CATHEDRALS OF POWER:

Re-energizing Historic Power Systems

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Abstract

Cathedrals of Power:

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Architecture

By providing a regional resource, electric power systems have provided urban environments unprecedented means for growth and expansion from the late 1800's to 1930's, as discussed by Thomas Hughes, in *Networks of Power*. The electric power systems and components associated with them developed during this time and into present day has challenged civilization to create an infrastructure capable of harnessing this dangerous resource for the powering of cities. This thesis will reveal the relationships between these historic architectures of power, in the form of both a specific substation, Historic Cushman Substation and the neighborhood around it, and demonstrate how these structures can continue to provide resources to its community. The project will attempt to connect artifacts of the past energy system to emerging technology of the 21st century, by developing an integrated system for the existing infrastructure of the substation. This project implements innovative solar technology in the form of luminescent solar collectors. More broadly, this thesis brings historic systems back into use by infusing appropriate energy systems to specific sites, while also celebrating the civic space now possible; while demonstrating the thesis with the infrastructure and architecture of an iconic 1920s substation.

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Acknowledgements:

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Also, I am so grateful for my family and friends who provided their encouragement along the way.

figure 1. cushman substation, tacoma wa

Introduction

Of the great construction projects of the last century, none has been more impressive in its technical, economical, and scientific aspects, none has been more influential in its social effects, and none has engaged more thoroughly our constructive instincts and capabilities than the electric power system.

-Thomas Parke Hughes, Networks of Power

By providing a regional resource, electric power systems have provided urban environments unprecedented means for growth and expansion from the late 1800's to 1930's, as discussed by Thomas Hughes, in *Networks of Power.* The electric power systems and components associated with them developed during this time and into present day has challenged civilization to create an infrastructure capable of harnessing this dangerous resource for the powering of cities, formulated from a variety of requirements, and manifesting as a landscape altering built environment. Transmission towers and other infrastructure also are integral to the process for suburban or urban locations; carrying power into a neighborhood through high voltage transmission lines.

As the urban embodiment of these systems, the electrical substations are integral with the areas they provide electricity. This architecture of power creates strong tensions between domestic neighborhoods and heavy industrialized processes in order to provide usable electricity from a high voltage resource.

The architecture of the early systems were designed to be the face of the power company, and embody all of the achievements that make the system possible, manifesting as monuments to the electric power system.

figure 2. cushman substation, adams substation in foreground

Once major civic landmarks for growing cities, today architectural substation buildings are becoming increasingly obsolete with the advent of changing technologies and demand.

This thesis will reveal the relationships between these historic architectures of power, in the form of both a specific substation, Historic Cushman Substation and the neighborhood around it, and demonstrate how these structures can continue to provide resources to its community. The project will attempt to connect artifacts of the past energy system to emerging technology of the 21st century, by developing an integrated system for the existing infrastructure of the substation. This project implements innovative solar technology in the form of luminescent solar collectors. More broadly, this thesis brings historic systems back into use by infusing appropriate energy systems to specific sites, while also celebrating the civic space now possible; while demonstrating the thesis with the infrastructure and architecture of an iconic 1920s substation.

figure 3. cushman substation doric temple entry: “danger high voltage keep away”

 figure 4. high voltage transmission towers north 21st street

Theoretical Framework:
Electricity as a Universal Resource

Electricity seemed to be the very essence of consumption; it was perpetually generated by falling water, permanently connected to every social institution, and effortlessly available at the flick of a switch. It had not yet become an ordinary detail in the social landscape. It had not yet faded into the unconscious background of experience as it has today, when noticed only if absent.

-David Nye, Electrifying America

The supply of electricity to U.S. cities in the late 19th century brought about a tremendous shift in the way urban environments operated as infrastructure and as place. A clean alternative to coal burning and other combustion generated energy, electricity proved to be a convenient and reliable source of energy used predominantly at first for artificial lighting, and then later for transportation systems and domestic applications. Electricity for the use of streetcars had a strong influence on accessibility of the city from suburbs, enabling travel through the city in a clean and efficient way. Domestic applications for electricity included interior lighting, and home appliances for example that provided a higher quality and more convenient way of living (Nye 1990, 76).

As David Nye describes in his book *Electrifying America: The Social Meanings of a New Technology*, the introduction of this new resource had an influence not only on the physical characteristics of the urban environment but also how people perceived these environments. He states “the city [was depicted] not as a place of chaos, darkness, and danger, but of order, light, and intelligibility” (Nye 76). As shown in examples of the work of Alfred Stieglitz (Figure 5) The Glow of Night, New York

figure 5. alfred stieglitz, the glow of night - new york, 1897

depicts the city as glimmering hub of life and activity. The application of electricity was nearly universal in the various modes that supported living and production. In addition, this new resource presented a completely new force to be controlled, harnessed, and integrated into the existing city fabric.

Architecture of Power

Electric power systems embody the physical, intellectual, and symbolic resources of the society that constructs them

-Thomas Hughes, Networks of Power

Between the late 1800's and the 1930's, the former systems of gas lamps evolved into a tightly organized system of supplying electric power to major cities in the US. This system was very important at an urban scale but also at a regional level. The electrical infrastructure produced an "architecture of power," the structures of power generation, transmission and distribution that needed to be integrated within the urban fabric (Hughes 1984, 7). The architecture of the power station, transmission lines and substations emerged as visible markers of the conveyance of this otherwise invisible resource, with the substation acting as a major component for neighborhood integration. These power systems carried national symbolism and scale as depicted in the electrification of the Cushman Substation. In 1925, the current president Calvin Coolidge remotely switches on the power project for the first time (Figure 3). The regional infrastructure is depicted with the Cushman Dam as well as the Cushman Powerhouse One serving as visual icons of the system.

As Thomas Hughes describes in his book *Networks of Power*, this infrastructure and architecture of power required the most advanced "technical, economical, and scientific aspects" of the current society that constructed them.

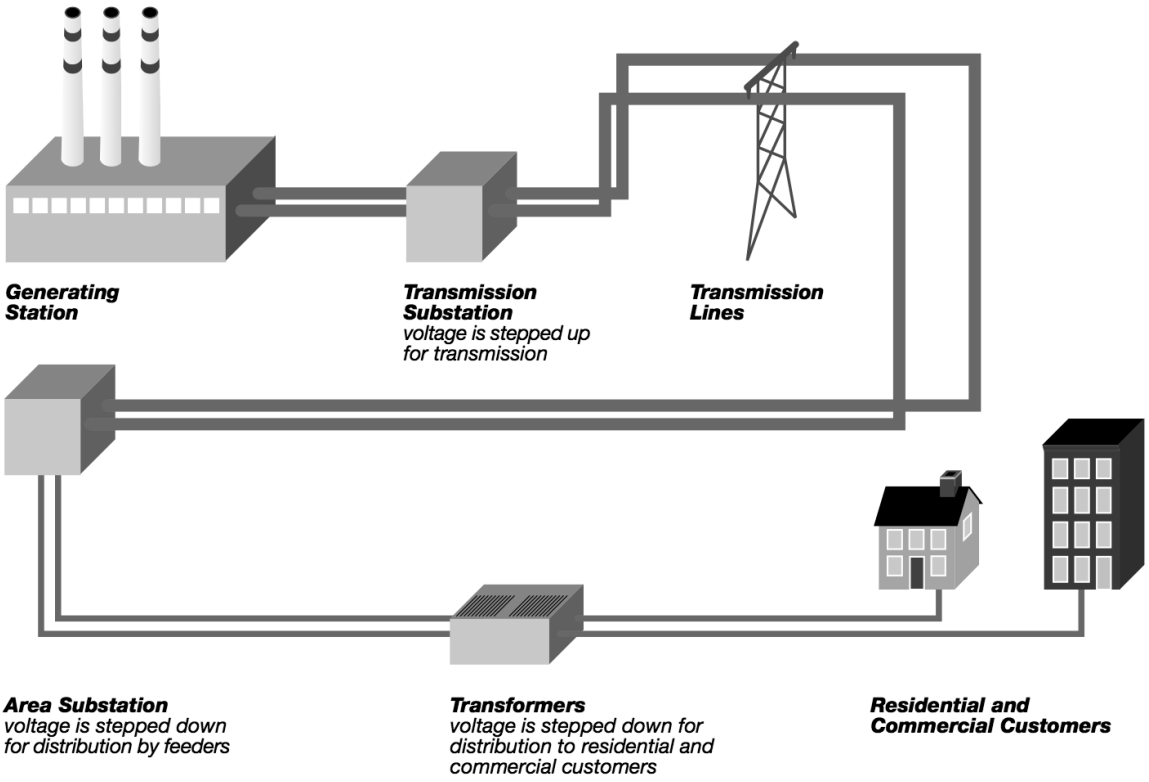


figure 6. con edison electric generation to customers

 figure 7. pylons at seal beach, ca 1936, will connell

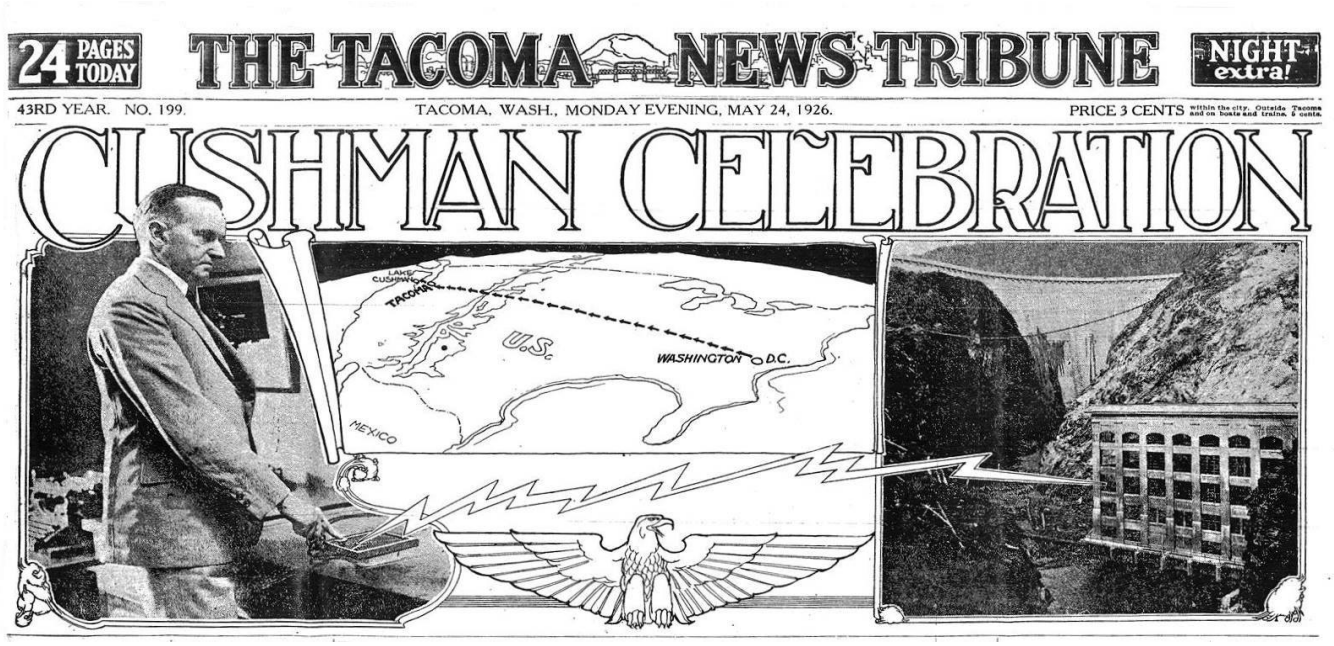


figure 8. the tacoma news tribune, cushman celebration, 1926

Transmission towers emerge as highly efficient lattice structures for suspending high voltage cables. The engineering of materials and systems for the design of infrastructure is a complex science. These systems transform the landscape into visible landmarkers for distribution of an invisible resource at a regional and local scale.

As a result, power stations and substations emerge as an architecture of power. In addition, the urban substation emerges with an architecture to reflect the electrical achievements through monumental style. The electrical substation also exhibits the engineering needed for these types of projects and infrastructure.

As Thomas Hughes describes: High voltage power is a necessity for long distance transmission but otherwise is too powerful for practical use, and as a result creates a tension by the attempts to integrate it within urban fabric (Hughes 7).

During the 1930s, motifs used in the ornamentation of power buildings illustrated the power and abundance of this resource such as in the Edison Commonwealth Substation exterior design; reinforcing the idea that civilization has become an expert in harnessing and deploying such a powerful resource. As a triumph over the natural occurrence, these expressions directly reflected the achievements of the power system.

 figure 9. commonwealth edison substation chicago, holabird and root 1931

In addition, the technology progressed, and required less of an architectural response for the building. These substations feature a new type of technology of Mercury-Arc Rectifiers that did not require the design for mechanically and manually oriented substations of the 1920s.

By the 1960's substations were even more compact and nondescript, with the advent of silicon technology, as well as remote control. There was an even further transition from the earlier manned substations, creating less of an opportunity for architectural design, substations become decorated boxes or complete non descript (Payne 2002, 25).

The architecture of these substations represent an urban synthesis of civilization's achievements and the importance placed on electric power systems. In the late 1990s, Christopher Payne Documented the New York substations that survived from the 20th century. The substation component in particular was used to convert the high voltage electricity needed for long distance transmission from the generation source, into manageable and usable electricity (Figure 6). This step in the system also allows for capacity and flexibility in meeting supply and demand for specific times.

