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High Desert Corridor Green Energy Report

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1. Executive Summary

This report describes the implementation of green energy technologies along the High Desert Corridor (HDC). The HDC is a multi-purpose, public private partnership (P3) project which will provide several forms of transportation and energy infrastructure across a tract of desert connecting the Antelope Valley in Los Angeles County to the Victor Valley in San Bernardino County.

The completed HDC environmental review documentation for California Environmental Quality Act (CEQA) clears the following five components under four build options:

- Bikeway
- Roadway (either Highway or Tollway)
- High-Speed Rail (HSR) Feeder/Connector
- Green energy production
- Green energy transmission

The study herein explores the application of green energy production and transmission along the right-of-way (ROW). Energy options were assessed based on their capital cost, ease of implementation, efficiency, and revenue potential. This executive summary outlines the following specific recommendations for the HDC project.

1. Through exchange with the regional energy market, approximately 20MW of renewable production is projected to functionally offset the entire energy footprint of the HDC. This intention for a net-zero corridor demonstrates a new standard for infrastructure environmental sustainability. Further analysis is suggested to specifically define the level of renewable energy production sufficient to fully offset all components of the HDC. Additional consideration may be made for energy production beyond the offset threshold for additional financial and environmental benefits.

2. The HDC's green energy production could contribute to the financial viability of the entire corridor by generating early cashflow and facilitating borrowing against a predictable future revenue stream.

3. The current political environment, from local to state to federal, provides unique time-sensitive alignments with the incorporation of green energy into the HDC corridor. Considerations should be made for project timeline

as it relates to goals of legislation such as SB 32 by 2030.

4. Solar stands above all other forms of renewables as the primary green energy source worthy of further exploration for production along the HDC. This report recommends that the High Desert Corridor Joint Power Authority (HDCJPA) solicit feedback from the private sector by holding an industry forum and subsequently issue a Request for Information (RFI) for a 20MW clustered solar system. Prior to the issuance of an RFI, HDCJPA must decide between in-house or private contracted energy development. A Power Purchase Agreement (PPA) is expected to be a critical aspect to any such planning.

5. There are multiple options for the layout of solar paneling that can meet the energy needs of the project, with some options far more expensive than others. Long narrow arrays of solar panels tend to be 50-75% more expensive than more clustered solar arrays, due to factors related to perimeter efficiency. Clustered solar layouts near utility substations are recommended for the HDCJPA to optimize efficiency and reduce costs.

6. Direct inversion of green energy produced on-site, for use in HSR infrastructure within the HDC, would be expensive and highly complex. Pursuit of an RFI to explore further is not recommended.

7. Construction of an energy transmission line along the HDC's greenfield ROW could be of tangible benefit to the regional grid in alignment with local population and economic growth. Southern California Edison (SCE) is open to further discussion upon clarifying the project timeline. Drafting a submission to California Independent System Operator's (CAISO) annual transmission planning process, with consideration for Federal Energy Regulatory Commission (FERC) order 1000, is recommended as a next step. FERC Order 1000 could be utilized to open up a competitive bidding process to allow agencies to bid to build the HDC transmission line within the HDC corridor once a ROW was established.

8. The specifications of the XpressWest and California High Speed Rail Authority (CHSRA) systems will be critical to interoperability as well as intelligence sharing between projects. Waiting for a green-light on XpressWest is suggested before any power infrastructure designs are determined for the HDC's HSR components.

9. When considering green energy offsets of transit infrastructure, the complexity of varied use cases and overall footprint can be most accurately modeled with Life-Cycle Assessment (LCA) and Life-Cycle Inventory (LCI), with consideration for Passenger Kilometer Traveled (PKT) vs. Vehicle Kilometer Traveled (VKT).

10. The green energy corridor concept could be broadened to include clean energy, such as natural gas, to more fully incorporate local infrastructure, address high load inertial needs, and provide long-term viability. Alternatives for cost-effective peak-use options may also be found in emerging battery technology. Exploration of a potential partnership with Palmdale Energy Project is recommended.

First, an estimated 20 MW of production of **green energy along the HDC ROW, with adjacent transmission, has the potential to offset the entirety of the HDC's energy footprint**. Further analysis is required to establish the specific capacity required for a full net-zero offset. Renewable energy can offset all five built components of pedestrian/bikeway, roadway, high speed rail (HSR), and the green energy components themselves. Interaction with the regional energy market will facilitate this offset through an outflow of energy produced on-site equivalent to the inflow of energy produced off-site. Such an arrangement is required to provide energy availability for the transit infrastructure components, especially the load demands of HSR. To have such a degree of environmental sustainability on a project of this scale would make the HDC a global case study in how energy and transit infrastructure can strategically co-exist. A marriage of energy and transit has the potential to offset both vehicle and transmission congestion through the HDC corridor.

Second, the production of green energy could carry a considerable economic impact. The **green energy build components could provide the HDC's financial model with critical early and predictable cashflow**. A construction schedule that brings renewable energy online quickly could produce revenue that supports the completion of other build components thereafter. Additionally, the net present value of future green energy revenues may provide an opportunity to address some portion of the current estimated gap of $1.5 to $2.3 billion in upfront capital costs through formation of a P3 and/or the issuance of debt. Federal and State tax incentives may be available through renewable energy production and transmission. Further exploration will be required to know what scale is possible for the green and clean energy components, as well as how non-energy revenue generation from user fees and/or tax increment financing would complement revenue from energy production and transmission. Consideration may be made for production of energy beyond the threshold of offsetting components of the HDC for additional financial and/or environmental benefit.

Third, the present political environment on a local city and county level, as well at the state and federal levels, provide a rich set of opportunities for alignment, collaboration, and shared objectives. **Intentions set forth by local general plans are brought to life under environmental goals set by California law through plans for this green energy corridor.** Vital statewide environmental goals sunset before the HDC's completion in 2020 (AB32) and potentially soon after the HDC's completion in 2030 (SB 350 and SB 32). The HDC would benefit from aligning its timeline with present legislation. At the federal level, infrastructure priorities that highlight the importance of P3 agreements may be advantageous only for a limited window of time. Opportunities therein can be highlighted throughout the process to ensure both political and material support of the HDC.

Fourth, the study found solar energy to be the most favorable renewable energy alternative for implementation along the corridor. Based on analysis of costs, total energy output and revenue generation, the inclusion of large scale solar would be the most effective way to offset energy consumption, generate revenue, and further environmental sustainability. The HDC energy infrastructure could be complementary to adjacent development of green energy production, such as private investments in solar farms, which could utilize the HDC's energy transmission infrastructure.

However, it is notable that photovoltaic (PV) solar does not have mechanical inertia and can only account for light load when addressing specific and regional energy needs. This is particularly relevant for the HDC because of the high peak load required for certain phases of HSR operation. Options combining solar with turbine-based generation and/or emerging battery technology could be a viable option and should be explored.

In addition to complementing renewable energy development, a transmission line component could also be part of a solution to expanding the Grid in the Southwestern US. Coordination with those entities contemplating or sponsoring regional transmission projects would be needed.

Before proceeding to scope out the solar design, it will be necessary to identify if the HDC intends to utilize an in-house energy development or contract a private third party. Risk tolerance and desire for the HDCJPA's future revenue to fluctuate with energy market prices should be taken into consideration.

Once the in-house or private energy developer determination is made, the immediate next step will be to hold an industry forum to facilitate interest in the project. This industry forum will help inform an appropriate framework for a RFI process. Upon issuance of the RFI, contractor and developer representatives will then analyze the site(s) and produce Engineering, Procurement and Construction (EPC) options for PV systems, allowing for direct comparison of available options, including financials pro forma. Options other than EPC may be explored for cost saving purposes, based on the JPA's desired allocation of risks and availability of funds.

It is notable that wind energy may also be a viable energy source for the project, and would require additional study. Cost and production for wind are attractive, but the land use, zoning restrictions and aesthetic consequences of the technology may preclude wind energy entirely.

Fifth, this report recommends that the **HDCJPA should primarily explore solar panel options that include large clustered installations** for optimal efficiency and minimal costs. While narrow rows of solar paneling along the ROW may seem aesthetically attractive, the 50-75% variance in costs does not justify such a layout. These elevated expenses are due to additional cable costs, higher inversion needs, more interconnection points, and increased voltage losses at lower voltage levels prior to transformation to a higher voltage. Overall these higher costs can largely be attributed to a lack of geometric perimeter efficiency in any narrow design. If P3s are formed for certain components of the project, such as sound barriers or pedestrian lighting, third party developers may choose to install less efficient solar layouts, but for the HDCJPA cost efficiency will be a critical consideration.

Sixth, the complexity of HSR electrical systems all but precludes direct inversion of green energy produced on-site. To further explore the potential for on-site solar energy to provide power to the HSR, the HDCJPA would need to involve SCE and CAISO. The immediate next step would be for the HDCJPA to work toward a RFI to determine what a green energy corridor coupled with powering the HSR system could look like. However, given the likely cost and complexity of such an exploration, **it is the recommendation of this report that no further studies be conducted on the inversion of on-site green energy for direct use in HSR electrical systems.** Green energy production and transmission can take place in parallel to transit, which captures nearly all the green energy corridor benefit without undertaking the costly inversion process of on-site energy production for immediate transit use. Energy offsets and financial gains could still be captured by selling energy for use within the regional grid.

