustainable Energy Reviews*. COMSATS Institute of Information Technology, Islamabad, Pakistan. April 9, 2007, www.sciencedirect.com (accessed October 27, 2008).

Krumdieck, Susan. "Systems Approach to Posing Problems and Finding Sustainable Solutions." University of Canterbury, New Zealand: 2004. *Doc Stoc.* http://www.docstoc.com (accessed November 20, 2008).

Leggett, Jeremy. "What They Dont't Want you to Know About the Coming Oil Crisis" *Energybulletin*. January 19, 2006, http://www.energybulletin.net/node/12226 (accessed 2 November, 2008).

McGowan, Alan H. "Rethinking Energy Options to Address Climate Change." *Wilson Web: Environment*. October, 2007, http://www.hwwilson.com/ (accessed October 23, 2008).

Parks, Noreen. "Shale Oil: Alternative Energy or Environmental Degradation." *BioScience.* Vol. 58 No. 6 . 2008, *Wilson Web*, http://www.hwwilson.com/ (accessed October 27, 2008).

Pearce, Fred. "Can Coal Live up to its Clean Promise?" *New Scientist Environment*. March 27, 2008, http://www.newscientist.com/article/mg19726491.500-can-coal-live-up-to-its-clean-promise.html (accessed October 23, 2008).

Scan, Brian. "The Frugal Cornucopian." *The Economist.* September 4, 2008, http://www.economist.com/science/tq/displaystory.cfm?story_id=11999219 (accessed October 20, 2008).

Schafersman, Steven. "Round Table Discussion on World Oil Supply and the Consequences for America." *Petroleum Experts Debate Impending World Oil Shortage*. October 10, 2002, http://www.freeinquiry.com/skeptic/badgeology/energy/debate-review.htm (accessed October 16, 2008)

Sels, T., C. Dragu, T. Van Cranebroeck and R. Belmans. "Electrical Energy Storage Systems: Existing Systems Versus Newest Systems - An Overview." *Belgium: Electrical Engineering, Energy Institute*. March 28, 2011, www.kuleuven.be/ei/Public/publications/EIWP01-04.pdf (accessed October, 2008).

"Solar Power Game-Changer: 'Near Perfect' Absorption of Sunlight." *Physorg*. November 3, 2008, http://www.physorg.com/news144940463.html (accessed November 10, 2008).

Stremke, Sven. "Energy-Conscious Regional Design: Synergy between Ecosystem Thinking and Spatial Planning," October 2008, http://architecture.ucd.ie/Paul/PLEA2008/content/papers/oral/PLEA_FinalPaper_ref_227.pdf (accessed December 20, 2010).

"Sustainable Energy Systems: Report and Demonstration of Architectural Measures." *Polycity*. May 5, 2006, http://www.polycity.net/en/index.html (accessed November 11, 2008).

Van Dyk, E. E., A.R. Gxasheka, and E. L. Meyer. "Monitoring Current-Voltage Characteristics and Energy Output of Silicon Photovoltaic Modules." *Science Direct*: *Renewable Energy*. University of Fort Hare, South Africa. April 20, 2004, www.sciencedirect.com (accessed October 29, 2008).

Webber, Michael E. "Energy Versus Water: Solving Both Crises Together." *Scientific American*. October 22, 2008, http://www.sciam.com/article.cfm?id=the-future-of-fuel&print=true (accessed October 31, 2008).

Websites

"America is Addicted to Foreign Oil." *PickensPlan.com*. August 7, 2008, http//:www.pickensplan.com (accessed November 14, 2008).

"California Gets Ahead of the Electric Car Game."" *NACS Online*. June 18, 2010, http://www.nacsonline.com/NACS/News/Daily/Pages/ND0618106.aspx (accessed June 28, 2010).

"California Quick Facts," *U.S. Energy Information Administration.* 2010, http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA (accessed December 20, 2010).

"Energy Comission Awards $1.9 Million for Improving California's Electric Vehicle Infrastructure." *Green Car Congress.* August 2010, http://www.greencarcongress.com/2010/08/cec-20100812.html (accessed December 20, 2010).

Los Angeles Department of Water and Power. 2011, http://www.ladwp.com/ladwp/homepage.jsp (accessed December 20, 2010).

"National Infrastructure Protection Plan." *U.S. Department of Homeland Security.* January 21, 2010, http://www.dhs.gov/files/programs/editorial_0827.shtm (accessed June 28, 2010).

"Plug in America" 2008. November 3, 2008, http://www.pluginamerica.org/faq.shtm (accessed June 28, 2010).

"Wind Energy Resource Atlas of the United States." *Renewable Resource Data Center*. November, 2008, http//:rredc.nrel.gov/wind/pubs/atlas/appendix_Ahtml#calculate (accessed June 20, 2010).

"Wind in Reserve." *State Energy Conservation Office*. November, 2008, http://www.seco.cpa.state.tx.us/re_wind-reserve.htm (accessed June 20, 2010).

"World Energy Outlook 2009 Fact Sheet." *International Energy Agency.* 2010, http://www.worldenergyoutlook.org/docs/weo2009/fact_sheets_WEO_2009.pdf (accessed June 28, 2010).

U.S. Census Bureau. 2010, http://www.census.gov/population/www/censusdata/density.html (accessed. December 20, 2010).

U.S. Department of Energy. 2010, http://www.oe.energy.gov (accessed December 20, 2010).

U.S. Department of Homeland Security. 2010, http://www.dhs.gov/xlibrary/assets/nipp_snapshot_energy.pdf (accessed December 20, 2010).