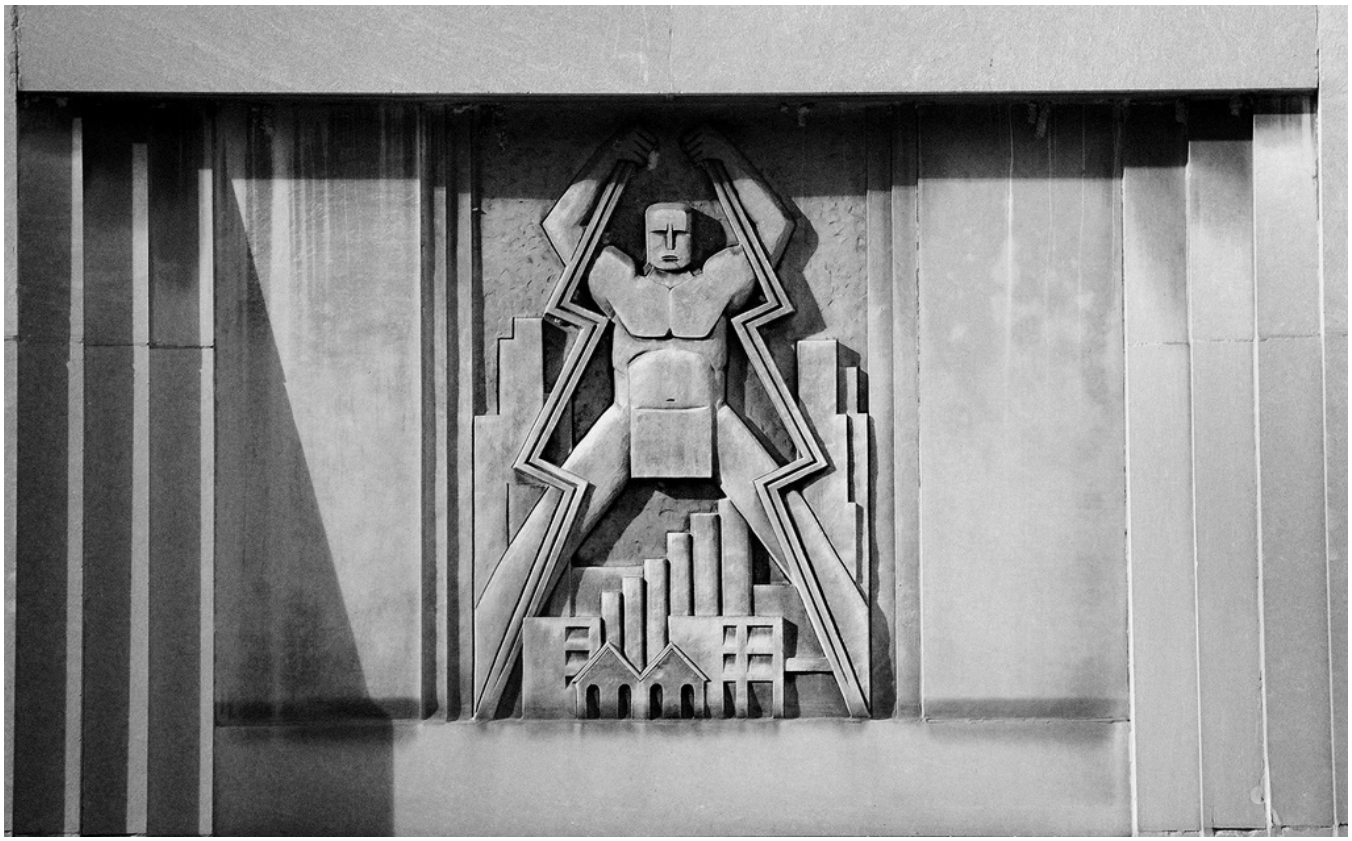


figure 10. sylvia shaw judson, the spirit of electricity 1931

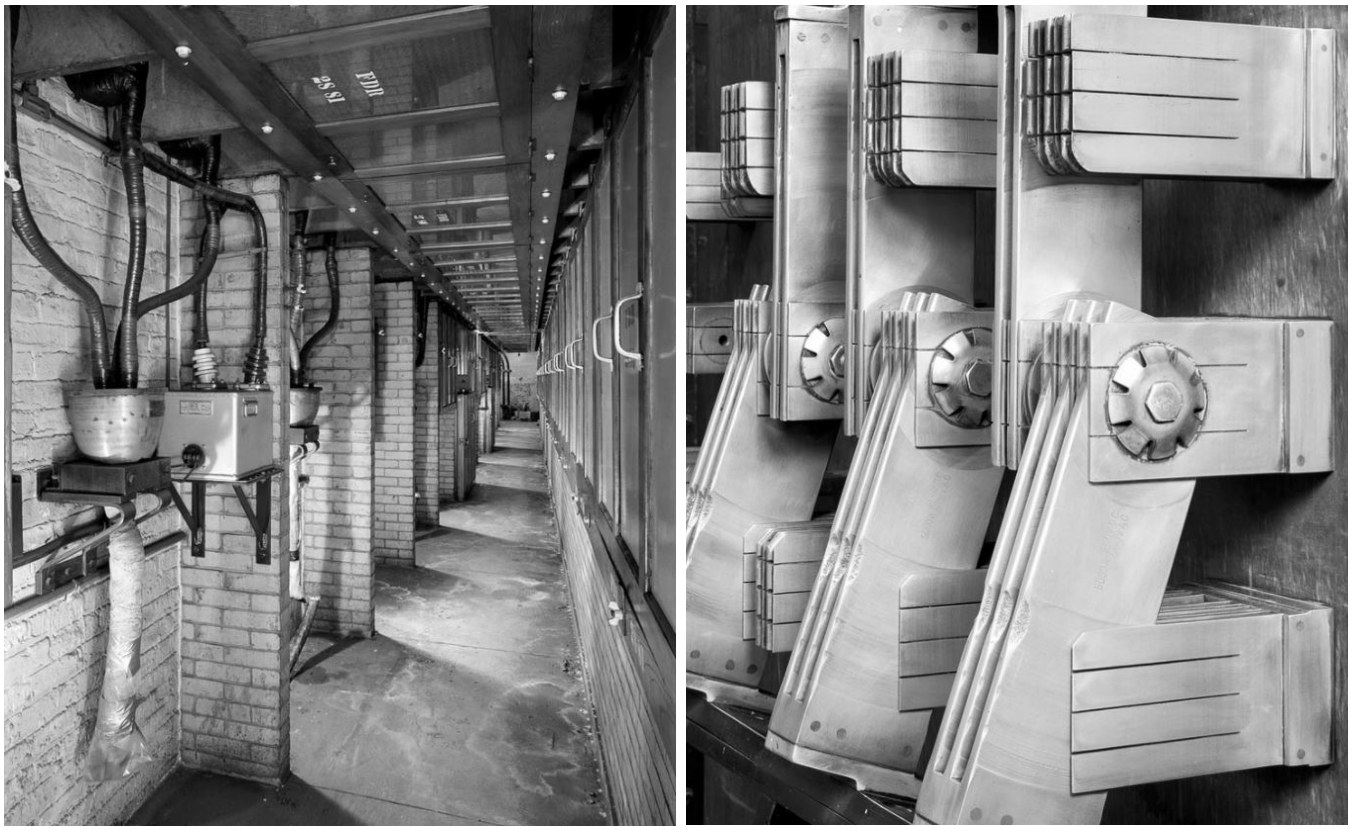


figure 11. 1920s electrical substations, new york, christopher payne

In addition, the need for human control resulted in substations with an interior program dedicated to the monitoring of electrical operations and components of the system, and the highly variable characteristics of the electricity (Payne 2002, 19). The switchyard is the first stage in stepping down the power before reaching the building. Here the stepping down before distribution to users occurs.

It was the most expressive of the system to pedestrians because of its presence in highly populated urban and suburban environments. In addition, the infrastructure of the substation is very utilitarian, with large open spaces for management of gigantic mechanized components, and controlled space, for channeling of conduit; in some cases conduit cast into the structure itself.

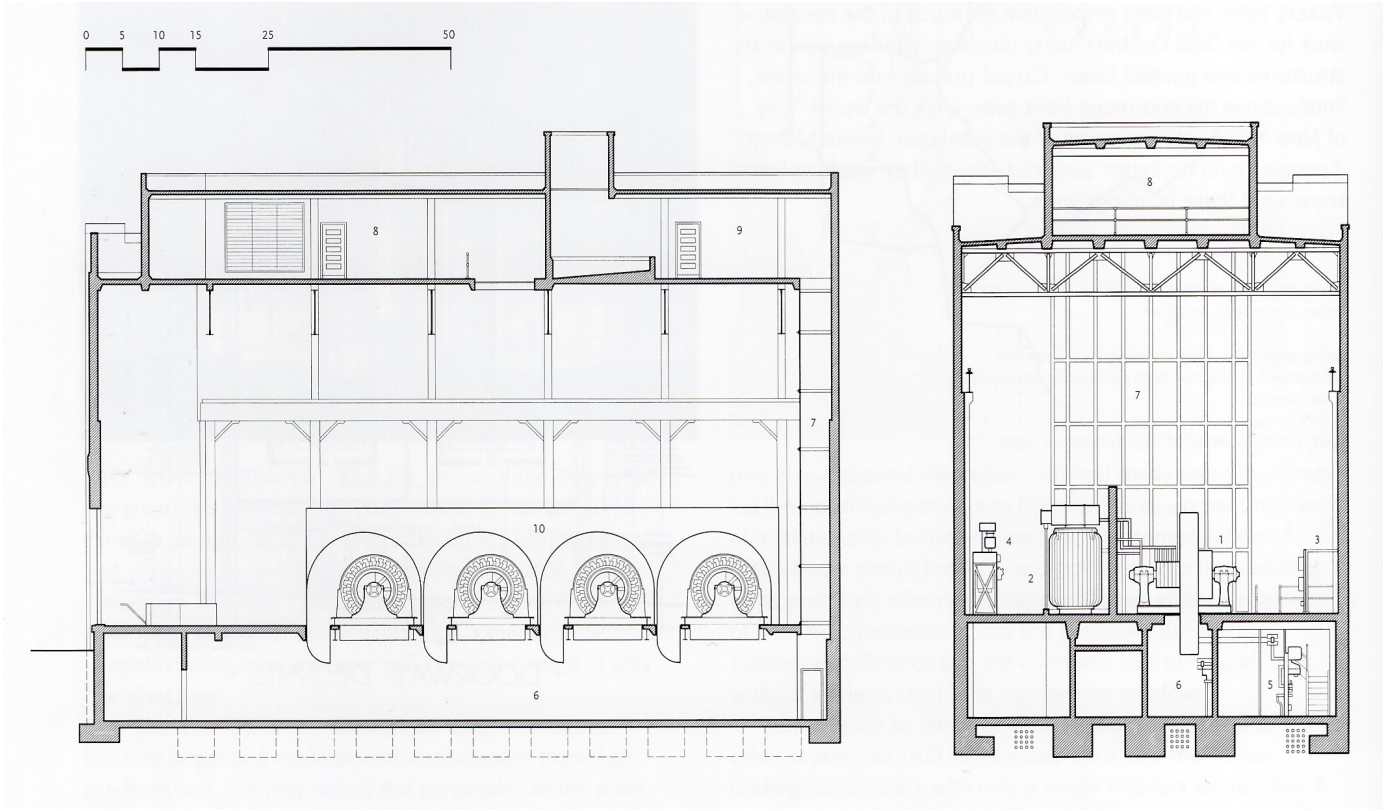


figure 12. 1920's electrical substations section, new york, christopher payne

 figure 13. cushman substation and steel lattice framework

The Electric City:
Tacoma Washington

The substation housed the means for efficient and economical distribution of electricity, which enabled the region to grow and expand and, therefore, made the Cushman Substation one of the most important and influential buildings of its time.

-Natalie K. Perrin

Beginning in the late 1800's and through the 1910's, the city of Tacoma began to increase at a fast pace due to the transcontinental link in 1883. To supply more power to the booming city, The Cushman Substation and Cushman Power Project, completed in 1926 is both a marker to the community but also represents investment and belief for a growing city. Located in one of the first Tacoma suburbs, the Proctor District, with its small business district, predominately single family residences, and the University of Puget Sound, the Cushman Substation Building and switchyard played a key role in the developmentof the area from 1926-1949, while the switchyard continued use at a certain level until 2017. By 2018, the Cushman Substation will be entirely decommissioned, leaving behind a system of components, and will no longer carry high voltage electricity (Perrin 2009).

Prior to the time of the substation, the Proctor Neighborhood benefiting from Allen C. Mason's efforts to develop the district with beautiful parks, boulevards, and roadways was a main attraction in marketing the City of Tacoma as the "City of Destiny" in 1910. The Proctor District of the north end became a desired suburb and alternative to living in the downtown area, with streetcar access (Gallaci 2008, 5). Much of the development was oriented towards downtown to the east. However, energy potential would come from the west, over 40 miles away at the Cushman Reservoir.

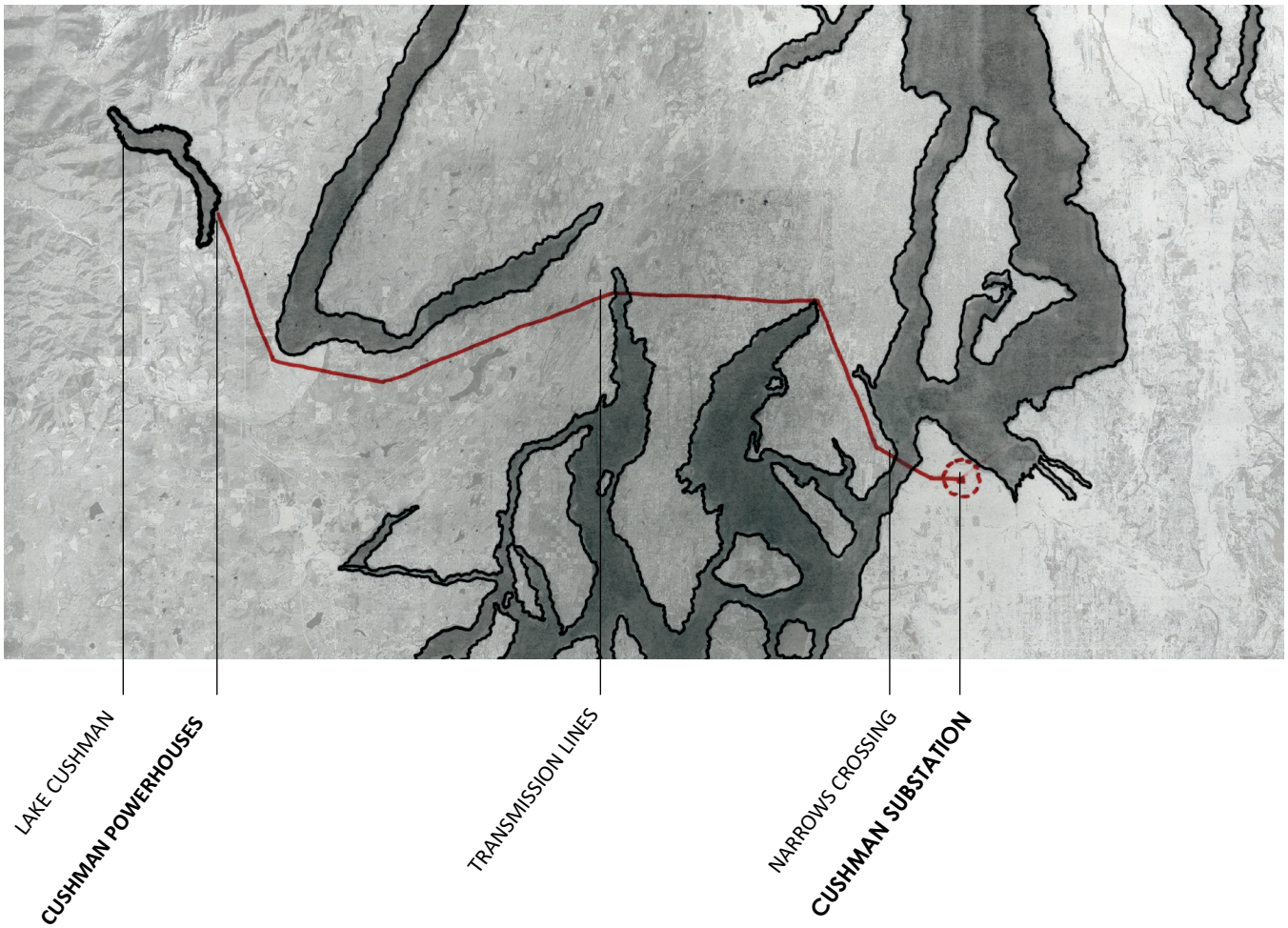


figure 14. cushman power project, region

The central location in the North End proved to be a practical location for the substation and distribution of power (Fig 14). Upon further development of the power project and owners, the City of Tacoma eventually became the operator of the project as a publicly owned resource, “Known for political Progressivism, the Pacific Northwest was at the vanguard of the reform movement to control utilities‘ cost and quality by placing them under public ownership. In the mid nineteenth century, most American cities awarded franchises to private utility companies. But reformers in the Progressive Party targeted the system‘s potential for graft, favoritism, and corruption.” (Perrin 7)

In the early 1920’s the Cushman Hydroelectric Project allowed Tacoma to provide some of the cheapest electricity rates in any city in the nation. Around this time, Tacoma was coined as “The Electric City” and the substation building aesthetic was designed to be an icon for this movement (Perrin 4).

figure 15. southeast aerial view cushman substation and neighborhood, 1963

Perrin reiterates that “The city‘s grand design for the Cushman No. 2 powerhouse exudes the sense of pride and progress felt by Tacoma City Light.” The neoclassical monumental architecture expresses the civic nature of the project, as a fundamental system for the city. The same analysis can be applied to the Cushman Substation (Perrin 6).