Seventh, transmission line infrastructure could benefit the connectivity of the regional power grid while fostering further economic growth and use of green energy in surrounding areas. The area surrounding the HDC is ripe with load and renewable possibilities. Addition of a transmission component would further improve transmission reliability in the future and facilitate planned load growth in the area. Further exploration of power flow, existing substations, and possible new interconnection points is required to evaluate such regional need. Green energy infrastructure could provide an opportunity for considerable job-creating and economically stimulating regional investments in solar farms and other forms of large scale clean energy production. **This report recommends the HDCJPA review the transmission line assessment upon completion for guidance** on working with SCE and CAISO, in addition to municipal utilities such as LADWP, Southern California Public Power Authority, and the City of Colton, to identify appropriate options for use of the HDC ROW for transmission line infrastructure. The HDCJPA could potentially form a P3 to lease a portion of the valuable greenfield ROW for the construction of the transmission line, thus reducing operational and other technological risks, while securing private-sector expertise from design and construction to operation and maintenance.

In addition to providing a backbone for green energy development within the high desert, a high-voltage transmission line could support delivery of energy between local renewable projects and renewable energy zones beyond the high desert. Integration with plans such as the Desert Renewable Energy Conservation Plan could prove beneficial to this end.

Eighth, **this report recommends that the HDCJPA defer any investigation of power infrastructure for the HSR component of the project until the XpressWest project is green-lighted.** Progress on the XpressWest project may provide further opportunities for interoperability as well as shared intelligence related to the integration of green energy production and transmission. This consideration is relevant both to the green energy and transit infrastructure of the HDC. It is assumed that the interoperability of the track and systems of CHSRA will also be coordinated to integrate across the HDC and XpressWest.

Ninth, **when considering environmental impact of transit infrastructure, considerations must be made for LCA as well as PKT versus VKT.** As part of LCA, LCI costs evaluate the environmental impact of the entire project, including non-immediate factors. The LCI allows for a comprehensive determination of costs related to the HDC's roadway and HSR. Additionally, varied numbers of passengers will have a considerable impact on the HDC's environmental and energy footprint. For the purposes of this report, both PKT and VKT are calculated based on LCI.

Lastly, **the green energy corridor concept could be broadened to include clean energy, such as natural gas, to more fully incorporate local infrastructure, address energy load and inertial demands, and provide long-term viability.** A potential symbiotic relationship can be created by partnering with the City of Palmdale on their proposed Hybrid Power Plant, which is now called Palmdale Energy Project. However, it is acknowledged that the next steps and timeline for the Palmdale Energy Project are unknown at the time of delivery of this report. Additionally, current trends indicate that cost-competitive options may become available through battery technology. This report recommends monitoring of innovations in battery use within systems for peak load demands.

2. Introduction

The HDC is a proposed 63-mile multi-modal transitway and green energy corridor connecting SR-14 in Los Angeles County with SR-18 in San Bernardino County, passing through the cities of Lancaster, Palmdale, Adelanto, Victorville, and the town of Apple Valley.

Currently, the U.S. relies largely on non-renewable fossil fuels for energy.[1] These resources are limited and thus have increasing usage costs as well as a negative impact on the environment. The HDC project seeks to identify itself as a green energy corridor, replete with solar energy production, energy transmission, electric transmission congestion relief, electric vehicle charging stations, hydrogen fuel cell refilling stations, and rainwater capture systems. The addition of these features will reduce greenhouse gas emissions along the route and increase the utilization of renewable energy resources in compliance with California sustainability goals. A variety of renewable energy technology alternatives were studied and this report provides a discussion of the feasibility of incorporating these technologies into the HDC project.

3. Renewable Energy Assessment

To determine the most feasible energy option for the HDC, an assessment was performed in which the energy alternatives were scored 1-5 in three categories: cost vs. production, ease of implementation, and overall fit. Cost vs. production is considered in terms of their capital cost versus production and project applicability (including access to required resources and HDC-specific project attributes). Data related to the capital cost and production efficiency were provided via online resources.[2] For further description of renewable energy options, please see Appendix A, titled "Renewable Energy Options".

The ease of implementation rating is based on conversations with relevant stakeholders with regional and HDC-specific interests. Overall fit is a summative rating based on initial knowledge of available technology and applicability for the high desert region. The table below shows the matrix of the renewable energy assessment. Pricing information is based upon December 2016 data.[3]

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1 Nonrenewable and Renewable Energy Sources, https://www.eia.gov/energyexplained/index.cfm?page=nonrenewable_home

2 Comparing the Costs of Renewable and Conventional Energy Sources, http://energyinnovation.org/2015/02/07/levelized-cost-of-energy/

3 Levelized Cost of Energy Analysis, https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf

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Table 1: Renewable Energy Assessment

Renewable Energy	**Advantage**	**Disadvantage**	**Cost vs. Production**	**Ease of Implementation**	**Overall Fit**
Solar	Taps sun heat to generate energy	Can be hampered by cloudy weather conditions	4.5	4.75	5
Wind	Uses wind motion to create energy	Soil erosion, disturbance to avian life, noise, views	4.5	3.75	4
Hydro-electric	Utilizes water movement to produce electricity	Negative environmental impacts from damming rivers	2	1.5	1
Geothermal	Leverages earth heat underneath for electricity	Expensive; better suited to localized power needs	1.5	1.5	1.5
Biomass	Organic matter decomposed to form energy elements	High cost of collecting biomass	4	3	2

Table 2: Energy Capital Cost and Efficiency Data

Energy	Capital Cost ($/MWh)[4]
Solar	55
Wind	48
Water	75
Geothermal	81
Biomass	52
Energy	**Efficiency (%)[5]**
Solar	20
Wind	35
Water	90
Geothermal	15
Biomass	34

4. Solar as a Primary Recommendation

The evaluation of each renewable technology favorably supports solar energy for the HDC. It is cost-effective with relatively high energy efficiency. San Bernardino County has the highest solar index in the state of California, which reflects the high desert's exceptional availability of solar energy. Financial feasibility studies performed in later sections of the report show that integrating solar energy into the HDC would generate significant positive returns annually, which could be used through a variety of financial mechanisms to help fund upfront and ongoing project costs.

4.1 Engineering, Production, and Cost

The National Renewable Energy Lab (NREL), a division of the federal Department of Energy, publishes an annual report on national industry trends and pricing. The 2016 report can be found here: http://www.nrel.gov/docs/fy16osti/67142.pdf. Much of the data and analysis herein relies on findings from this NREL report.

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4 Comparing the Costs of Renewable and Conventional Energy Sources, http://energyinnovation.org/2015/02/07/levelized-cost-of-energy/

5 Energy Efficiency, http://www.mpoweruk.com/energy_efficiency.htm

The following discussion outlines cost and production variances that might impact the project due to a range of factors:[6]

- Component pricing: Solar systems include the solar panels, racking, inverters, and wiring. Larger projects have lower system component costs per watt owing to bulk buying and resulting economies of scale.
    - The HDC will benefit from clustering solar panels to optimize perimeter efficiency and reduce costs.
- Engineering-interconnection: Proximity to existing transmission lines and/or substations can affect costs greatly, with systems closer to existing electrical infrastructure having significant cost advantages. Sometimes, these costs are borne by the eventual solar developer, solar owner and/or by the utility.
    - The inclusion of a transmission line along the HDC ROW will benefit not only the green energy corridor, but also any adjacent energy development such as private solar farms. Such infrastructure would allow electrons to flow more freely throughout the area and improve electric transmission reliability.
    - Coordination with regional utilities, such as SCE, Southern California Gas Company, and/or Los Angeles Department of Water and Power, along with CAISO, will be critical to project success.
    - The HDCJPA may choose to expose future energy revenue to market forces by pursuing an in-house energy developer. Alternatively, the HDCJPA has the option to form an external energy contract and/or lease out the transmission line project to a utility company and secure a power purchase agreement for the consumption of power.

[6] U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016, http://www.nrel.gov/docs/fy16osti/67142.pdf

- Engineering-system design: The most cost-effective system designs are "clustered," minimizing the number of required inverters and wiring and optimizing for perimeter efficiency. Furthermore, how panels are attached to the racking can differ; some tilt on an axis, following the sun as it moves across the sky, and some do not. Systems that are unable to move, called "fixed-systems," are more cost-effective initially but produce fewer kWh; those that move with the sun, those with either "single-axis" or "double-axis" trackers systems are more initially expensive but produce more kWh over time.

- Further research is needed to determine how the availability of space along the ROW would determine an appropriate approach for clustering as well as fixed vs. tracker systems.

- Regulatory/policy requirements: Prevailing wage, high-road standards, topography, soil condition, etc. can also affect cost. Often, municipally affiliated projects will require some type of related requirement. Cost increases will vary by region.
  - Further study is required to establish specific costs and related factors of such a project. This could be structured into requests for information or proposals that go out for P3 involvement.

Once the HDCJPA determines whether to have an in-house energy developer or form an external contract, the immediate next step will be to hold an industry forum to facilitate interest in the project. This industry forum will help inform an appropriate framework for an RFI. Through the process, contractor and developer representatives will analyze the site(s) and produce EPC options for solar systems, allowing for direct comparison of available options, including financials pro forma. Options other than EPC may be explored for cost saving purposes, based on the JPA's desired allocation of risks and availability of funds.