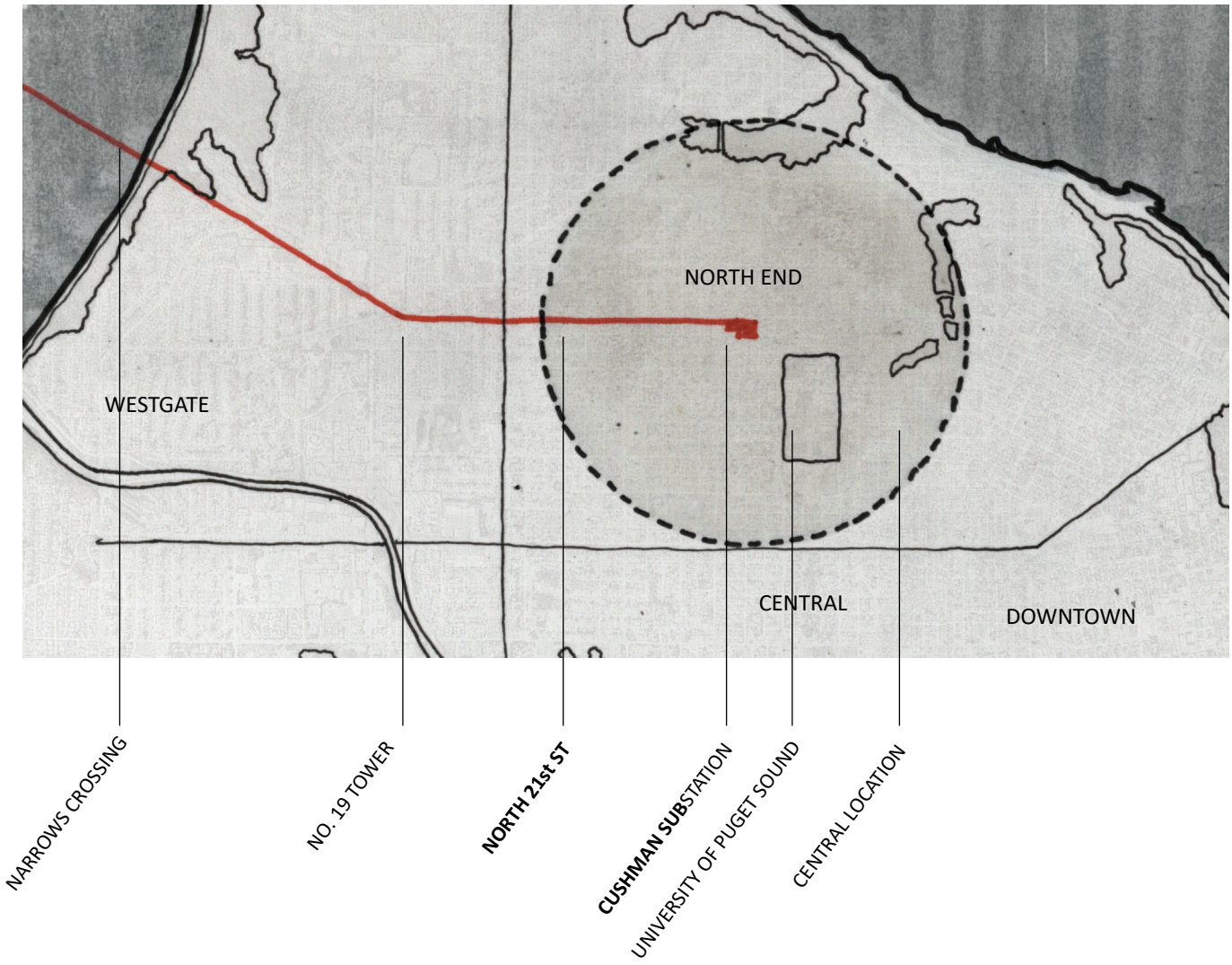


figure 16. cushman power project, original demand

With further development of Tacoma, in the 1960s control buildings lessened in importance. Large fields of electrical equipment on open sites proved to be more effective and efficient. Remote controlling allowed for the elimination of a building to house equipment and operators for the electricity management. In the case of the Cushman Substation, demand changed to accommodate more growth to the west of the north end resulting in the Pearl Street Substation, rendering the Cushman substation less critical for operations, beginning the transition to its obsolescence (Tacoma Public Utilities).Essentially, the concrete building and surrounding switchyard will be completely disconnected from the electrical grid.

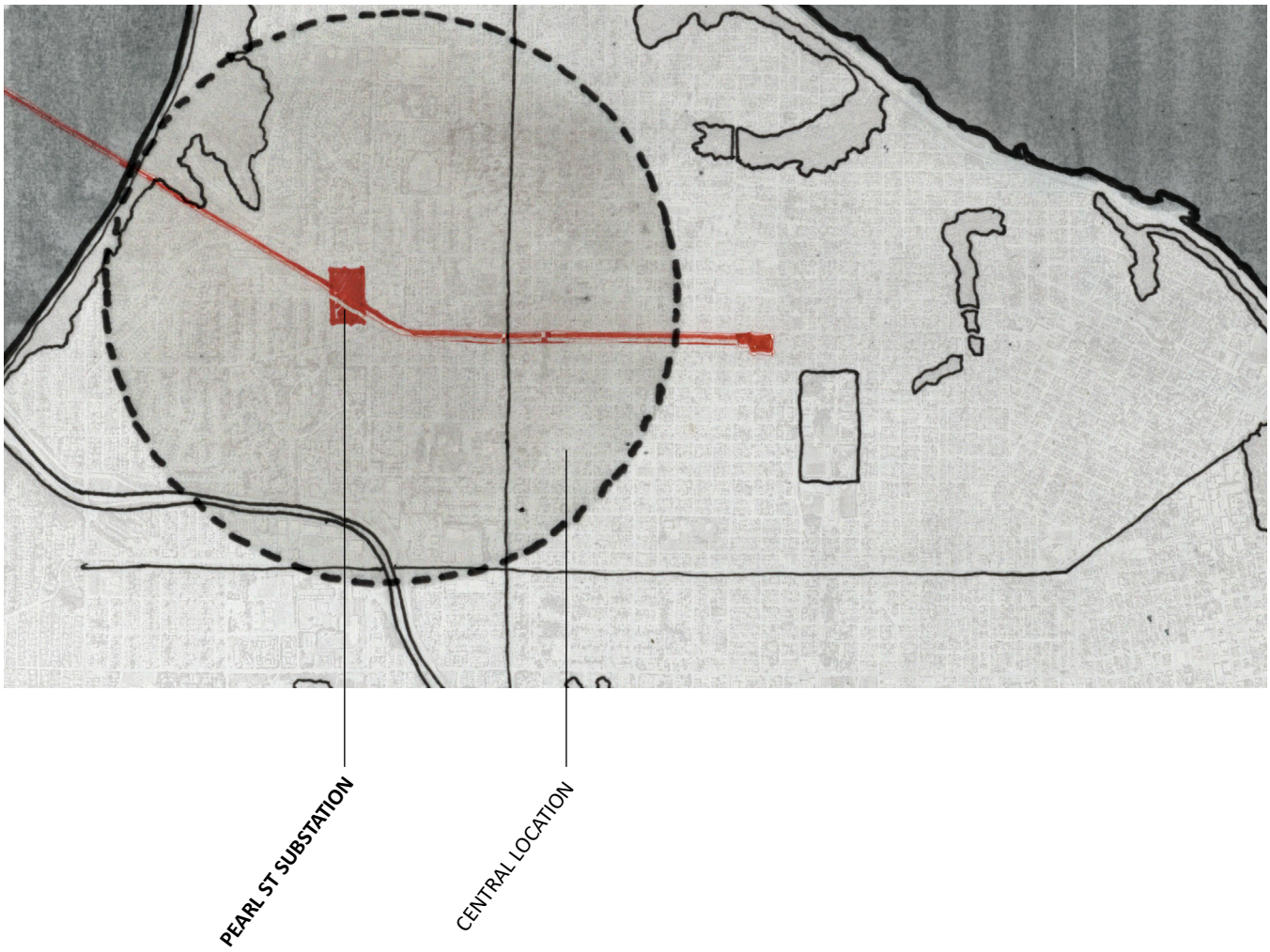


figure 17. cushman power project, addition of new substation

Although not originally a road for automobiles towards the west of the site, 21st St accommodates 16 towers that originally lead high voltage power into the substation site for distribution to the surroundings at a lower voltage. The actual substation project occupies not only a full city block but also an auxiliary quarter of a block adjacent to the main site on the west side (Figure 22).

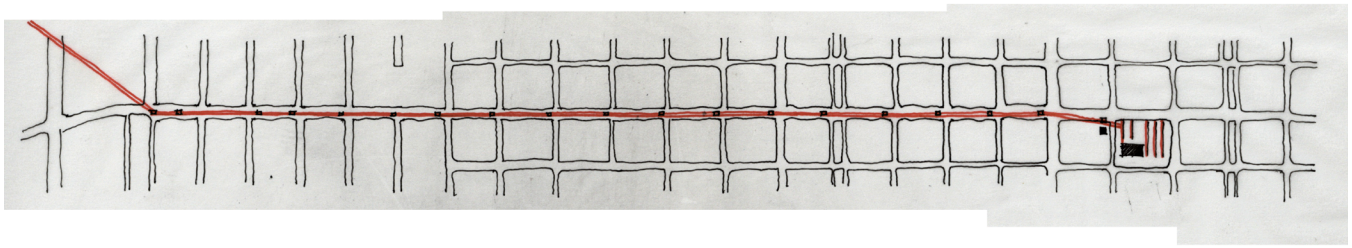


figure 18. cushman substation established

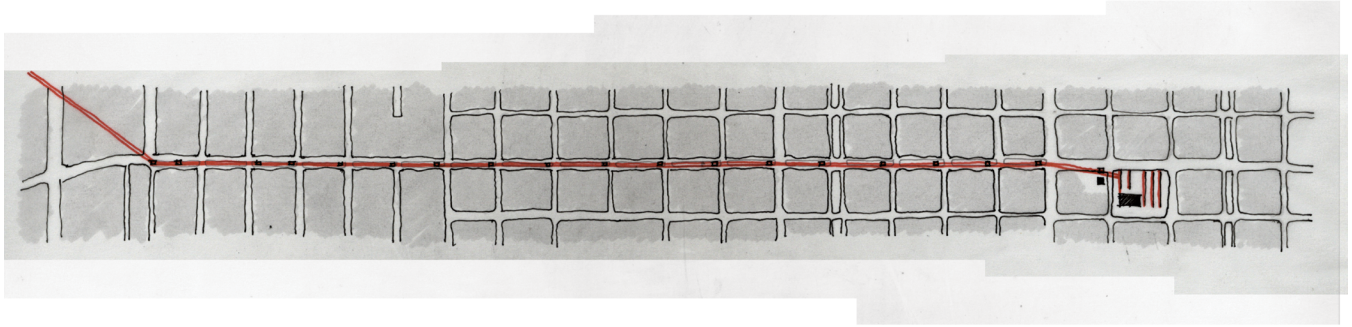


figure 19. neighborhood development in progress

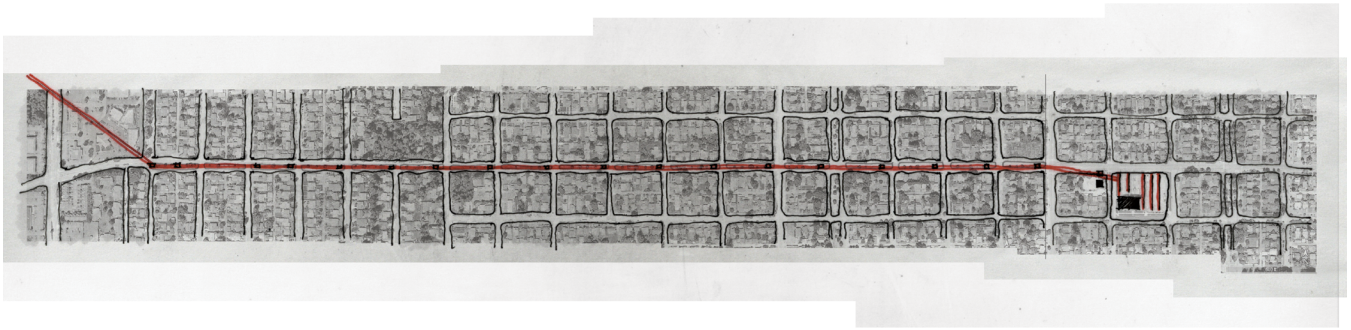


figure 20. full development

figure 21. change in high voltage lines

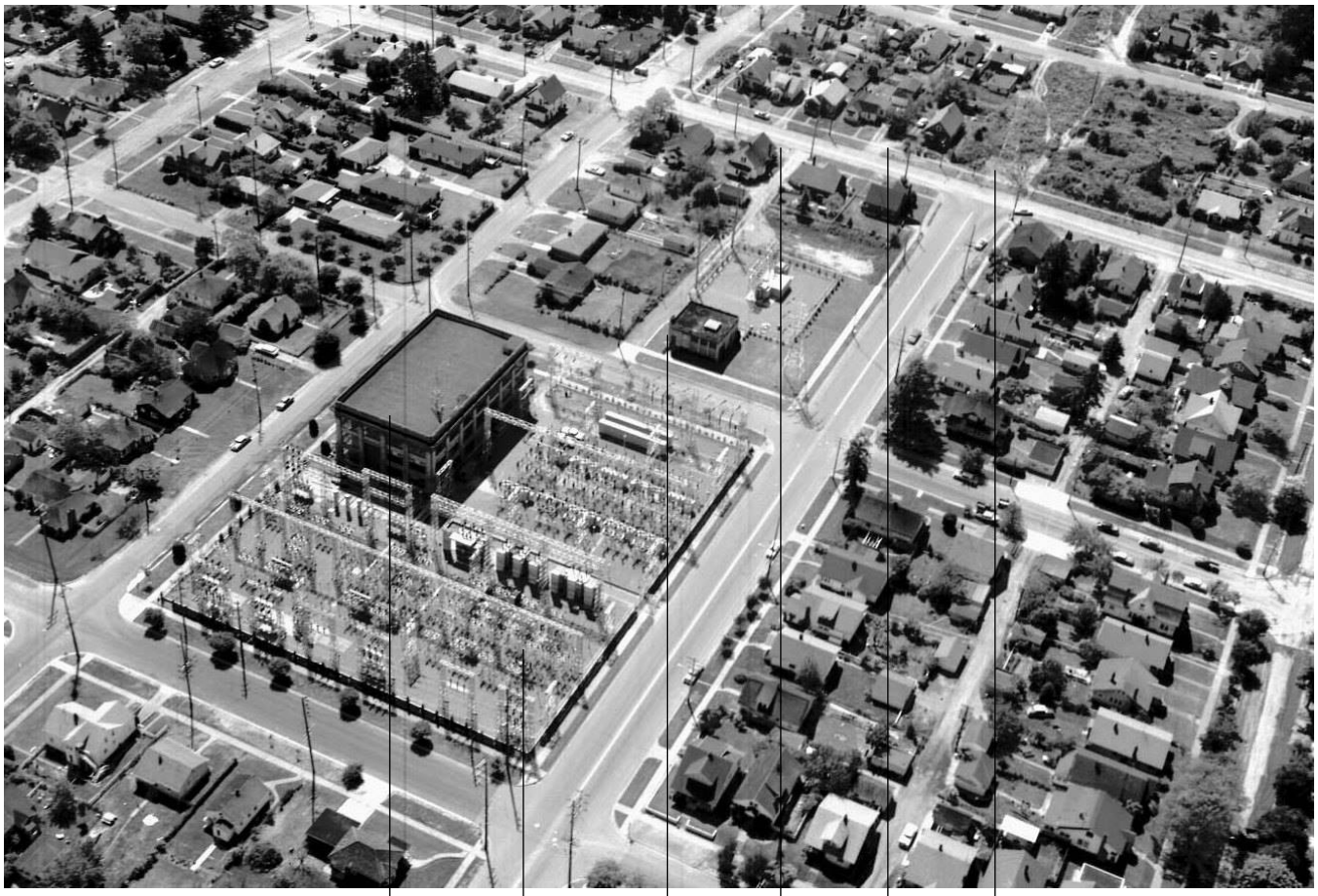


 figure 22. neighborhood development, early 1960's

figure 23. cushman substation components

Since its construction in 1925, the Cushman substation has always been much larger in scale than its surrounding fabric, and a noisy neighbor; reinforcing the fact that it supplied such a dangerous resource to its surroundings (Perrin 4). 21st street is currently a four lane road that accommodates the very large bases of the 1920s lattice style towers that rise to 75' in height, that becomes a major transmission corridor not only of electricity but also automobile traffic.

Approaching from the west side, the No. 1 tower is placed next to the sidewalk marking the start of the electrical integration to the substation. Originally oriented towards the major roadway at the time, 19th St, the front door of the substation does not face 21st St where one would expect it. The major switchyard actually serves as the dominant the main visual feature to the passerby, while the Classical substation sits further back on the southwest corner of the site. (Figure 23) While often seen as a work of engineering, the Cushman Substation stands as a monument of classical design.

 figure 24. high voltage transmission tower

Program

The program of the proposed project is the result of studying the substation as a specialized and unique building typology, including its specific central location. The spaces are formulated by merging the original intentions of the electrical power system, while infusing it with other innovative infrastructure related to emerging innovative electricity systems.

The program is anchored by a high-tech data and management space (occupying the original high voltage management space) which will receive data from the new energy system (Luminescent Solar Collectors). This system will allow for expansion of the Tacoma Solar Sharing Program; the community can take part in owning segments of the system, and while receiving financial incentives for the energy produced. The exterior program includes outdoor space designed around the original switchyard infrastructure, while implementing landscaping for multi-purpose public space. Overall, this progam allows for the re-generation of the site through physical energy, while also including the public.

Program Components:

Infrastructure:

solar boulevard

Public:

multi-use park

condenser room exhibit space

Operations: data and management space,

panel storage and maintenance space

 figure 25. existing infrastructure, lattice framework

Design Approach

An in depth study and documentation of existing infrastructure was primarily used to begin the design approach. This included an analysis of the power flows, beginning with North 21st street, leading to the Cushman Substation site, and finally distributing to the neighborhood. The original power flow infrastruture relied on steel lattice frames, with suspension of insulated high voltage connections and wiring, as well as a variety of electrical components.

Essentially, the towers carry high-voltage-power lines 19 blocks along 21st street into the site. The towers are highly visible, three-dimensional lattice type structures with broad medians to accomodate the bases. The high voltage lines are fed onto the switchyard where the steel lattice structures and attached components allowing for wiring to be directed to either bypass the substation (to be directed to area substations for further distribution) or directed to the switchyard infrastructure for stepping down. From there, the electricity is directed beneath the site and into basement tunnels of the substation that connected with the integrated conduit of the monolithic concrete structure.

The large condensers received the high voltage where it is stepped down further and held as capacity for feeding back out to the switchyard; from there it is distributed at appropriate voltages to the surounding neighborhood for the end user.

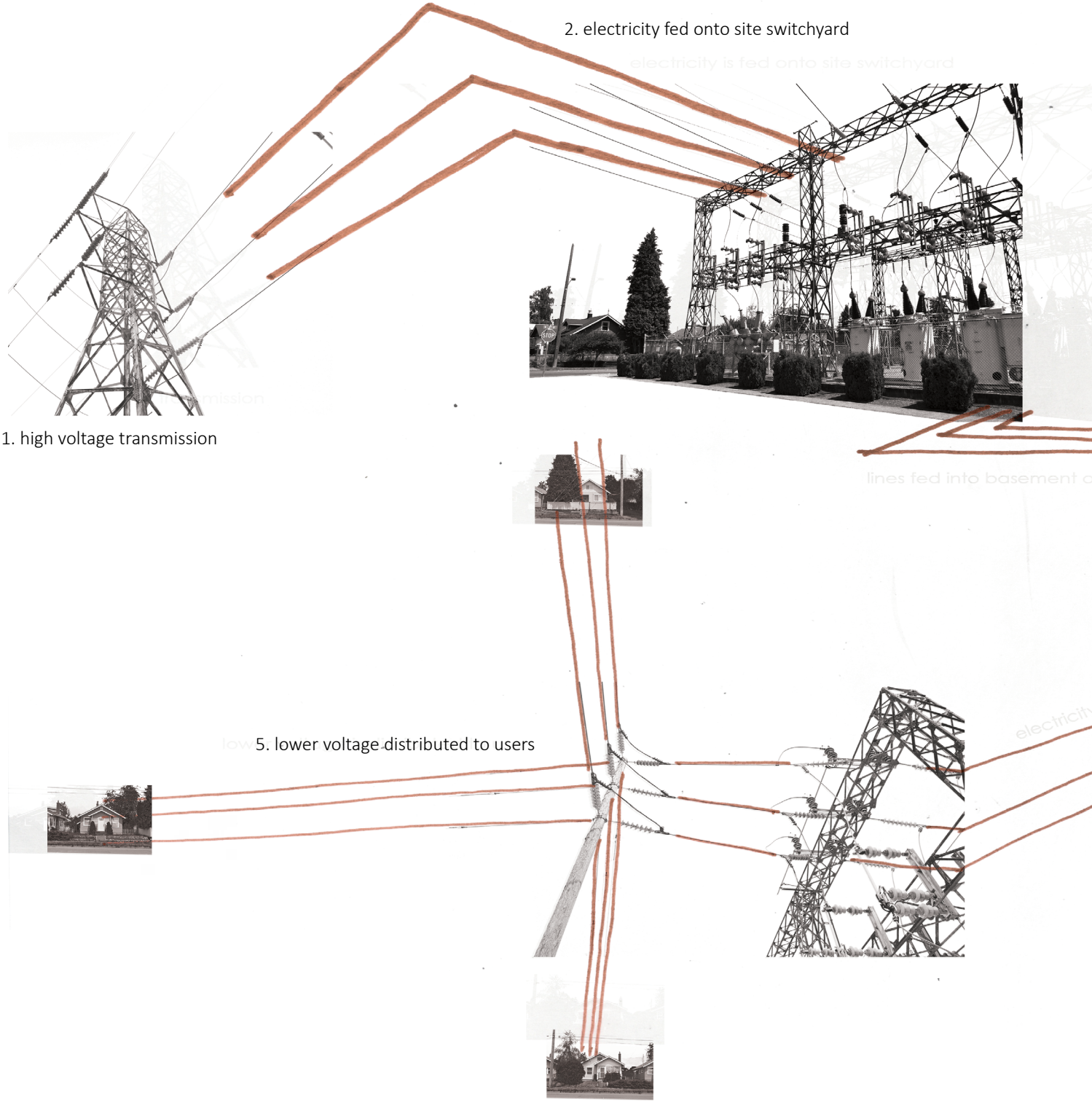
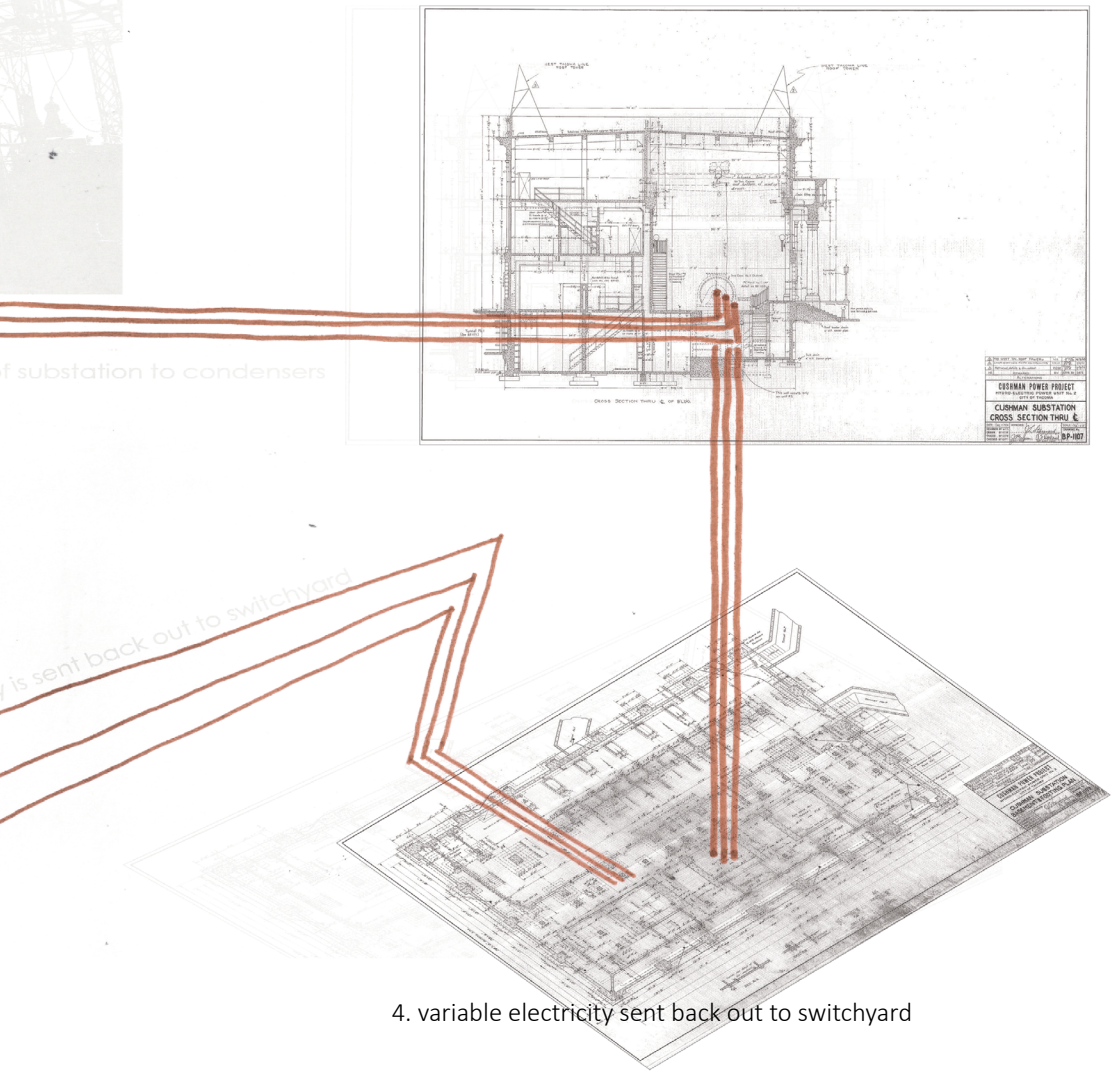


 figure 26. electrical site flows

3. lines fed into basement of substation to condensers



4. variable electricity sent back out to switchyard

figure 27. cushman substation and switchyard 1926

figure 28. cushman substation condenser room 1926

figure 29. existing steel lattice frames w/ original electrical components

Essentially, removing the high voltage electricity, as a result of the change in demand and obselecence of the site. The implementation of low voltage energy sources allows for a site now accessible to the public, while still retaining a level of electrical infrastructure.

Seeking to re-energize this site physically, in order to continue the inherent utility and structures of the site and meaning, this thesis looks to energy generation technology. The proposal makes use of the existing lattice and their inherent capabilities of supsending linear elements with other components. This leads to a potential intervention that provides energy in the form of linear components capable of being suspended. In addition, this thesis looks to enhance a system that is highly visible, as a way to promote the project as a central location that can influence its surroundings.

This system would be the beginning of a alternative means of energy different from hydropower. The intent is to creating more resilience and backup for a predominately hydroelectric system which is currently 89% of Tacoma's electricity resource, and also supplement resources from infrastructure not owned by the city (TPU). There are several alternative means of energy production, one of which is solar power.

Traditional photovoltaic panels have been a popular way to capture energy when applied to commercial and residential rooftops.

figure 30. traditional photovotaic panel

However, it could be argued that this solution is somewhat constricted to these applications only, while also being relatively expensive. Above all, the use of traditional PV panels is a generic response, limited in aesthetic quality, and therefore is mostly employed to be hidden on rooftops, limiting its expressiveness in the built envrionment. Along with the un-attractiveness, the panels are often heavy, and must be oriented in one consistent direction.

figure 31. the luminescent solar collector, a2 highway, the netherlands

In the same way material technology development responded to the advent of electrical systems, this thesis looks to emerging technology; the goal is to retro-fit with a once innovative structure of steel lattice frames.

One emerging technology, is the Luminescent Solar Collector. It has been undergoing intensive developments by different groups, all with the main goal of making the photovoltaics more efficient and therefore reducing cost. But above all, the intent is to make these installations, and thus widening the application in the built environment.

These groups developing this technology include Michigan State University, Ubiquitous Energy, and Eindhoven University of Technology. A response to the cost of PV cells, this solution employs a dyed molecule lightweight plastic panel which captures ambient and direct sunlight, then reflects the light within the panel, and directs a magnified light to the edge, where the PV is located and recieves the light. The PV then manifests itself as a small area of a thin strip, opposite to traditional PV where the whole panel is PV and recieves light directly from the sky. (Rhodes 2015)

Because the panel is much better at capturing ambient light, its direction and orientation is less rigid, and is targeted for regions with less direct sunlight throughout the year.