As a component of this RFI, the HDCJPA can include a set range of expectations for costs, revenue, and energy generation in a way that ensures all potential contractors are bidding toward a project that is both environmentally and financially sustainable.

4.2 Explore Wind as an Option

Wind pricing and production is comparable to utility-scale solar. However, initial engineering for solar is much more widely available than wind and accessible through federal Department of Energy sources. Initial studies must be performed, and those studies budgeted for, to fully explore wind as an option. Additionally, whether wind is a palatable option within the high desert is unclear. Regional aesthetic concerns and legal ramifications of zoning regulations remain in question.[7] If somehow these concerns are addressed, and wind turbines or energy kites are viable along the HDC from an engineering perspective, then wind power could potentially be considered either alongside or in place of solar.

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[7] Potential Wind Capacity, https://apps2.eere.energy.gov/wind/windexchange/windmaps/resource_potential.asp

Given the proximity of the HDC to the Tehachapi Renewable Transmission Project (TRTP), a review of the current buildout and production of TRTP could provide further regional context and specific intelligence for the HDC's green energy components.

4.3 Renewable Energy Technology Alternatives

4.3.1 Photovoltaic Solar Highways

A range of projects involving solar highways have been developed at various Department of Transportation (DOT) facilities and highway ROW. Solar power is normally harnessed via PV technology using panels installed in solar tracking systems to optimize the conditions of solar radiance at a specific location. A 100kw solar system was implemented by Oregon DOT across 8,000 square feet of purchased land along the ROW which could produce over 100,000 kwh per year, offsetting their use of energy at an interchange requirement of 400,000 kwh by over 30%.[8] Due to greater solar irradiation (solar exposure) in the proposed HDC, a similarly sized system would produce about 160,000 kwh per year.

Furthermore, the pursuit of a large-scale solar clustering formation would reduce costs and improve efficiency in comparison to Oregon's narrow PV array. Solar energy technology generally requires a large amount of land, which makes it favorable for the HDC's proposed route, especially since the energy would not need to be transported far to gain grid access. Exactly how and where the system(s) are installed along the HDC for optimal proximity to utility substations and related considerations will require further exploration.

4.3.2 Solar Panel Installation on Barrier Walls and/or Median Strips

Solar panels could be installed in the ROW along desert-portions of the road, and/or PV noise barriers could be implemented along the residential areas of the corridor to reduce noise and mitigate visual impacts. Both options seem attractive due to minimal additional land acquisition costs and "fit" within the existing project layout and structure. Further, the potential noise reduction to residential and commercial buildings bordering the ROW would be significant.[9]

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[8] California Department of Transportation, http://www.dot.ca.gov/d7/env-docs/docs/hdc/The%20Physical%20Environment/HDC%20Green%20Energy%20feasibility%20Study-June%202014.pdf

[9] Sound-Absorbing Noise Barriers, http://www.autobrennero.it/en/the-motorway-network/safety-and-comfort/sound-absorbing-noise-barriers-/

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Unfortunately, the estimated increase in cost for this layout would also be significant, estimated at 50%-75% higher. The required long and narrow layout would require significant increases in system components including wiring and inverters. Over time, maintenance and operation costs could be considerably higher. Also, the interconnection could be made much more difficult. Overall, both due to costs and complexity, any solar array design with low perimeter efficiency would not be recommended as a direct cost to the HDCJPA. However, such technology could be included in a third-party proposal.

4.3.3 Bicycle Path Renewable Energy Alternatives

The HDC proposes the development of bicycle paths throughout the corridor. While expensive, PV paneling could be mounted on street lights along these trails, making the lights self-sufficient and potentially creating further surpluses to be sold back into the grid.

This would have significant social benefits, but would likely prove too costly for the HDCJPA's financial model. Each solar panel would have to be mounted on a pole, requiring drilling and a concrete base. Significant mounting, racking, wiring and inverter inefficiencies would be necessary, driving up costs. Furthermore, maintenance and operations costs would be higher than normal due to difficult accessibility.

It is estimated that installation costs per watt would be approximately triple those of a traditional ground-mount, clustered system. The desire for on-site solar powered lights may or may not justify this expense. If clusters of solar panels are available along the transmission line, then it would be far more efficient to simply power the streetlights from the grid and offset their energy use accordingly.

Figure 1: Solar Light for Bicycle Path (source: http://www.resourcefulthinking.org/story/solar-

lighting-for-bike-paths)

4.3.4 High Speed Rail Station Grid Neutrality

CHSRA is working to develop an HSR station in Palmdale by the year 2029. Solar paneling could be installed at the train station, with further systems installed at the park and ride section of the station, to offset the energy usage which would reduce the overall utility cost for CHSRA. Additionally, energy produced in solar clusters along the HDC (either by the green energy corridor and/or private solar developers) could be utilized for energy offsets in the future.

It is the recommendation of this report that the HDCJPA consider suggesting exploration of rooftop solar for all development in and near all HDC transit and energy infrastructure.

4.3.5 Alternative Energy Fuel Stations

Off-ramp development adjacent to the HDC ROW can provide sustainable charging/fueling stations, additional green energy production, water-conscious construction, and bolstered collaboration with and among regional cities. In keeping with its identity as a green energy corridor, the roadway could make use of a combination of electric vehicle charging stations and hydrogen fueling stations, each supplementing its power supply with PV rooftop solar arrays. These structures would allow increased mobility for drivers of electric and hydrogen fuel cell vehicles, allowing them to travel the length of the corridor and potentially facilitating movement of green vehicles between Los Angeles and Las Vegas (a distance which can be prohibitively far for EV and fuel cell vehicles with limited ranges). These stations could also feature rainwater capture systems, allowing them a higher level of self-sufficiency with respect to utilities and reducing strain on the local watershed.

The presence of these charging and refueling stations would attract environmentally friendly motorists from around the greater Los Angeles region, boosting business to other commercial centers on the ROW and increasing the property values.

Electric charging and alternative fuel infrastructure are in growing demand. Car manufacturers are diversifying away from traditional engines more and more to meet demand. Year-on-year growth in USA electric vehicle sales for the month of January in 2017 was 70%.[10] While vehicular ranges continue to expand, it becomes all the more critical for charging to become available in fast growing population areas away from major urban centers. Such availability in the high desert is particularly important as environmentally responsible vehicles decrease in price, and thus become more affordable to working class families. Given the socio-economic status of many residents along the HDC, and the growing number of industrial jobs, the installation of electric and alternative energy fueling stations would have positive impacts on both social and environmental well-being.

In addition to renewables, a clean energy approach inclusive of compressed natural gas refueling stations, may contribute to the environmental sustainability of the project.

Although the most recent drought has come to an end, southern California will always be a region where water is a valuable resource. The high desert is certainly no exception. Incorporating water-conscious infrastructure both into the HDC as well as into off-ramp and adjacent developments would have considerable benefits to both the project and the region. The HDC would see immediate benefits from access to grant funding and special financing options. Local water districts, municipalities, and residents would benefit from improved water quality, water storage, flood control, and regional self-reliance.

Alternative fuels such as biofuel and hydrogen can be provided at the interchanges along the HDC. This would promote the use of alternatively fueled cars and help reduce greenhouse gas emissions. These additions would supplement the reduction of fossil fuel consumption and further the overall sustainability impact of the HDC.

Encouraging alternative energy fuel stations and electric vehicle charging stations along the HDC, complete with rooftop solar and sustainable water infrastructure, is a meaningful opportunity for environmental leadership beyond the footprint of the HDC ROW.

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[10] U.S. Electric Vehicle Sales Soared In 2016, https://www.forbes.com/sites/rrapier/2017/02/05/u-s-electric-vehicle-sales-soared-in-2016/#12ec79b5217f

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5. Layout Options for Solar Paneling

Because solar energy was the clear renewable energy choice per the assessment, related technologies were further studied to determine which would be most appropriate for the HDC.

One key factor in considering solar layout and design is perimeter efficiency. Given a constant number of solar panels, cost-efficiency of a solar array is highly correlated with perimeter efficiency. Perimeter efficiency is a geometric term referring to the ratio between the perimeter of a polygon and the surface area therein. A circle has a 100% perimeter efficiency, as it requires the smallest possible amount of perimeter to generate a given amount of surface area. Correspondingly, squares with four equal sides have greater perimeter efficiency than rectangles with two longer sides and two shorter sides. As a rule, the less like a straight line and the more like a circle, the higher a given shape's perimeter efficiency. Due to the nature of solar energy maintenance, costs of wiring, and logistics of transmission, a higher perimeter efficiency reduces costs up front and over time. Hence, a single near-circular or square-shaped cluster of solar panels will be more cost efficient than a long, narrow array of an equal number of panels.

Figure 2: Clustered Solar Layout (source: *http://www.livemint.com/Politics/3UP3IA2VxwQRnmij4nDION/India-plans-solar-parks-for-up-to-20-gigawatts-of-capacity.html*:)

5.1 Large Scale Solar Clusters

Solar panels could be installed at one or more points along the HDC, aligned with accessible interconnection points and utility substations. These clustered layouts would optimize for perimeter efficiency, thus saving considerably on costs. This would require the purchase or lease of additional parcels of land. Whether eminent domain could or should be utilized bears consideration, particularly if the HDCJPA elects to explore forming an Enhanced Infrastructure Finance District (EIFD).