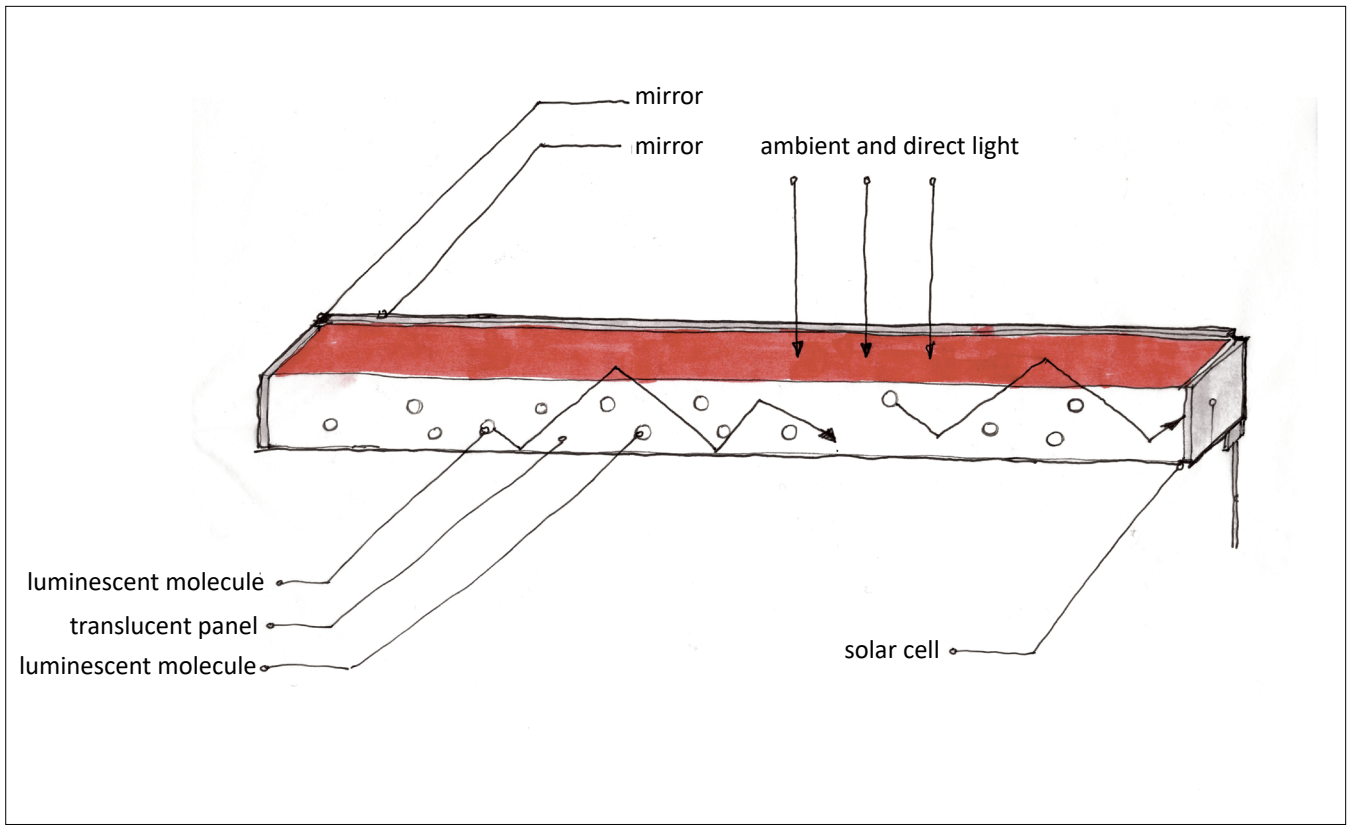


figure 32. the working principle of the luminescent solar collector, exaggerated depth

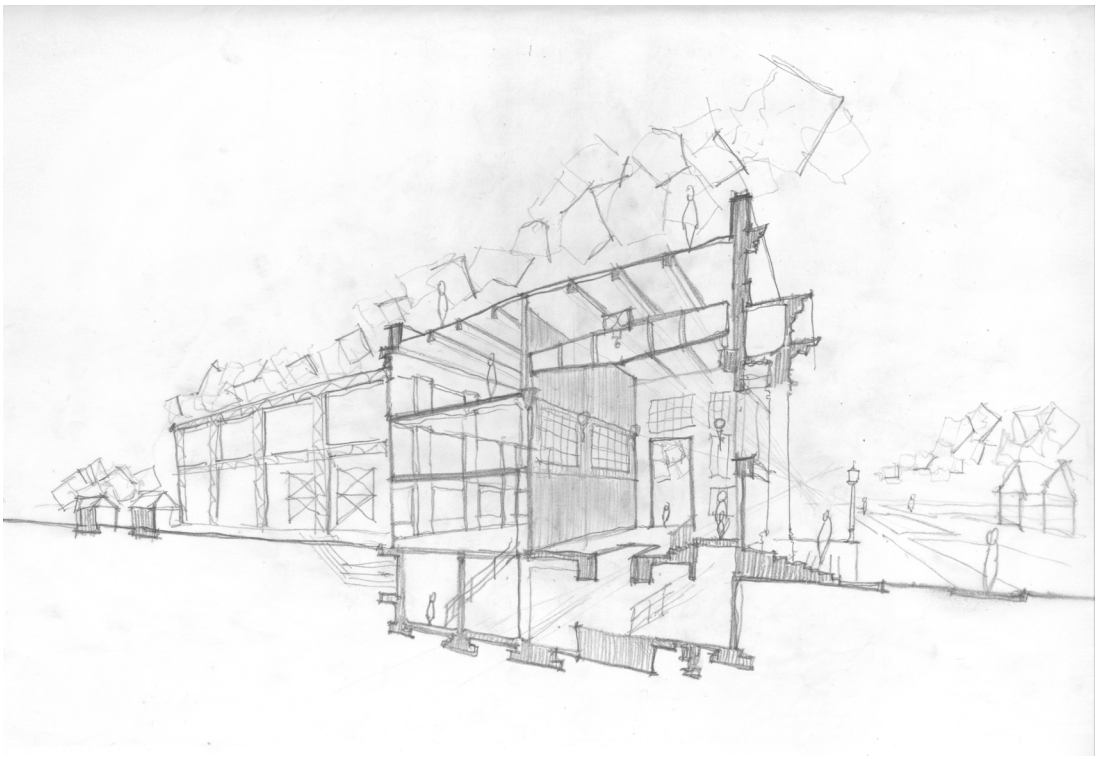


 figure 33. concept sketch

Design Response: Cathedrals of Power

Electric power systems embody the physical, intellectual, and symbolic resources of the society that constructs them

-Thomas Hughes

The visitor to the new energy center at the Cushman Substation can reach the site in a variety of ways, such as on foot, by bus (public transit bus stop a block away), or by car. The proposed intervention on 21st st is highly visible and guides the visitor towards the substation site. A series of towers with translucent red panels act as a solar boulevard, expressing the new technology, while simultaneously marking the original transmission corridor. The visitor is guided along the street until nearing the substation site.

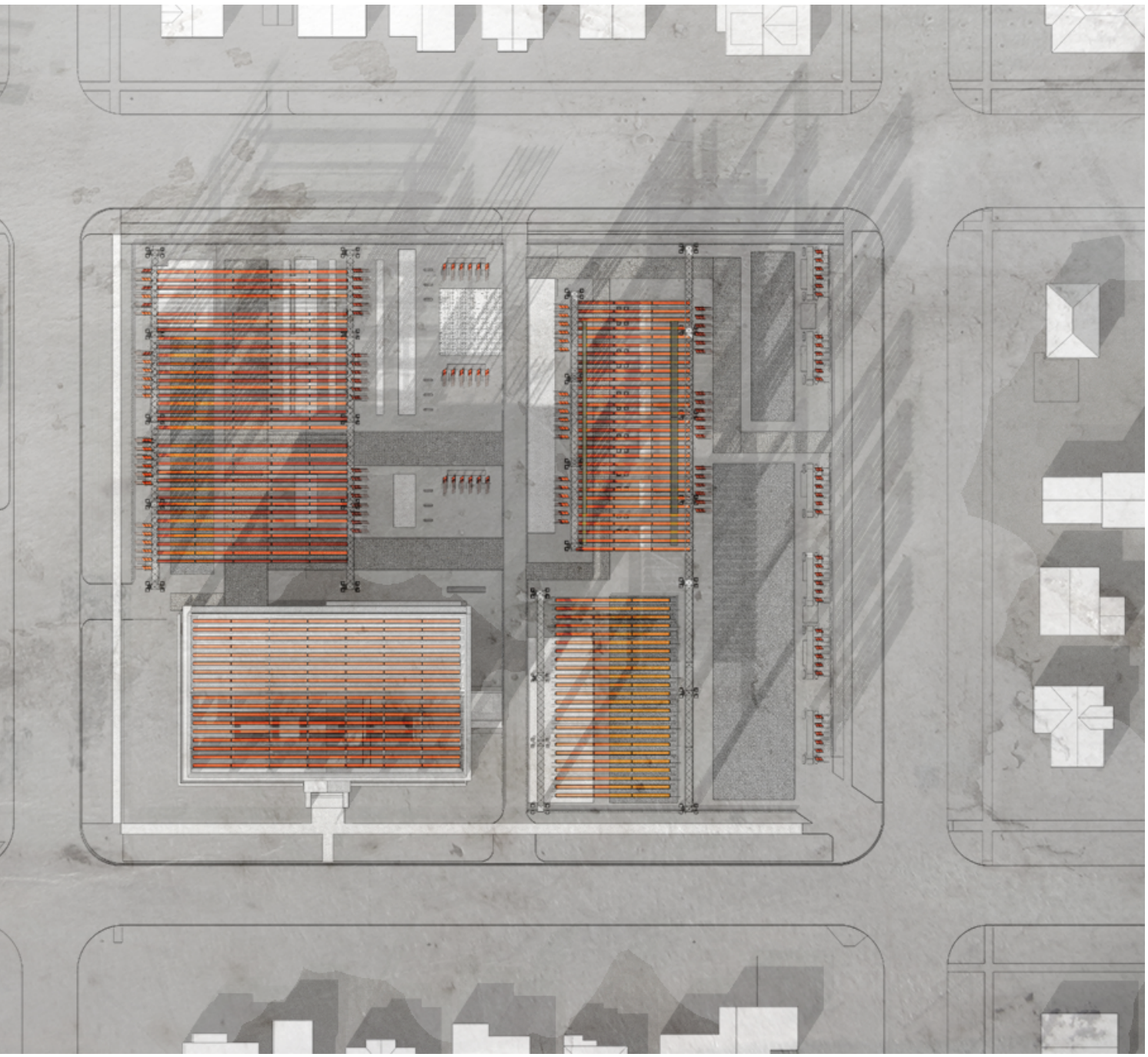
Each former landmark of the old electrical system is retained to lead the user into the site, incorporating new elements, while enhancing the old power flows. The new intervention of translucent luminescent solar collectors brings new life to the site, as the new public space reveals and expresses itself as the user approaches the site. The Cushman building is visible overlooking the back of the site serving as a fundamental support component for the project. The site is arranged with a main entry off of 21st street with the main circulation through the center of the site, that once was the main utlity path.

The new technology paired with the old trellis framework creates a variety of public spaces, shaped by the skeletal-like frames and illuminated by the translucent panels. The predestrian has the ability to meander and explore the workings of infrastructure, in this newly formed public space.