Given an initial scan of local land pricing, the land acquisition cost would likely be easily offset by the cost savings of a clustered solar layout. Reduced system components would lower costs considerably when compared to narrow layouts such as the barrier wall and median strip options. Further, there will be reduced contractor design challenges, lower lifetime maintenance costs, and economies of scale for installation.

For the aforementioned reasons, economic and initial engineering analyses herein strongly suggest large scale solar array(s) grouped together in one or more cluster(s) as the primary design for installation of solar energy production.

6. Green Energy Offsets and Financial Impact

6.1 Renewable Energy Output and Revenue Generation

This report demonstrates confidence that the proposed solar system for the HDC will be revenue positive. This assertion is supported both by market knowledge and modeling pro forma from the NREL's System Advisor Model (PV – PPA Single Owner). Developed by International Energy Agency, this was used as a secondary source to confirm such market intelligence.

The project is expected to attract private sector interests, including EPCs, developers, and investors. Such P3 arrangements will be a source of positive cash flow for the HDC.

The model below is based on the following assumptions.

- The project transportation systems will run 24 hours
- 20,000 kW PV solar system is used
- 0.5%/year degradation rate of the solar system
- The 20,000 kW (DC) system will produce first-year kWh of 35,121,292 (AC)

- Estimated installation cost per watt is $1.50 (this may change by +/- 20%)

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Power purchase agreement cash flow, detailed through Year 6, for a 30-year pro forma is shown here (See the Appendix B, titled "Solar System Pro Forma Cash Flow" for all 30 years of cash flow).

<u>Table 3: Power Purchase Agreement Cash Flow</u>

Power Purchase Agreement	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**30 Year Total**
EXPENDITURES								
Project Cost	$ 30,000,000							$ 30,000,000
Financing	$ (30,000,000)							$ (30,000,000)
PPA Payment		$ 2,484,337	$ 2,533,713	$ 2,584,071	$ 2,635,429	$ 2,687,808	$ 2,741,229	$ 60,287,783
O&M (begins Year 21)								$ 3,511,497
Insurance (begins Year 21)								$ 731,562
Annual Expenditures		$ 2,484,337	$ 2,533,713	$ 2,584,071	$ 2,635,429	$ 2,687,808	$ 2,741,229	$ 64,530,842
Cumulative Expenditures		$ 2,484,337	$ 5,018,051	$ 7,602,121	$ 10,237,551	$ 12,925,359	$ 15,666,588	$ 1,219,367,073
INCOME								$ -
Energy Savings		$ 2,965,522	$ 3,068,722	$ 3,175,513	$ 3,286,021	$ 3,400,375	$ 3,518,708	$ 152,585,283
Annual Income		$ 2,965,522	$ 3,068,722	$ 3,175,513	$ 3,286,021	$ 3,400,375	$ 3,518,708	$ 152,585,283
Cumulative Income		$ 2,965,522	$ 6,034,243	$ 9,209,757	$ 12,495,778	$ 15,896,152	$ 19,414,860	
Annual Net Nominal		$ 481,184	$ 535,008	$ 591,442	$ 650,592	$ 712,566	$ 777,479	**$ 88,054,441**
Cumulative Net Nominal		$ 481,184	$ 1,016,193	$ 1,607,635	$ 2,258,227	$ 2,970,793	$ 3,748,272	

Assumptions: Energy production and lease payments begin 1 year after Notice to Proceed; current cost of electricity $.0816; PPA price $.065. Annual energy escalation of 4%; annual O&M and insurance escalation of 1.5%. GFS has provided illustrations of PPA repayment schedule, assuming moderate to good credit. Final eligibility, amortization and payment schedule will be determined upon formal project submission and approval.

GFS does not provide tax advice. Project owners should consult their accountant or tax professional.

Discount Rate	3.00%
NPV	**$46,486,694**

Table 4: Monthly Energy Production

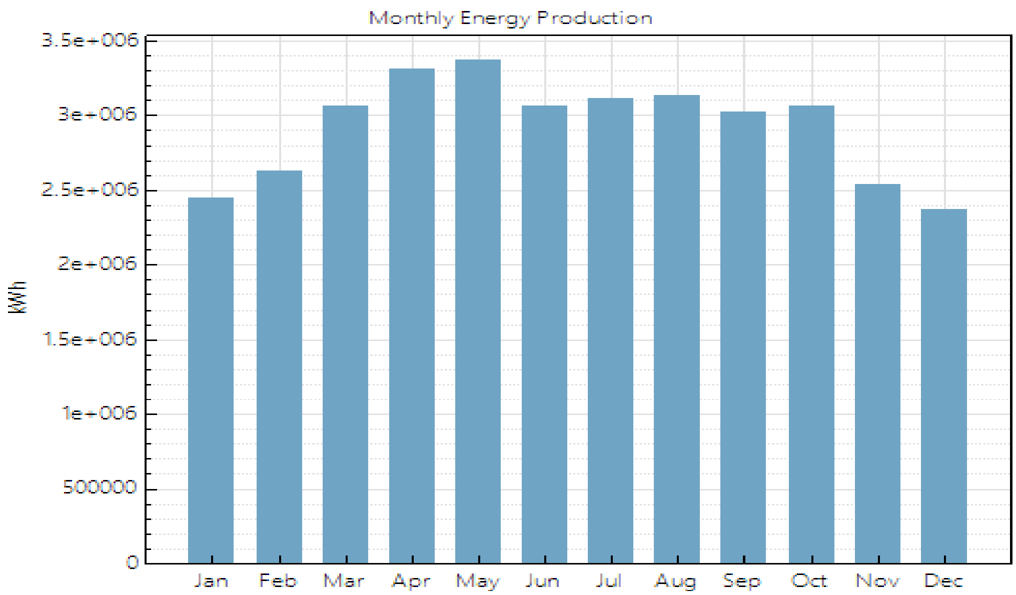
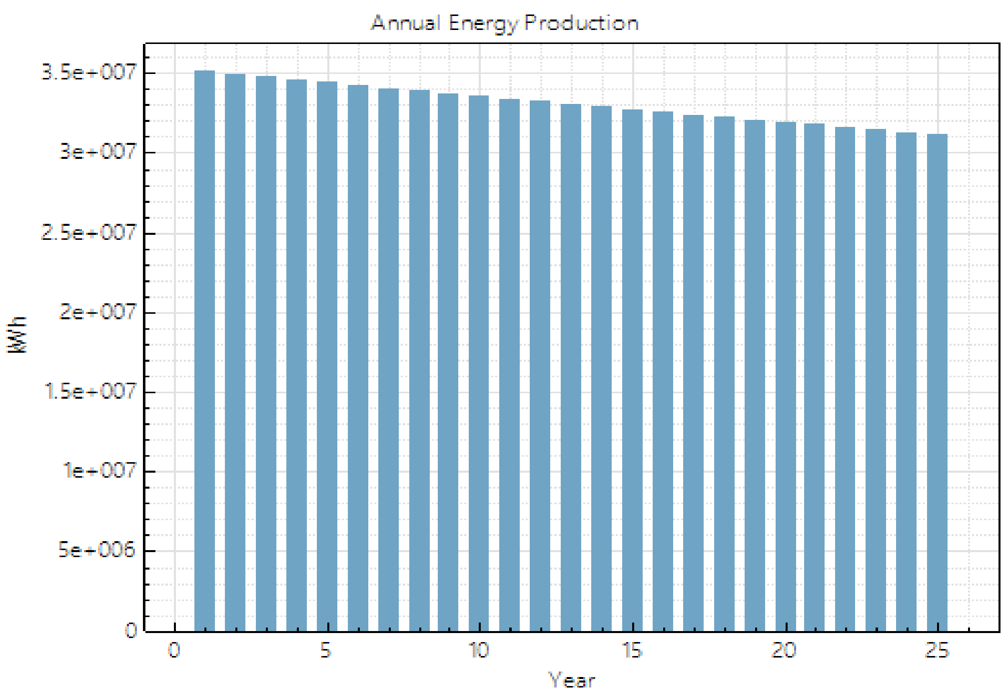


Table 5: Annual Energy Production



6.2 Financial Analysis

Solar system ownership carries significant tax benefits. Since municipal entities are unable to capture those tax benefits, many municipal and nonprofit entities have entered third-party ownership models. In short, a P3 model allows a non-governmental entity to capture the tax benefits and pass the savings on to the municipal host. Potential partners for such a P3 might include regional utilities, energy companies, large non-profits (e.g. universities), and corporate interests.

The net present value of a well-designed solar system creates an attractive opportunity for sustainable long-run asset management. The core of this net present value lies in the actual energy production, with additional benefits coming through energy offsets and tax incentives. Utilizing one or more P3 agreements in this process will be critical to efficiency and effectiveness.

7. Transmission Line

7.1 P3 Considerations

In July 2012, a report was filed by Infra-Consult with LA Metro that included the importance of leasing a portion of the HDC ROW for the development of a transmission line.[11] Ongoing study of green energy options further supports this conclusion, which is why Infra Associates has secured an independent transmission line consultant to generate a transmission line assessment. To continue conversations regarding transmission line development with SCE and CAISO, as well as municipal utilities such as LADWP, a timeline for the HDC project may be required. Regardless of immediate next steps, a transmission line remains critical to the power infrastructure of the HDC, and a P3 may be critical to construction and operation.

8. Integration of Green Energy Production with Transmission Line

The inclusion of a transmission line ROW along the HDC is critical to the green energy corridor approach. Integration between green energy production and transmission may be beneficial depending on the need for electron flow across and within the HDC. Construction of a transmission line may be valuable even if it is fully independent of the HDC's green energy production. These factors are under consideration currently in the creation of a transmission line assessment.

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[11] LA Metro Board Archives, January 2013, http://boardarchives.metro.net/Items/2013/01_January/20130116P&PItem36.pdf

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Construction of a transmission line could facilitate energy produced on site to be utilized in the regional grid, reducing construction costs while generating a future revenue stream. As previously noted, attempts to invert on-site energy production into immediate use for transit are likely to be prohibitively costly and complex.

Construction of a transmission line may prove to be of significant benefit to financial, environmental and electric reliability considerations. . The HDCJPA can work with SCE, and potentially other utilities, in conjunction with CAISO, to incorporate the HDC's green energy production toward regional goals for sustainability while simultaneously offsetting energy used by the HDC's transit infrastructure.

In pursuit of a sustainable financial model, the leasing of a ROW to build a transmission line may be of strategic value to the HDC, particularly in a P3 arrangement which can reduce costs while providing a stable financial model. Regardless of immediate use, a utility ROW within the HDC is certain to provide tangible benefit and should be included in any design considerations.

9. Infrastructure Compatibility and Technology

9.1 Interoperability with CHSRA and XpressWest

The specifications of the XpressWest system will be critical to HSR interoperability along the HDC. General intelligence sharing between projects would also be of benefit. This report recommends that the HDCJPA defer any further investigation of power infrastructure for the HSR component of the project until the XpressWest project is green-lighted. Progress on the XpressWest project may provide further opportunities for interoperability, as well as shared strategies for integration of green energy production and transmission. This consideration is relevant both to the green energy and non-green energy aspects of the HDC.

Interoperability with CHSRA will also be critical for the HDC's HSR component. To the extent that green energy infrastructure is interrelated with the HSR transitway component of the project, coordination will benefit all parties.

One specific example of potential interoperability between CHSRA, XpressWest, and the HDC would be a net-zero green energy-powered transitway from Los Angeles to Las Vegas. CHSRA's route from Palmdale to downtown Los Angeles is currently scheduled for completion in 2029. If this can be complemented by XpressWest's route from Victorville to Las Vegas and the HDC's route from Palmdale to Victorville, a full HSR route for passengers (and potentially freight) would exist from downtown Los Angeles to Las Vegas. Connecting some 25 million people, such a project could be pursued as a net-zero green energy powered route by using energy offsets from solar power in the high desert. While there are many steps between the present status of these projects and such a collaboration, this is a simple example of how interoperability may prove beneficial to the HDC as well as CHSRA and XpressWest.

9.2 Selecting an HSR Technology

The anticipated operational energy demands for the HSR component of the HDC may vary depending on which technology is utilized for the underlying HSR infrastructure. It will be critical to consider all relevant factors when determining which HSR technology to utilize for the HSR. Further study is recommended, with interoperability with XpressWest and CHSRA to be considered as a primary factor.

CHSRA estimates for energy needs are 59 kWh per mile per train, while XpressWest (running at a lower speed of 150 mph) estimates energy needs of 38 kWh per mile per train. Based on energy consumption measured by the European MEET project (Methodologies for Estimating Air Pollutant Emissions) a German ICE high-speed train consumes between 31–53 kWh/mi.[12] Analysis of German ICE high-speed trains are often used for building models for CHSRA, and as a result, will be used for the HDC as well. Provided that the HSR would run along the entire 63-mile HDC, energy demands can be estimated to fall between 1,953 kWh and 3,339 kWh for a single HSR trip from one end to another of the HDC. The actual number would vary based on the technology, size and shape of the HDC train as well as the speed, the passenger load, and the time spent active vs. inactive.

[12] Methodology for Calculating Transport Emissions and Energy Consumption, http://www.ocs.polito.it/biblioteca/mobilita/MEET.pdf

It is notable that varied HSR technologies do have varying energy efficiency at different speeds. The following chart provides a brief insight into HSR efficiency variance comparing the German ICE train with the German Transrapid Train.

Table 6: Energy Demand for ICE 3 And Transrapid in Watts Hours Per Square Meter of Usable Interior Space and Kilometer. (extrapolated value)*

Speed (kilometers/hour)	Specific energy consumption (Watts hours m^{-2} km^{-1})	
	ICE 3	Transrapid
150	24	27
200	28	31
250	33	35
300	40	41
330	46	45
350	50*	47
400	-	56
430	-	64

There are great potential energy savings within operations of an HSR system. At 300 miles per hour, certain maglev trains may consume as little as 0.4 megajoules per passenger mile compared to 4 megajoules per passenger mile of oil fuel for an 8.5-kilometers per liter (20 miles per gallon) auto that carries 1.8 people at 96 kilometers per hour (60 miles per hour).[13]

Although CHSRA has ruled out maglev, and XpressWest is seeking more cost-effective build options, there are other emerging technologies that may offer similar energy efficiency.

Given the varied costs and impacts of different HSR technology, it is recommended that the HDCJPA immediately build a more specific strategy regarding the type(s) of HSR under consideration. Interoperability with California HSR, and correspondingly XpressWest, will be critical to this decision. Once that decision is made, further research will be required on the specific type(s) of HSR to build appropriately specific environmental, energy and financial impact model(s).

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13 MAGLEV the New Form of Transportation for the 21st Century, http://www.21stcenturysciencetech.com/articles/Summer03/maglev2.html

10. Environmental Impact of Transit Infrastructure

10.1 Life-Cycle Assessment and Life-Cycle Inventory (LCA and LCI)

When modeling and predicting the environmental and financial costs of the HDC's roadway and HSR, it is critical to consider LCA in addition to specific construction and/or operational costs. LCA can be modeled by an LCI. Knowing such costs allows a more comprehensive nature by which the environmental impact of the entire project can be estimated, including often-excluded factors.[14] LCI can provide a complete model of the overall environmental and economic dynamics of the HDC.

It is notable that within the HDC, LCA considerations highlight the importance of including a HSR component. Per the LCI, both environmental and financial costs are consistently higher for vehicular roadway travel than for HSR options.

[14] Life-Cycle Assessment of High-Speed Rail: The case of California, http://iopscience.iop.org/article/10.1088/1748-9326/5/1/014003/meta#erl334561s2

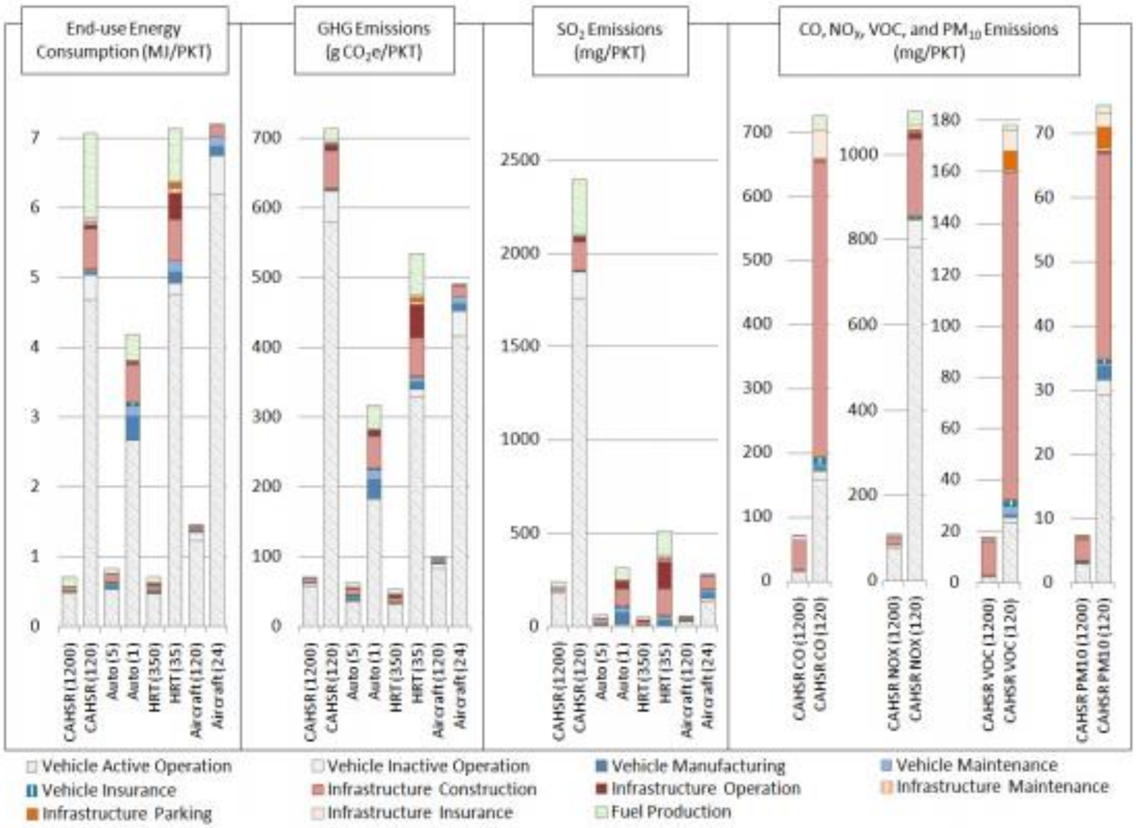

Figure 3: Energy and Emissions Life-CycleRresults per PKT (Source *http://iopscience.iop.org/article/10.1088/1748-9326/5/1/014003/meta#erl334561s29326/5/1/014003/meta#erl334561s2*)