 figure 34. arrival to the site


N 21ST ST

 figure 35. site plan



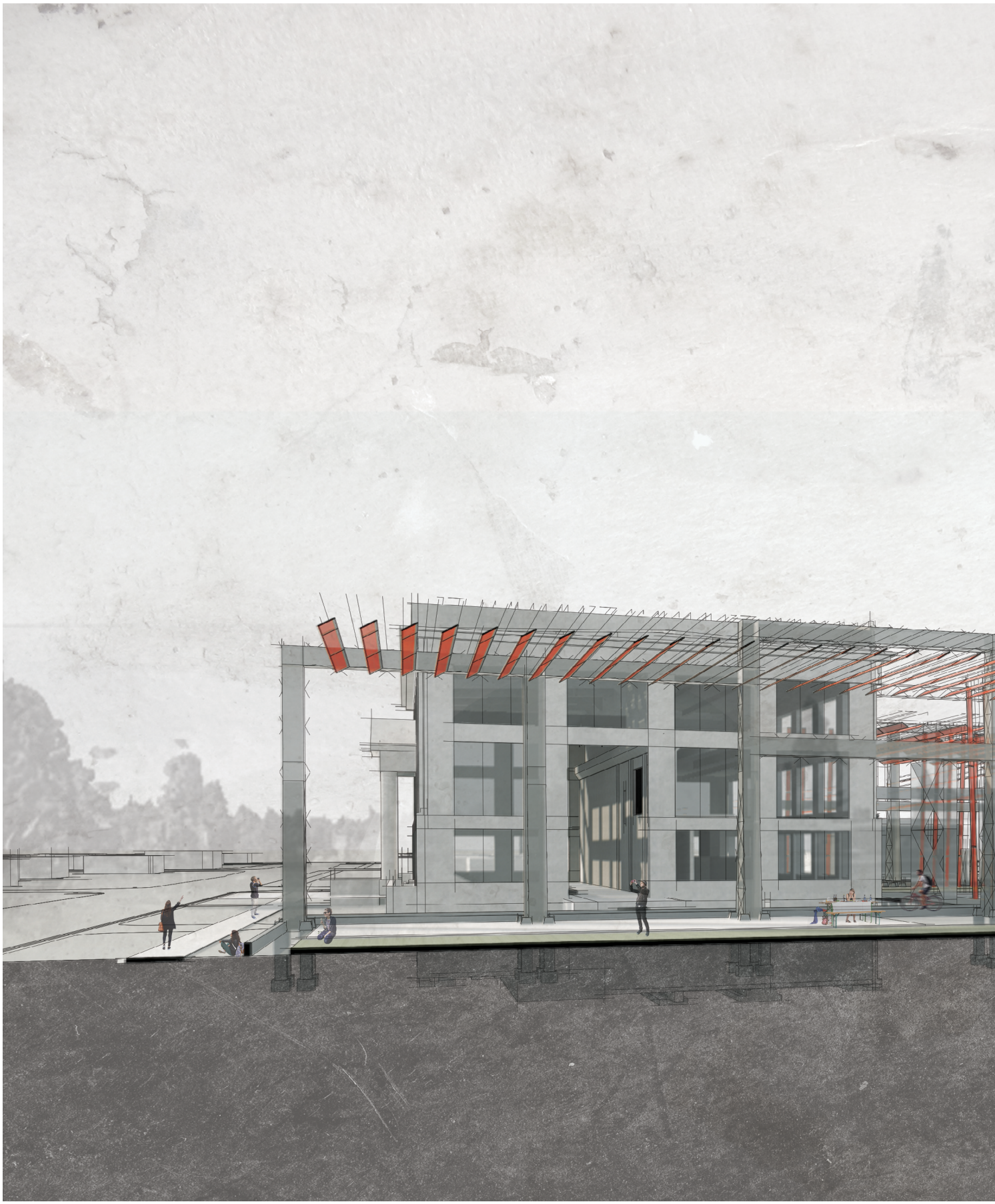


 figure 36. north-south section perspective

 figure 37. within the cathedral

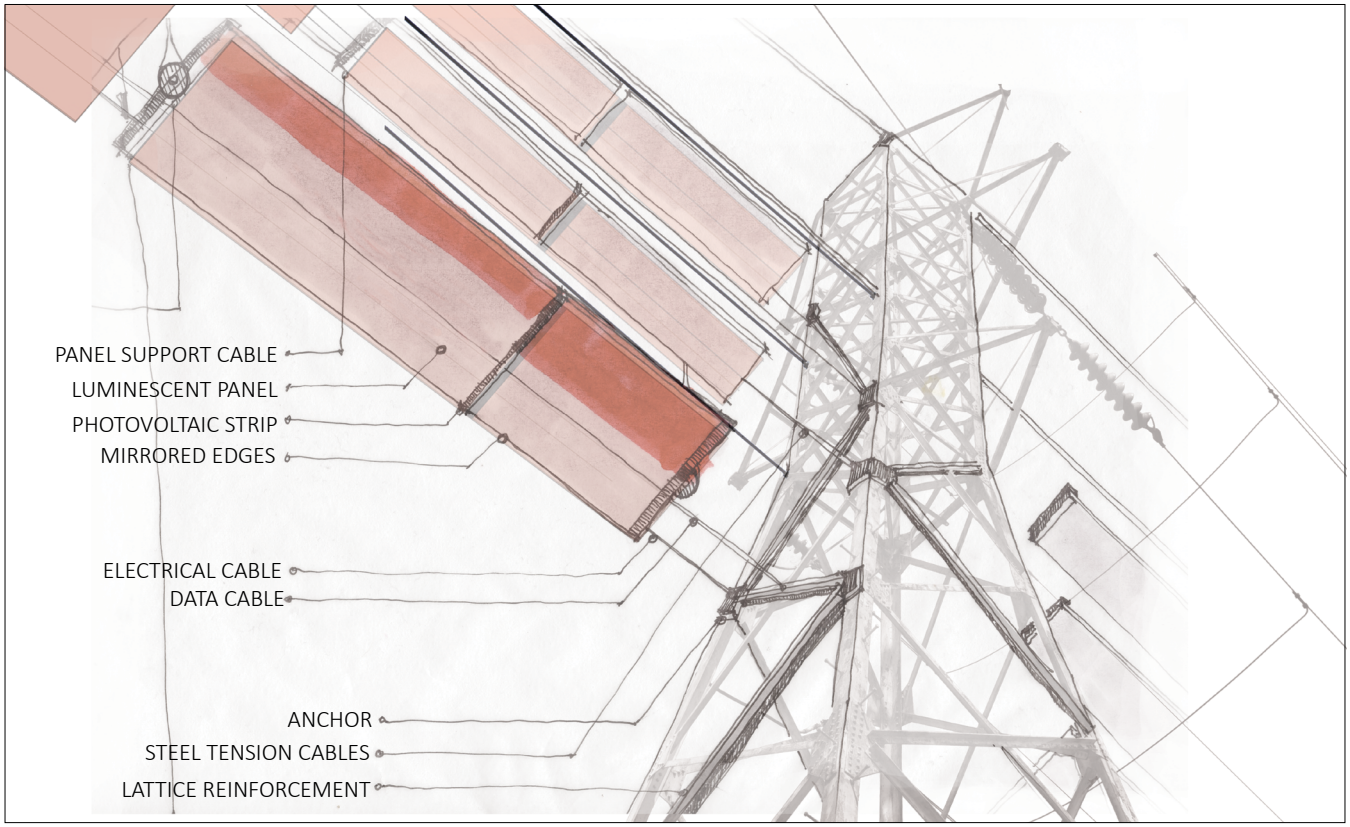


figure 38. luminescent solar collector, integration with lattice structure

The original steel lattice structures are fitted with new structural support members, while steel cable is strung between the towers. The new technology, Luminescent Solar Collectors are suspended from the cables with the ability to be oriented in multiple directions.

Data wiring sends information to the Cushman substation, including the energy generated by the panel and its specific location and orientation. Power generated by these panels is spread throughout the grid in a way to maximize efficiencies, while members of the solar sharing program benefit from the energy generated, regardless of their own housing type or proximity to the panel location.

This new solar boulevard represents the influence of this new energy system at multiple scales and and the same time integrates with the existing infrasructure.

Overall, the intervention is intended to reflect the exterior switchyard equipment while adding new layers of infrastructure. The existing concrete piers and slabs on the groundplane are retained, while adding permeable paving and grass landscaping. The original engineering and ordered electical structures are complemented by simple pathways and landscape for leisure and activity.

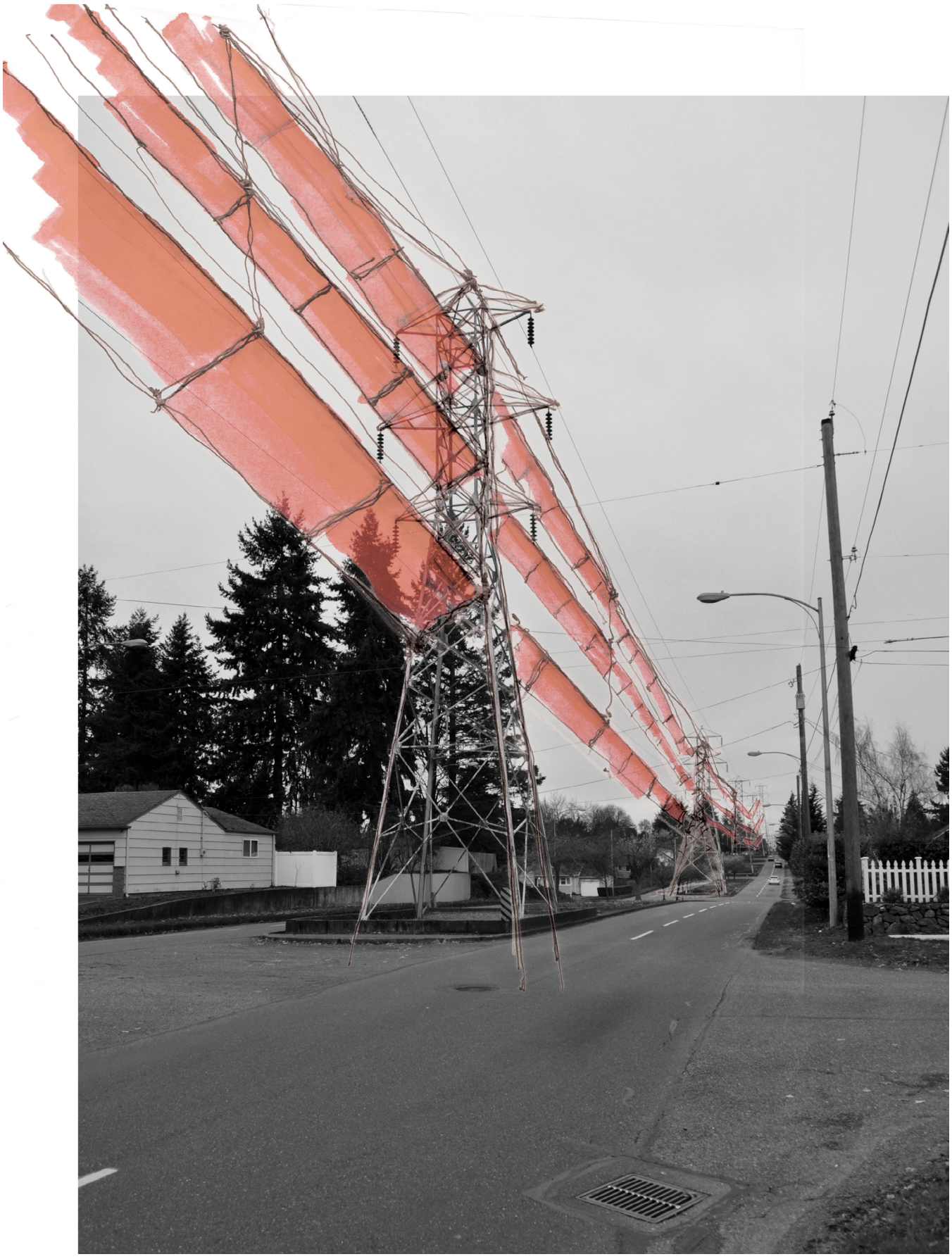


figure 39. solar boulevard

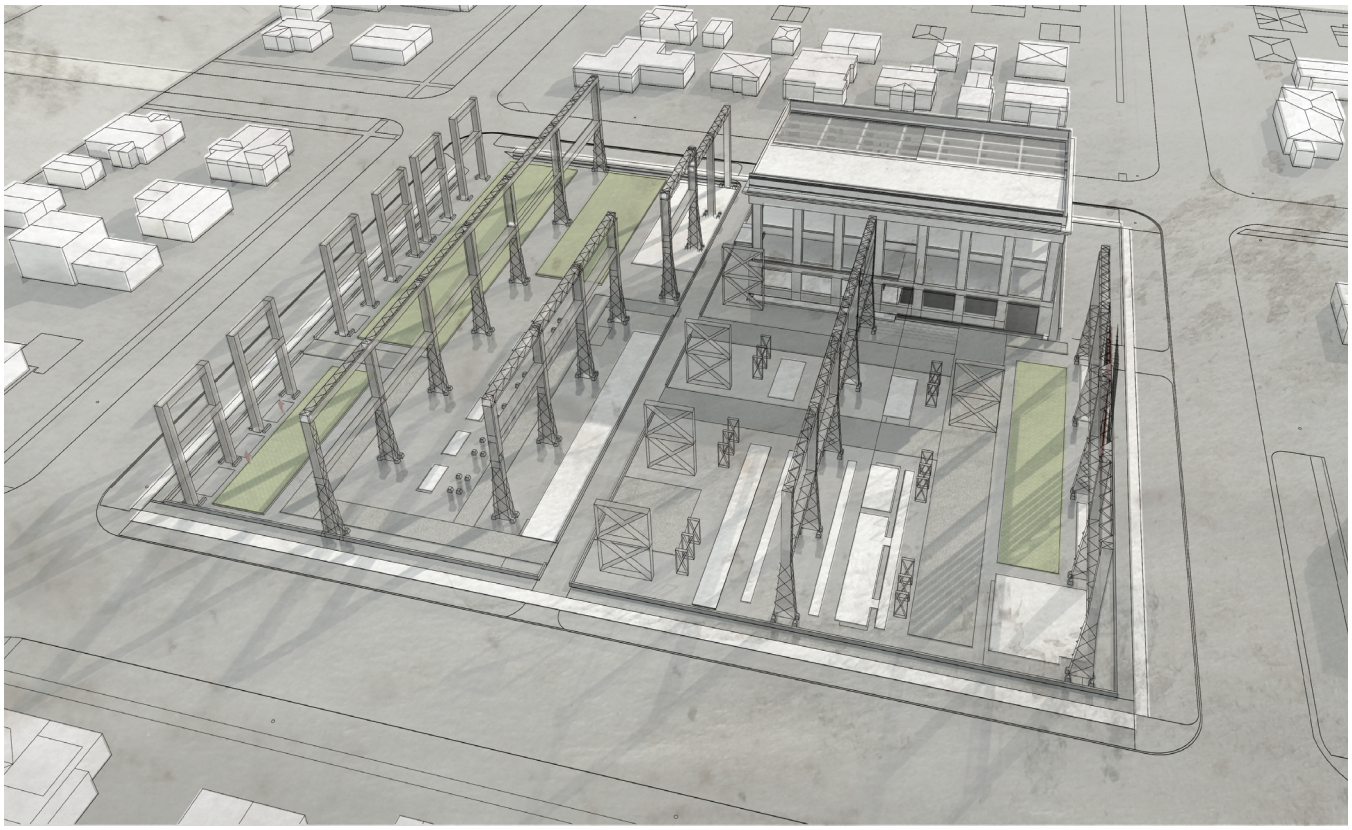


figure 40. public space integration with existing infrastructure

The suspension of panels on the framework is acticulated by filling out the original framework that divides the space into multiple *cathedrals* of varying scale and proportions. Contained within these spaces are sculpture galleries, multi-use activity spaces, and overall lesure spaces as park space, and for experiencing the new architeture.

The panel system is highly outfitted within the original swithayrd and clearly distinguishes itself in scale and architecture from the small scale residential surroundings.

The system also takes different scales in the form of small interventions within backyards and alleys, expressing how this sytem may spreading and influence the context over time. The integration of the solar sharing program, creating cohesion throughout the city with a new architecture of power aesthetic. The main condenser space of the old, paired with the new cathedrals, "serves as a visual icon and center to this new power generation, synthesizing the historic system in transformation to a new age", that expresses a newly collective community energy.

figure 42. application sketches

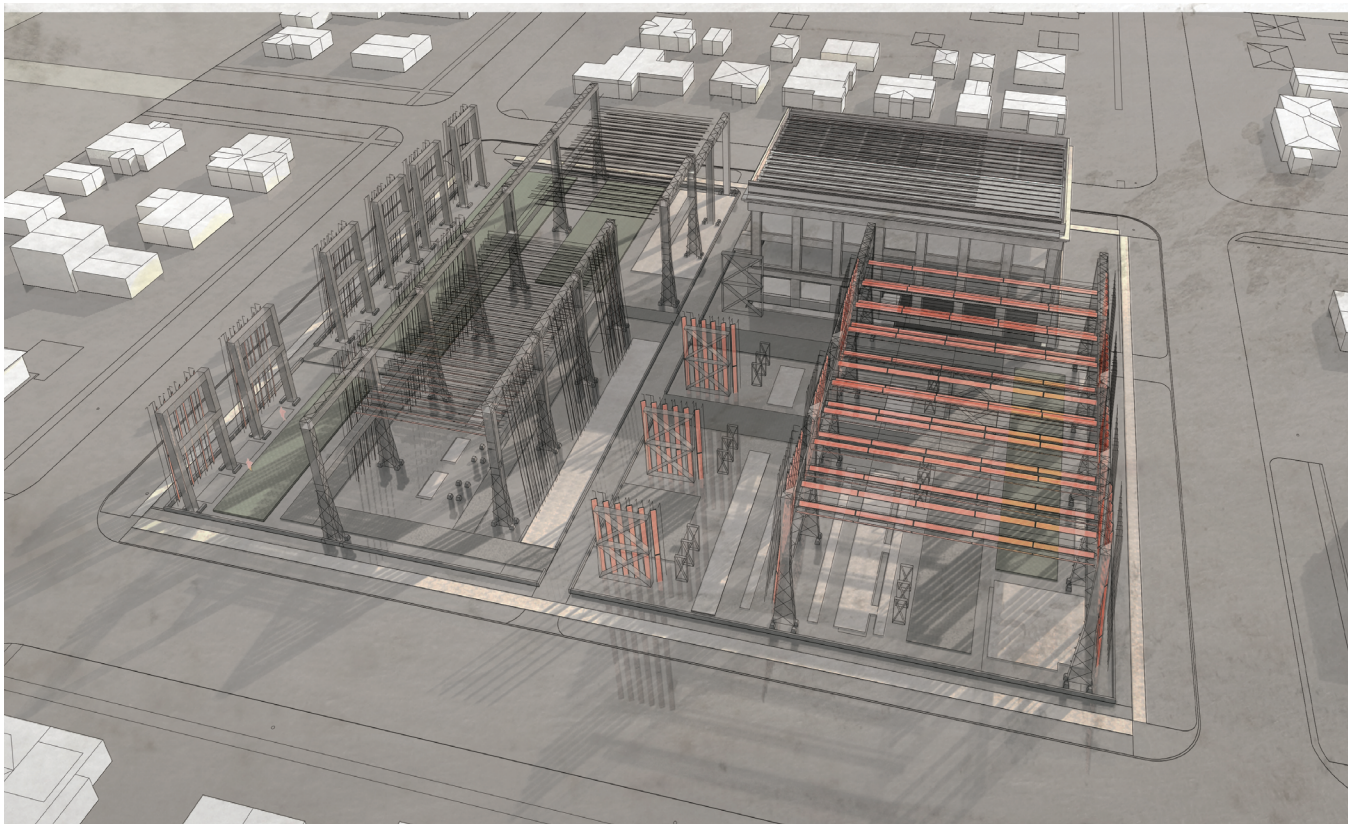
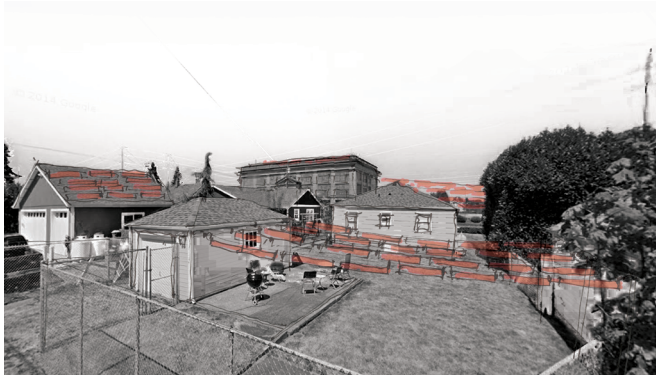