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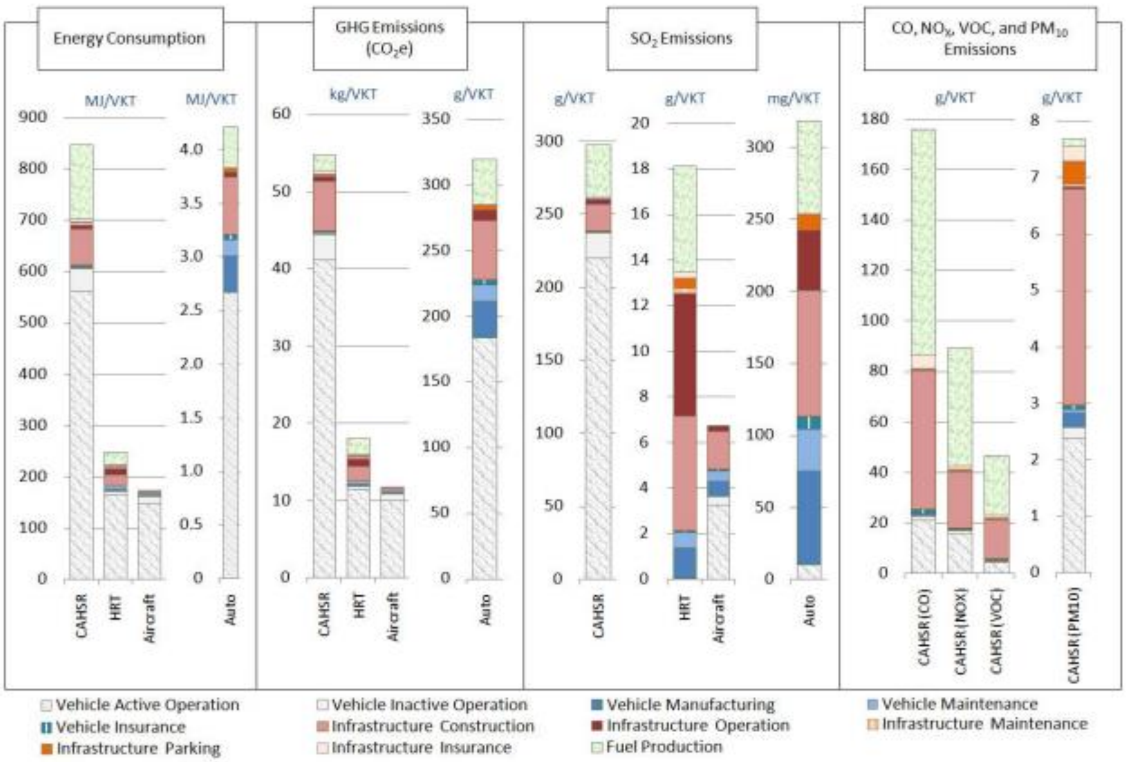
<u>10.2 Passenger Kilometer Traveled and Vehicle Kilometer Traveled (PKT and VKT)</u>

When building potential financial models and projecting energy demands of the HDC, it is critical to consider impact per PKT as well as VKT. For the purposes of this report, both PKT and VKT are calculated based on LCI.



<u>Figure 4: Energy and Emissions Life-Cycle Results per VKT (Source http://iopscience.iop.org/1748-9326/5/1/014003/media/erl10_1_014003supp.pdf)</u>

11. Green and Clean and Storage

11.1 Natural Gas

Palmdale has proposed the construction of a hybrid power plant called Palmdale Energy Project (formerly known as Palmdale Hybrid Power Project (PHPP). Palmdale Energy Project would consist of clean natural gas-fired combined-cycle combustion equipment incorporated with solar thermal-generating equipment. The combined-cycle uses two natural gas-fired combustion turbine generators and the solar thermal equipment uses parabolic collector arrays to generate heat for the process fluid.[15] Both methods are thermally integrated to produce heat energy.

Interconnection between the HDC and Palmdale Hybrid Power Plant could increase the usability of the HDC's renewable energy by providing supplemental inertia through PHPP's turbine power generation. Such high load energy availability is critical for HSR operation and may prove of significant value to the regional grid. If the interconnection point coincides with the transmission component, further benefits may become available.

Palmdale would benefit from the opportunity to reduce its carbon emissions and thereby lower the taxes it pays on such pollutants. Using excess energy from a sustainable source, such as the HDC's solar power, as an offset would be a much simpler option for the plant than building and processing its own additional equipment to comply with emissions standards. Formation of a partnership could serve as an additional future revenue stream for the HDC. A meeting with the Palmdale Energy Project would be useful to further discuss the feasibility of this opportunity.

11.2 Battery Storage

Increasing capacity and reducing costs of large scale battery storage are producing an increasingly relevant option for peak energy demands. Lithium ion batteries continue to increase overall market share with efficient manufacturing, improving cathodes and anodes, and exploration of solid state options. Emerging technologies such as lithium air, lithium-sulphur, and vanadium flow are presently being researched.[16]

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[15] Palmdale Energy Project, http://www.energy.ca.gov/sitingcases/palmdale/

[16] The Future of Battery Technology, http://www.visualcapitalist.com/future-battery-technology/

In January 2017, SCE and Tesla Motors introduced one of the world's largest energy storage facilities at the Mira Loma substation in Ontario.[17] Containing nearly 400 Tesla powerpacks on a 1.5-acre site, this 20MW facility was designed and built in less than 100 days.[18] The scale and speed of this project alone make consideration of battery storage relevant. The pace of change and progress within the battery industry suggests that similar projects may soon become an industry standard.

Emerging battery technologies would complement PV solar by addressing peak inertial demands, including those of the HSR component of the HDC.[19] As these technologies move into the mainstream and costs reduce, such options may well prove feasible for use within the HDC. Further exploration, including an ongoing awareness of recent innovations in battery storage, is recommended.

11.3 Further Considerations – Compressed Natural Gas Refueling Stations

Compressed natural gas refueling stations have become increasingly commonplace over the past 15 years. Private transportation companies have begun to adopt the technology for their trucks and taxis, renovating their fleets and building private refilling stations. However, these hubs cannot be used by the public and do not provide for long-distance travel due to a lack of fueling station availability. Despite their growing popularity, there are only about 992 compressed natural gas refueling stations in the United States today.[20]

There is strong political support for the use of compressed natural gas in the federal government, which would create ample federal grants opportunities for the HDCJPA. The HDC could profit from leasing ROW at off-ramps to one or more natural gas refueling station(s), while promulgating its identity as a green energy corridor in the process.

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[17] Edison and Tesla unveil giant energy storage system, http://www.latimes.com/business/la-fi-tesla-energy-storage-20170131-story.html

[18] A look at the new battery storage facility in California built with Tesla Powerpacks, https://arstechnica.com/information-technology/2017/01/a-look-at-the-new-battery-storage-facility-in-california-built-with-tesla-powerpacks/

[19] Enabling inertial response in utility-scale battery energy storage system, https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/24270/1/PAPER_ISGT_Asia_2016_v1.pdf

[20] Smith, Rebecca. (May 23rd 2012) "Natural Gas Fueling Stations: Few and Far Between." The Wall Street Journal, http://online.wsj.com/article/SB10001424052702304707604577422252404819664.html

12. Political and Civic Landscape

12.1 California Green Energy Legislation

The HDC would bolster progress under California state legislation AB 32 and SB 32, which promote the statewide decrease in greenhouse gas emission levels and encourage the goal of emissions 40% below 1990 levels by 2030.[21] The unique urban-adjacent greenfield nature of the HDC creates opportunities for innovation and new technology that could provide a model for multi-faceted green energy transit corridors around the world. Further research, and outreach to interested parties, will determine which approaches to reducing environmental impacts through generation and transmission of green energy will be incorporated alongside the HDC's transit assets.

The following overview of California state policy includes both historical and future targets for reference. Under the best-case scenario, the HDC would not be operable prior to 2020. However, policies oriented toward 2020 are key contributors to the overall policy environment supporting the construction of infrastructure such as the HDC.

AB 32 - September 27, 2006 - The California Global Warming Solutions Act of 2006 dictates that, by 2020, the statewide greenhouse gases emissions levels must be equivalent to or lower than the statewide emissions levels in 1990.[22]

SB X1-2 - April 12, 2011 - This legislation mandates that 33% of the total electricity sold to retail customers in California per year be generated via specified renewable energy means by December 31, 2020. This goal applies to all retailers of electricity in California, including community choice aggregators, publicly owned utilities, investor-owned utilities, and electricity service providers.[23]

SB 350 - October 7, 2015 - This legislation aims to increase the retail sale of renewable electricity to 50% of all electricity sold within the state by 2030, and to double the energy efficiency savings for natural gas and electricity end uses by 2030.[24]

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21 California Climate Change Legislation, http://www.climatechange.ca.gov/state/legislation.html

22 Assembly Bill 32 Overview, https://www.arb.ca.gov/cc/ab32/ab32.htm

23 Senate Bill X1-2, http://www.leginfo.ca.gov/pub/11-12/bill/sen/sb_0001-0050/sbx1_2_bill_20110412_chaptered.html

24 Senate Bill 350, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350

SB 32 - September 8, 2016 - The California Global Warming Solutions Act of 2016 continues the mission of its predecessor, AB 32, by extending the goal to emissions 40% below 1990 levels, achievable by 2030.[25]

SB 354 (Introduced February, 2017) – If approved, this bill would mandate that utilities produce 100% of their electricity from renewable energy sources by 2045.[26]

12.2 Local City and County General Plans

12.2.1 Los Angeles County

Los Angeles County's 2015 general plan has placed a priority on infrastructure development and highlights a variety of transit and economic objectives that would be furthered by the construction of the HDC. It is Los Angeles County's intention to only undertake sustainable ventures. Under this intention, projects that utilize solar and other energy-efficient and environmentally friendly mechanisms will be more highly regarded than those that do not. The general plan encourages investment in environmentally sensitive transportation design, including hydrogen gas stations, Intelligent Transportation Systems (ITS), and electric vehicle charging stations.[27]

The HDC is committed to the development of a green energy corridor that would allow for the installation of some combination of these features along the ROW. Los Angeles County would therefore receive the benefit of augmenting its transportation infrastructure, improving its public transit viability, and furthering connectivity with other transportation systems - all while advancing toward its goals for environmental protection, green energy, and sustainability.

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[25] Senate Bill 32, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32

[26] 100% by 2045 renewable energy bill introduced in California, https://www.pv-magazine.com/2017/02/21/100-by-2045-renewable-energy-bill-introduced-in-california/

[27] Los Angeles County General Plan, http://planning.lacounty.gov/generalplan/generalplan

12.2.2 San Bernardino County

Adopted in 2007, San Bernardino County's current general plan largely focused on improving infrastructure without damaging the environment. In order to address both commercial and residential needs, development must be multi-modal and operate at regional, county-wide, community, and neighborhood levels.[28] The HDC would reduce the county's environmental impact by reducing vehicular dependency, improving public transit options, offering bike and pedestrian paths, offsetting power consumption through green energy generation and transmission, providing fueling stations for renewably powered vehicles, and improving regional collaboration. The county's general plan discusses at length its desire to conserve natural resources, comply with environmental expectations, promote safe energy extraction, and develop alternative energy opportunities- all of which could be achieved within the HDC's proposed approach.

12.2.3 City of Palmdale

The City of Palmdale released its current general plan in 1993, which expresses a desire to promote transportation accessibility and reduce vehicle miles travelled.[29] The bike and walking paths of the HDC proposal will help to satisfy Palmdale's adherence to local and statewide air quality standards by encouraging non-vehicular transportation, while the green energy corridor will further reduce the environmental footprint of the project within the city boundaries.

In pursuit of those intentions, plans are underway for Palmdale Energy Project, formerly known as PHPP. Once operational, Palmdale Energy Project would have considerable complementary dynamics with the HDC's green energy corridor, including the potential for the HDC's green energy to offset the Palmdale Energy Project consumption of natural gas. In March of 2016, the California Energy Commission reviewed a new plan to build out the project. Subsequent updates are pending.

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[28] San Bernardino County General Plan, http://www.sbcounty.gov/Uploads/lus/GeneralPlan/FINALGP.pdf

[29] City of Palmdale General Plan, http://www.cityofpalmdale.org/Portals/0/Documents/Business/Planning/General%20Plan/03-LandUse.pdf

12.2.4 City of Lancaster

Adopted in 2009, Lancaster's general plan directly describes its intention to promote a transportation corridor in the high desert. The city notes its desire to utilize its unique desert climate to develop and integrate green energy technologies and conservation efforts into its planning.[30] The city of Lancaster has been instrumental in paving the way for a green energy community. The city's goal of becoming the nation's first "Net Zero Energy" community is well underway. The HDC's green energy corridor approach, replete with solar paneling to take advantage of the copious sunlight, transmission infrastructure, electric vehicle charging stations to reduce emissions, and rainwater capture systems to salvage the sparse precipitation, could complement Lancaster's already outstanding environmental efforts, and thus help get the city closer to its goal of being one of the world's first "Net Zero Cities." Finally, the presence of running and bike trails along the corridor would help the city achieve its goals of emphasizing healthy living and reducing vehicular traffic.

12.2.5 City of Adelanto

The City of Adelanto adopted its most recent general plan in 1994, focusing on environmental mitigation techniques and inter-jurisdictional participation to foster growth. Adelanto would like to promote the use of alternative forms of transportation to lessen the frequency of single-passenger car trips for local and regional travel, while expanding the existing network of running and bike trails.[31] Adelanto is ready to work with San Bernardino County, Caltrans, and other jurisdictional organizations to orchestrate and secure innovative financing for infrastructure projects. The HDC could supplement each of these goals, enhancing Adelanto's accessibility and reducing harmful local emissions.

12.2.6 City of Victorville

Victorville released its current general plan in 2008. The city stressed creating improved vehicular and multi-modal access to satisfy the transportation infrastructure needs of current and future passenger travel as well as goods movement.[32] The HDC corridor would allow Victorville to connect effectively with other regional roadways, and the alternative energy components would limit the environmental impacts of the increased through-traffic.

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[30] City of Lancaster General Plan, http://www.cityoflancasterca.org/home/showdocument?id=9323

[31] City of Adelanto General Plan, http://www.ci.adelanto.ca.us/DocumentCenter/Home/View/221

[32] City of Victorville General Plan, http://www.victorvilleca.gov/uploadedFiles/CityDepartments/Development/GeneralPlan.pdf

12.2.7 City of Apple Valley

According to its 2009 general plan, Apple Valley has already set about reserving ROW in the future area of the HDC. The town notes that the presence of walking paths, bike lanes, and off-street trails is especially important along major roadways in the community. Apple Valley also set out a series of objectives that it believes to be important for operating a sustainable transportation system. These include: network connectivity, operational balance, emissions reduction/ energy efficiency, pedestrian accommodations, transit readiness, and quality public space.[33] Upon completion, the HDC would offer considerable progress toward each of these objective areas.

13. Conclusion

The green energy components of the HDC provide potential for the project to establish cutting-edge success in environmental responsibility, financial management, community engagement, regional collaboration, policy alignment, and transit-energy hybrid infrastructure.

By developing a robust and efficient solar system and transmission line along the HDC, the project can meet triple bottom line goals from an environmental, economic, and civic perspective, while strategic P3 agreements can assure long-run efficiency, effectiveness, and sustainability.

In parallel to the HDC itself, such a project will generate a range of positive impacts in surrounding areas, ranging from clean energy availability, improved transit options, private sector investment, and green energy job creation.

The HSR component of the HDC provides a powerful opportunity to further advance the project's values and impact. Energy offsets could be structured to create the first net-zero impact transit of such scale anywhere in the world, while that same energy production can drive solid long-term asset management. Collaboration with CHSRA and XpressWest will be critical for interoperability, and creates opportunity for furthering the dynamic HDC model beyond its immediate footprint.

[33] Apple Valley General Plan, http://www.applevalley.org/home/showdocument?id=13926

The alignment of local interests, state policy targets, federal infrastructure priorities, technological innovation, and private sector interest come together to make a compelling case for the HDC as a green energy-powered, multimodal transitway to break ground as a critical piece of high desert infrastructure.

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Smith, Rebecca. (May 23rd 2012) "Natural Gas Fueling Stations: Few and Far Between." The Wall Street Journal, http://online.wsj.com/article/SB10001424052702304707604577422252404819664.html

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U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016, http://www.nrel.gov/docs/fy16osti/67142.pdf

Wind Turbine Separation Distances Matter, http://www.na-paw.org/Mitchell/Mitchell-Wind-Turbine-Separation-Distances.pdf

15. Appendices

15.1 Appendix A: Renewable Energy Options

15.1.1 Solar

Solar energy uses special cells to convert sunlight into electricity. The solar cells can be expensive to produce, but continual technological advancements are making the devices more cost-effective and energy-efficient. Because solar panels only generate electricity during daylight hours, and can be hampered by cloudy conditions or pollution,[34] additional gains are often gleaned when pairing solar with battery storage. Sophisticated contractors and developers are often able to offer this option.

Analysis of construction costs, ongoing maintenance and operation costs, overall energy generation, and ongoing revenue potential make solar energy the most appropriate means of energy production for the green energy corridor. The recommended solar panels would be arranged in one or more clusters to reduce costs and maximize both environmental and financial benefit.