figure 41. integration of panel system



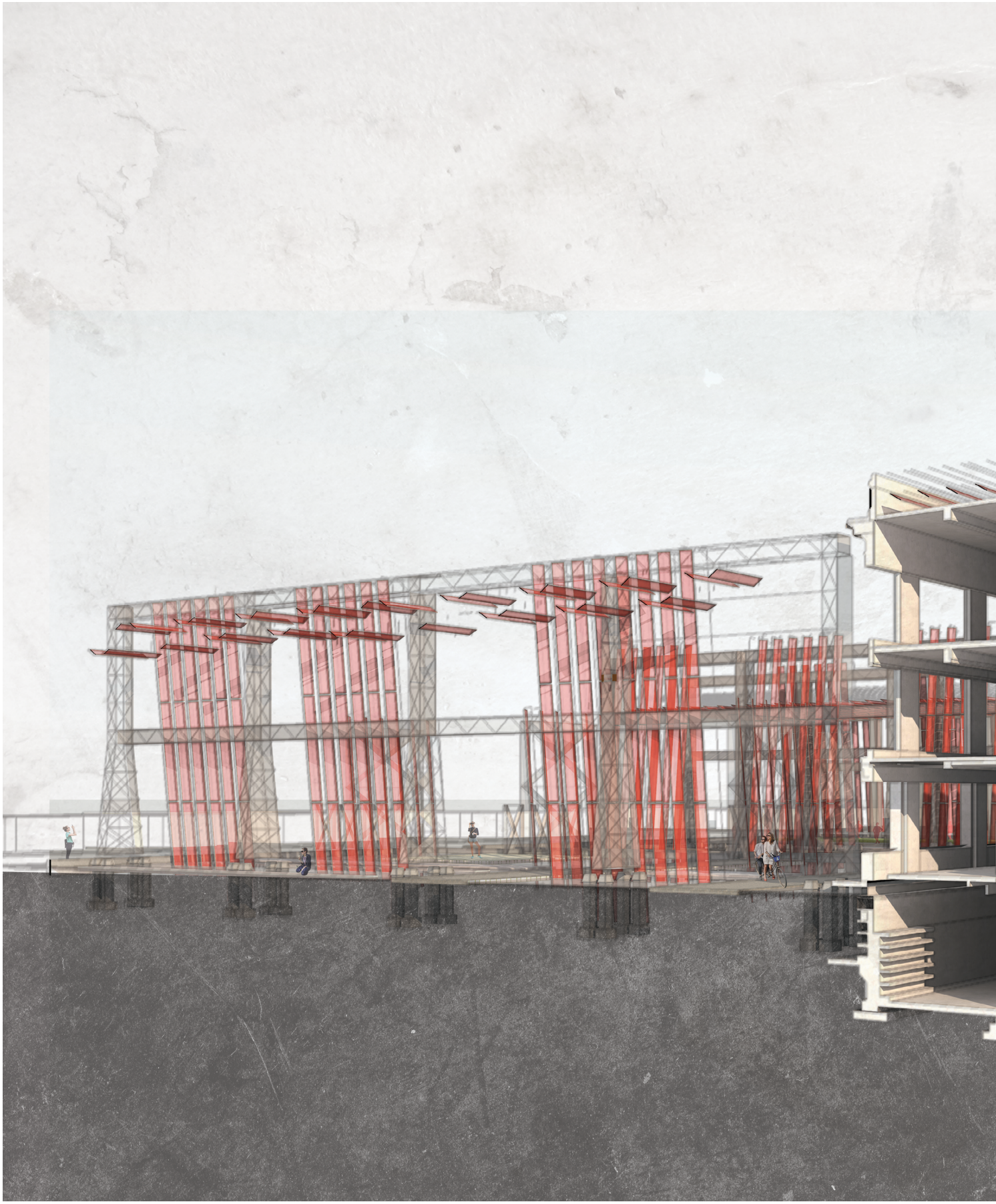


 figure 43. cathedrals of power, section through centerline of cushman substation

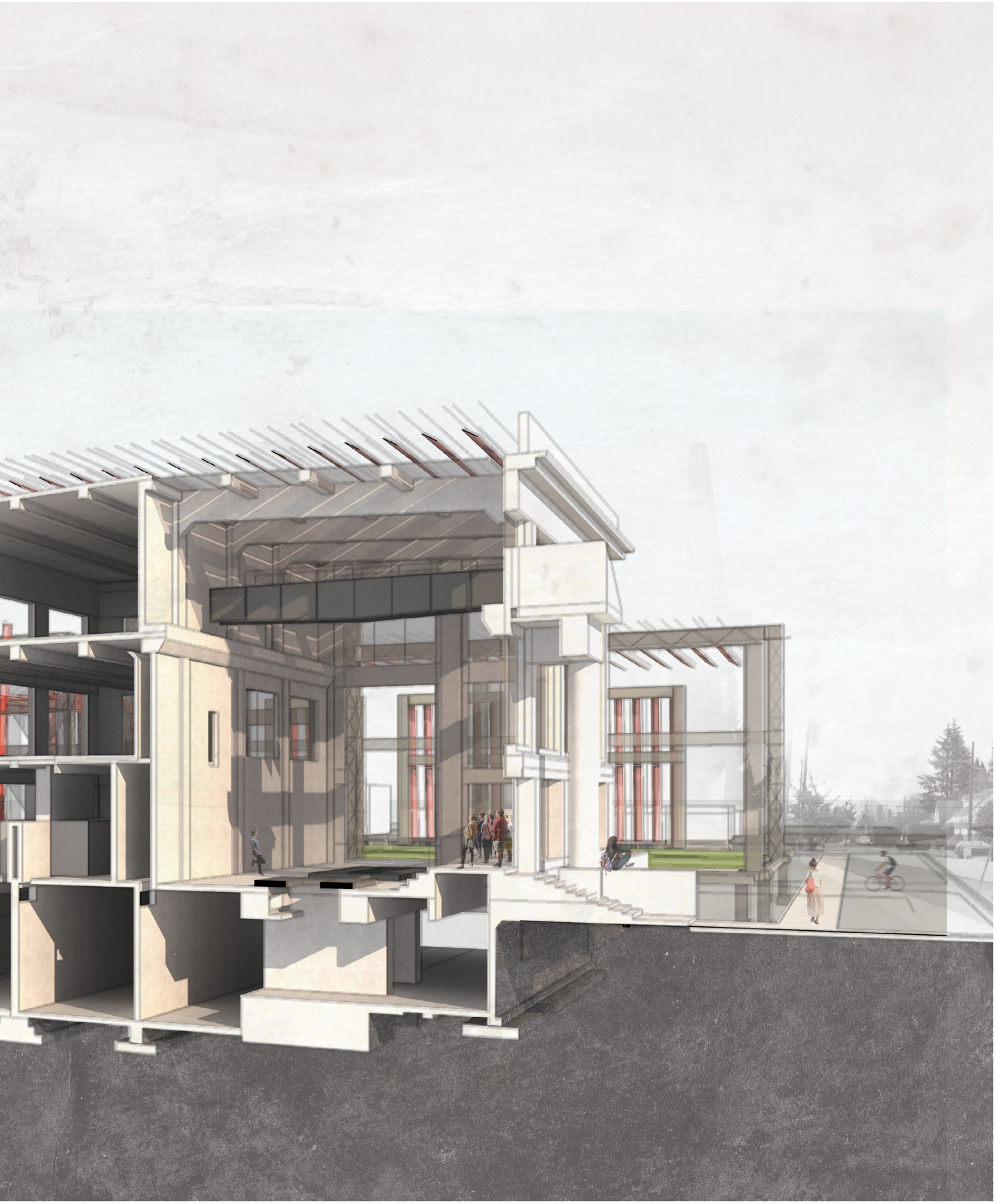


 figure 44. the cushman substation main entry

Reflection

The Cushman Substation and its associated infrastructure represents a specialized architecture originally intended for the interface of high voltage electricity in the city of Tacoma. The transition to disconnection from the grid, leaves behind an infrastructure without electricity. This project offers much potential for the implementation of alternative energy sources as a way to continue the legacy of power supply. This thesis proposes typology for the electric power system, demonstrated by a new architecture that at the same time connects with the history of the site and celebrating its own time period of iconic civic power design.

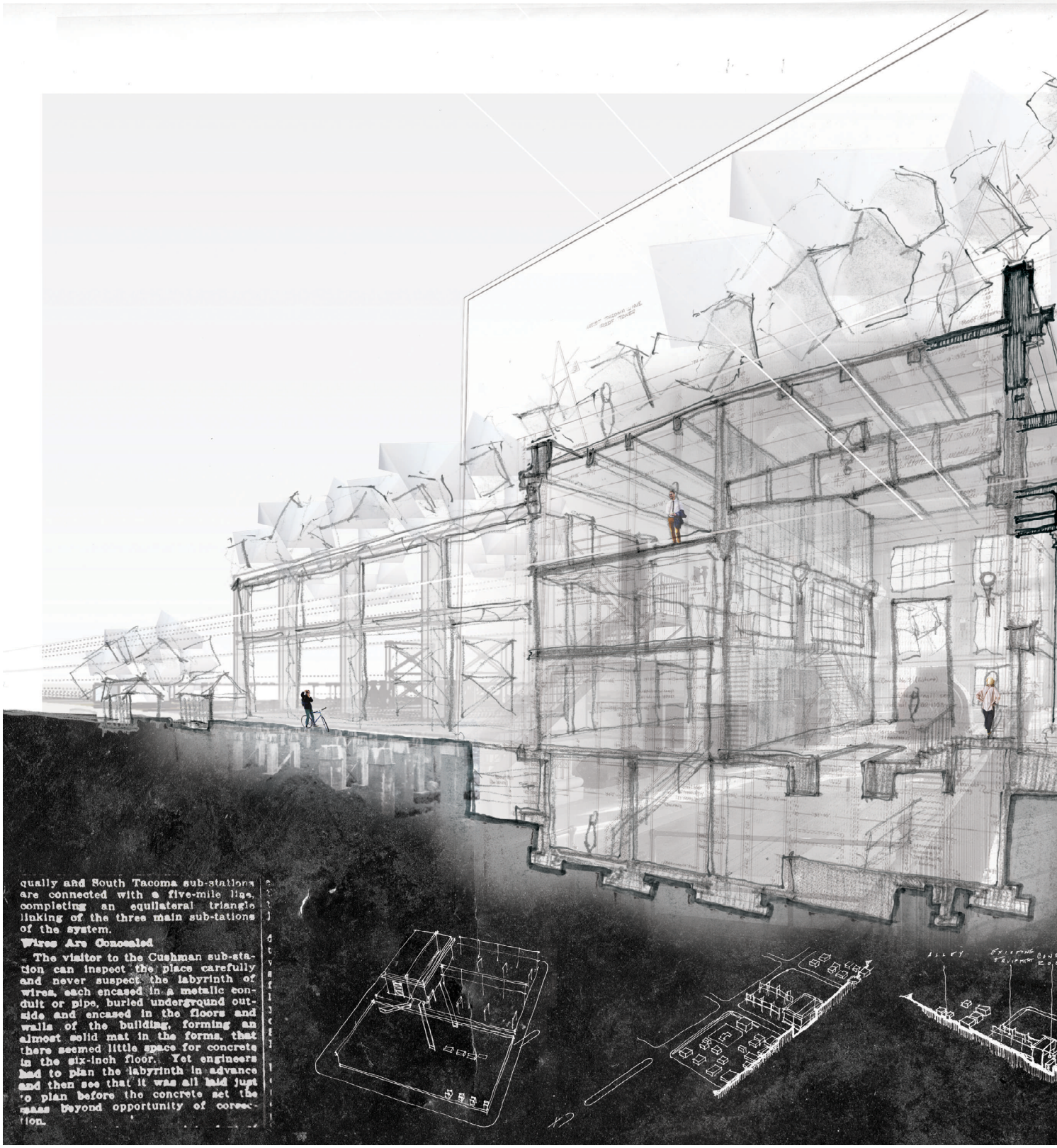
The adaptation of existing lattice frames and concrete building allow for a cohesive system of energy generation by luminescent solar collectors; enabling a growth of this new technology along with facilitating public interaction and community involvement. Therefore the site now creates its own dynamic surrounding low voltage solar energy.

The approach of analyzing the original power flows in relation to infrastructure is important in order to describe the original relationship of this project to the neighborhood, city, and region. The universal nature of the steel lattice frames provides an opportunity to integrate the luminescent solar collector in a practical way, becoming a new architecture of power. The freedom of placement allows for a dynamic formation of space with lighting and spatial qualities enhanced by the translucent panels.

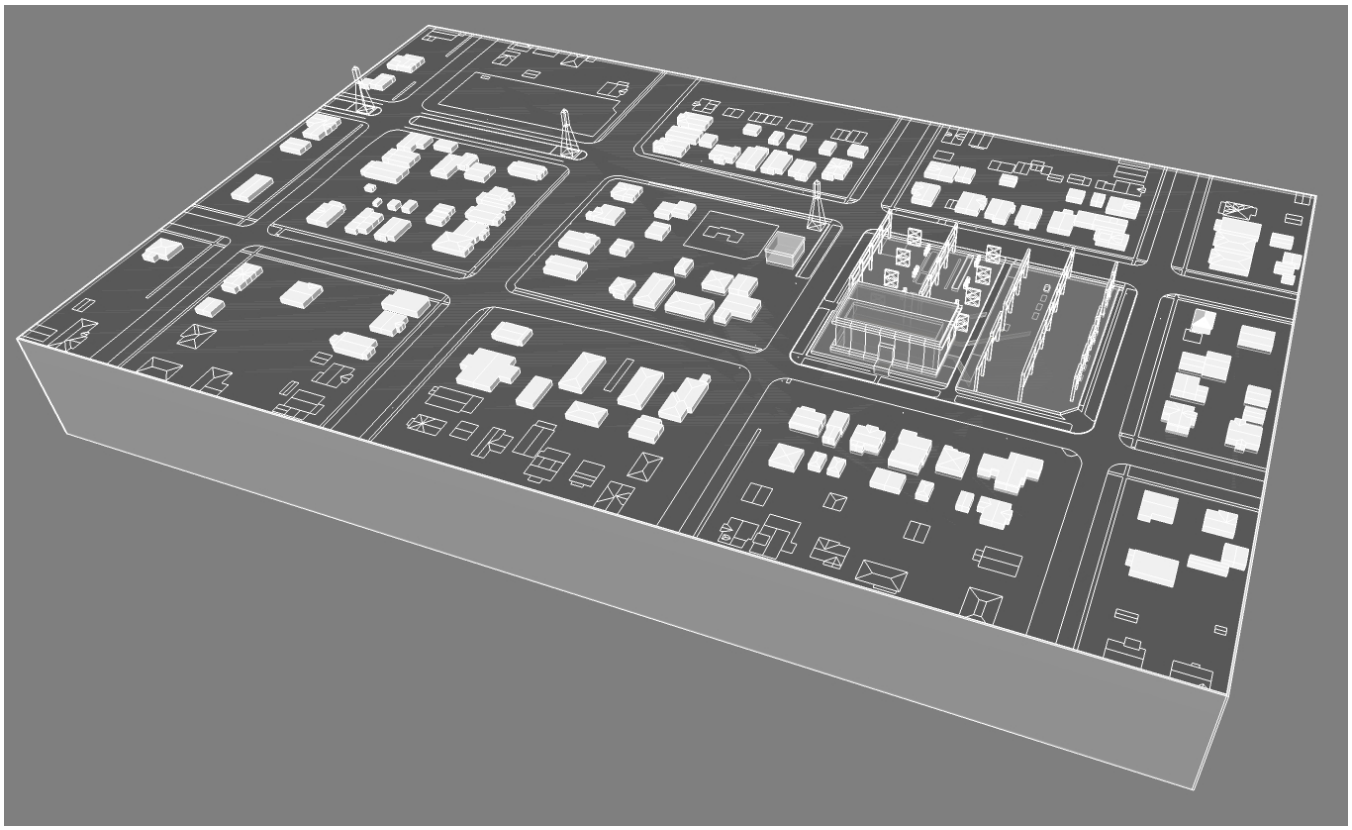
The combination of the new program and infrastructure, identify the new project as an electricity generating site. With the removal of high voltage, this site manifests itself as a center for the community, where the public can interact with the energy source which becomes a new architecture of power; both technology and culture can serve the surrouding community, like the electricity once did. This public center embodies a new outlook and form for energy supply into the 21st century, shaped by a system that helped to develop and sustain a city for over 90 years.

Appendix, Models, Etc.

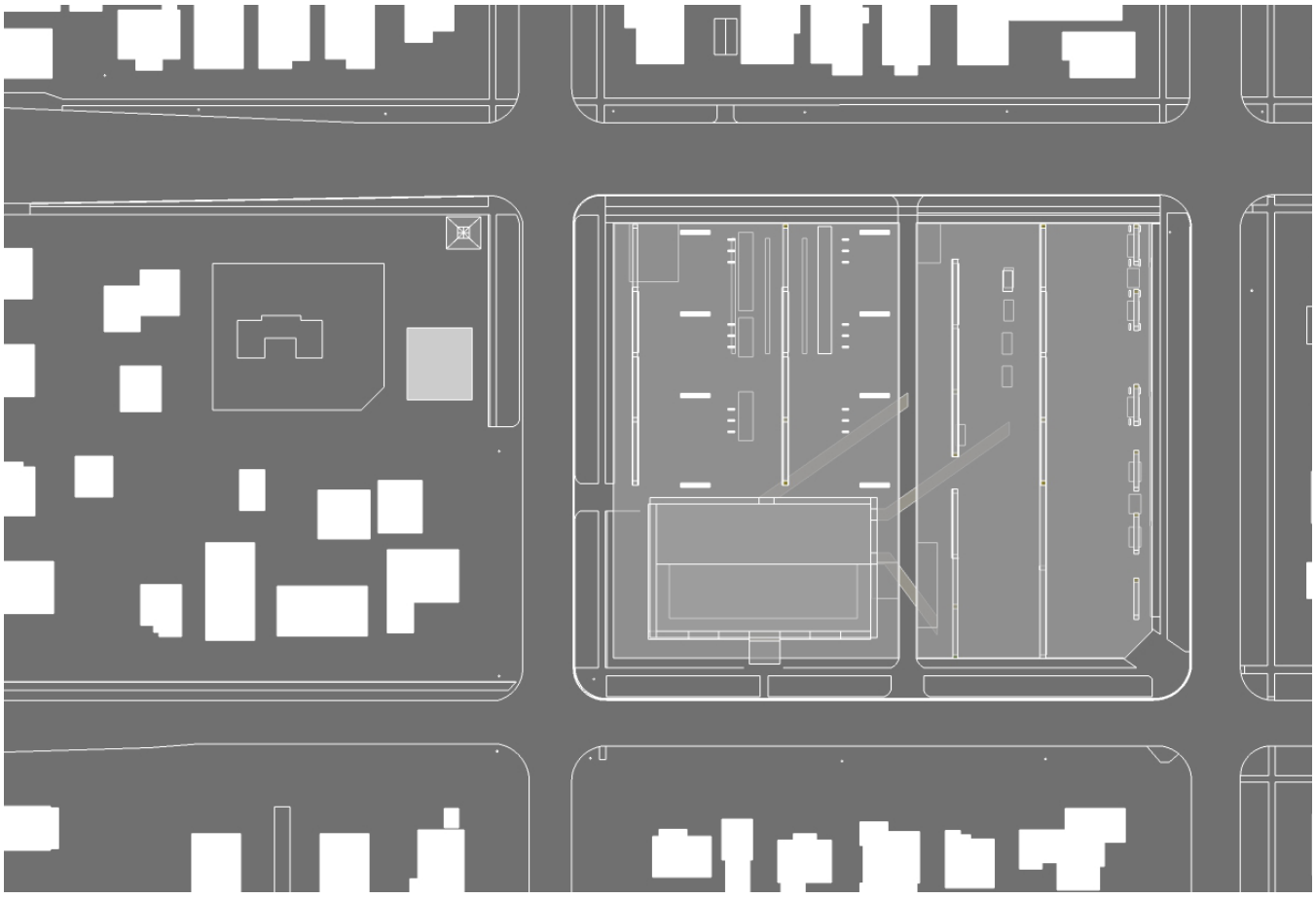
architectural archaeology


qually and South Tacoma sub-stations are connected with a five-mile line, completing an equilateral triangle linking of the three main sub-tations of the system.
Wires Are Concealed
The visitor to the Cushman sub-station can inspect the place carefully and never suspect the labyrinth of wires, each encased in a metallic conduit or pipe, buried underground outside and encased in the floors and walls of the building, forming an almost solid mat in the forms, that there seemed little space for concrete in the six-inch floor. Yet engineers had to plan the labyrinth in advance and then see that it was all laid just to plan before the concrete set the mass beyond opportunity of correction.

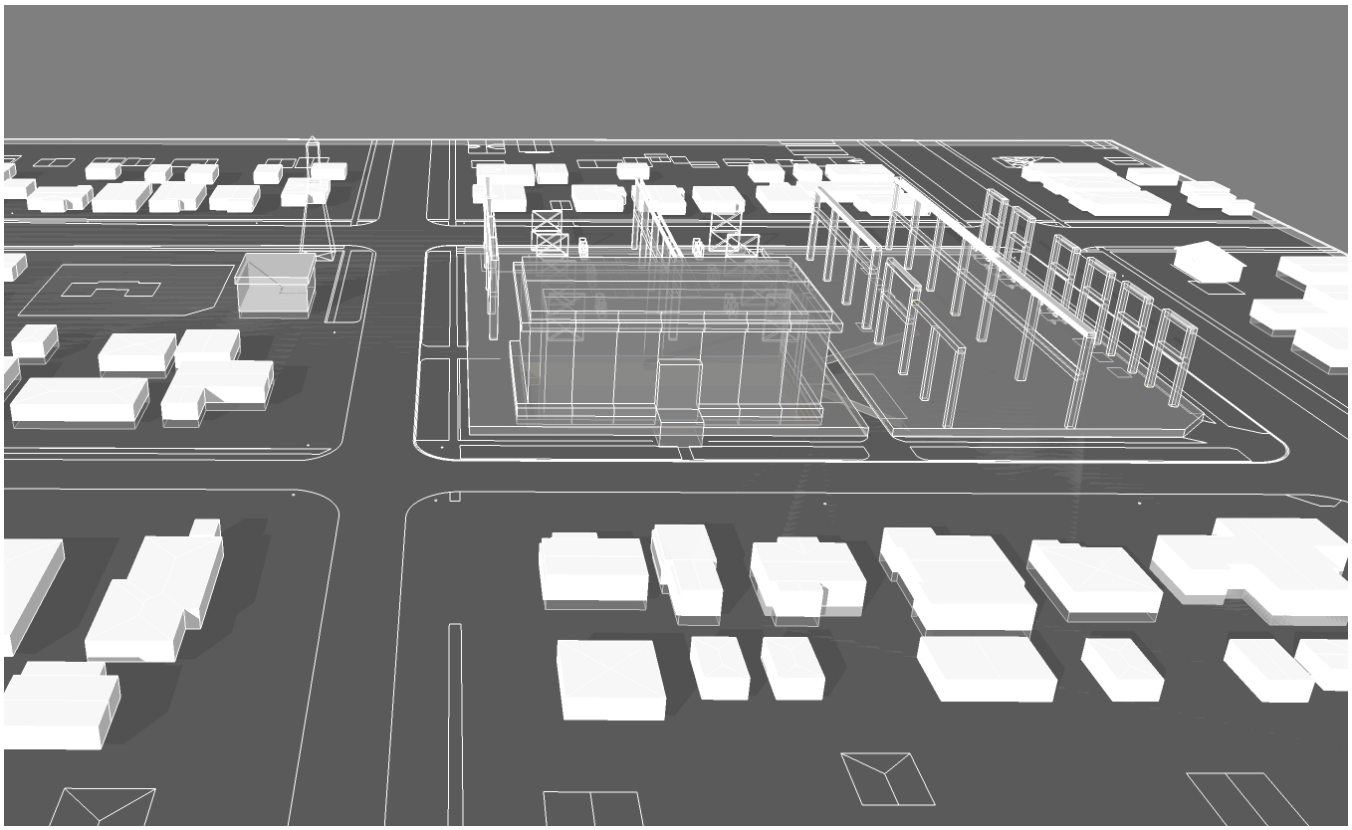

WEST TACOMA LANE
ROOF TOWER



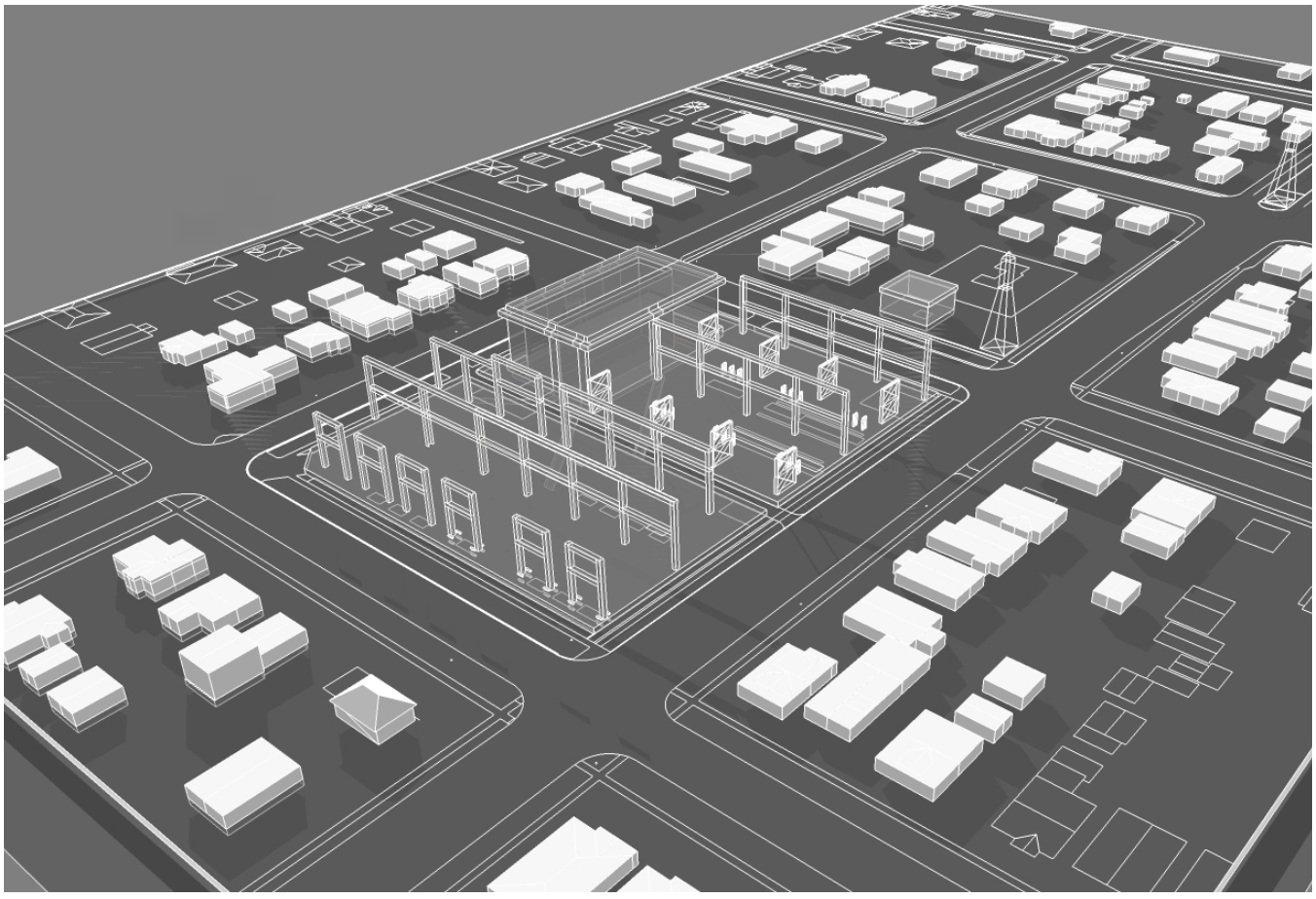
existing cushman substation



 existing site plan



existing south elevation



aerial from northeast

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images created by author unless otherwise noted