Figure 5: Solar Panels (source: http://www.thealternativedaily.com/solar-energy-bright-future/)

[34] Institute for Energy Research: Solar, http://instituteforenergyresearch.org/topics/encyclopedia/solar/

15.1.2 Wind

Machines utilizing wind power spin turbines to generate electricity. However, these turbines can have an adverse influence upon local wildlife, particularly bird populations, and produce significant noise pollution. Additionally, many people feel that the equipment used obstructs scenic views.

Concerns related to land use and aesthetics are of particular importance when considering wind power along the HDC.

It is possible, however, to construct wind turbines in various sizes. They can be made for single residential use or constructed on a large commercial scale. Generally, the larger the turbine, the more cost-effective it is long-term. The initial challenge would be securing the requisite land for construction of large scale wind turbines. In parallel, challenges related to existing land use policy and concerns of aesthetic and/or environmental impacts may emerge.

Each turbine requires a significant geographic footprint, including not just the turbine itself, but also enough clearance to ensure smooth and uninterrupted wind flow. Each turbine must be far enough from other turbines that the inevitable turbulence created by one turbine doesn't disturb other turbines. The general rule of thumb is that turbines ought to be spaced seven rotor diameters from each other.[35] For a 1MW turbine (likely optimal size for this type of project), approximately 8.5 acres would be required. This represents approximately five times as much land for similar electric production.[36]

[35] Wind Turbine Separation Distances Matter, http://www.na-paw.org/Mitchell/Mitchell-Wind-Turbine-Separation-Distances.pdf

[36] Land Requirements for Carbon-Free Technologies, https://www.nei.org/CorporateSite/media/filefolder/Policy/Papers/Land_Use_Carbon_Free_Technologies.pdf?ext=.pdf

Figure 6: Wind Turbines (source: http://www.wpm.co.nz/)

15.1.3 Geothermal

Geothermal energy leverages the near-constant temperature of the Earth's upper levels of 50-60 degrees Fahrenheit, providing heat in the winter and cooling in the summer.[37] Holes are drilled through the upper 10-20 feet of land into the Earth to connect the ground-level geothermal heat pumps via a set of looped piping, and water is then pumped through installed piping. In winter, the water reaches the 50-60-degree temperature of the Earth, higher than the air temperature, and is warmed; in summer, the water reaches the 50-60-degree temperature of the Earth, cooler than the air temperature, and is cooled. The water is then pumped back up through the looped piping and is then used to heat or cool buildings, provide hot water, or used to create steam to power a turbine.

The cost of a geothermal system is higher than other renewable energy sources.[38] Also, geothermal is typically used to heat, cool or power a building, as the significant network of piping required makes distributing the energy over distance very difficult and expensive. For a building's power needs, geothermal can be attractive in certain circumstances, though the payback is typically longer than wind or solar.

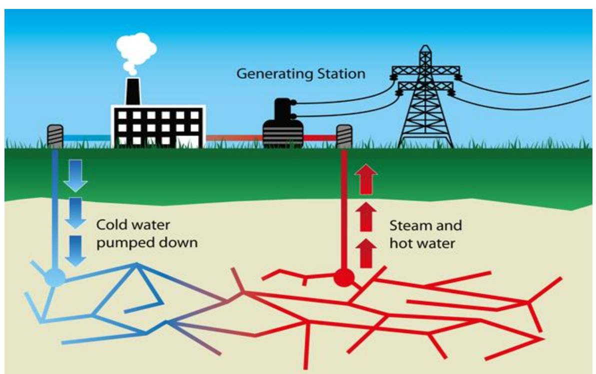

Figure 7: Diagram Showing the Principle of Geothermal Energy Generation (source: http://www.carbonneutral.com/carbon-offsets/geothermal-energy)

37 Geothermal Energy http://www.legacyproject.org/legacycenter/geothermal.html

38 Geothermal Basics - Power Plant Costs http://geo-energy.org/geo_basics_plant_cost.aspx

15.1.4 Hydropower

Hydroelectricity is an age-old source of power, channeling fast-moving water in dams to spin turbines in generators that produce electricity. Though the energy production process does not produce pollution, there are other environmental concerns and ecological impacts associated with the damming of rivers. Despite these issues, hydroelectric power remains one of the more cost-effective means of generating renewable energy.[39]

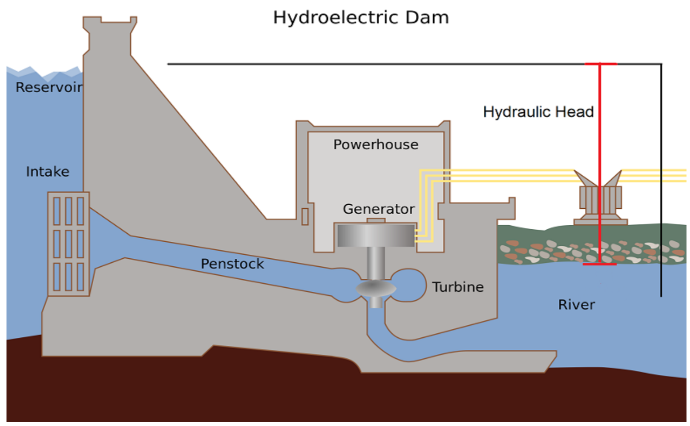

Figure 8: Diagram Representing a Hydroelectric Dam (source: http://energyeducation.ca/encyclopedia/Hydraulic_head)

15.1.5 Biomass

Biomass is organic matter gathered from living organisms. It can be used as a source of energy when combusted or converted to other biofuel forms via thermal and biochemical methods.[40] However, it is expensive to gather a large amount of biomass and the process of obtaining large quantities of biomass can be impeded by regulatory issues.[41]

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39 Energy from Moving Water https://www.eia.gov/Energyexplained/?page=hydropower_home

40 Biomass—renewable energy from plants and animals https://www.eia.gov/Energyexplained/index.cfm?page=biomass_home

41 Biomass Energy Pros and Cons http://www.conserve-energy-future.com/pros-and-cons-of-biomass-energy.php

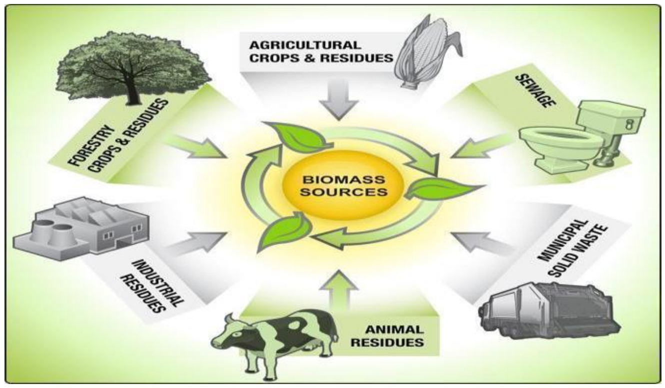

Figure 9: Diagram Showing the Sources of Biomass (source: http://theearthproject.com/biomass/)

15.2 Appendix B: Solar System Pro Forma Cash Flow Over 30 Years

Power Purchase Agreement	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	30 Year Total
EXPENDITURES								
Project Cost	$ 30,000,000							$ 30,000,000
Financing	$ (30,000,000)							$ (30,000,000)
PPA Payment		$ 2,484,337	$ 2,533,713	$ 2,584,071	$ 2,635,429	$ 2,687,808	$ 2,741,229	$ 60,287,783
O&M (begins Year 21)								$ 3,511,497
Insurance (begins Year 21)								$ 731,562
Annual Expenditures		$ 2,484,337	$ 2,533,713	$ 2,584,071	$ 2,635,429	$ 2,687,808	$ 2,741,229	$ 64,530,842
Cumulative Expenditures		$ 2,484,337	$ 5,018,051	$ 7,602,121	$ 10,237,551	$ 12,925,359	$ 15,666,588	$ 1,219,367,073
INCOME								$ -
Energy Savings		$ 2,965,522	$ 3,068,722	$ 3,175,513	$ 3,286,021	$ 3,400,375	$ 3,518,708	$ 152,585,283
Annual Income		$ 2,965,522	$ 3,068,722	$ 3,175,513	$ 3,286,021	$ 3,400,375	$ 3,518,708	$ 152,585,283
Cumulative Income		$ 2,965,522	$ 6,034,243	$ 9,209,757	$ 12,495,778	$ 15,896,152	$ 19,414,860	
Annual Net Nominal		$ 481,184	$ 535,008	$ 591,442	$ 650,592	$ 712,566	$ 777,479	**$ 88,054,441**
Cumulative Net Nominal		$ 481,184	$ 1,016,193	$ 1,607,635	$ 2,258,227	$ 2,970,793	$ 3,748,272	

Assumptions: Energy production and lease payments begin 1 year after Notice to Proceed; current cost of electricity $.0816; PPA price $.065. Annual energy escalation of 4%; annual O&M and insurance escalation of 1.5%. GFS has provided illustrations of PPA repayment schedule, assuming moderate to good credit. Final eligibility, amortization and payment schedule will be determined upon formal project submission and approval.

GFS does not provide tax advice. Project owners should consult their accountant or tax professional.

Discount Rate	3.00%
NPV	**$46,486,694**

Power Purchase Agreement	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	30 Year Total
EXPENDITURES									
Project Cost									$ 30,000,000
Financing									$ (30,000,000)
PPA Payment	$ 2,795,711	$ 2,851,275	$ 2,907,944	$ 2,965,740	$ 3,024,684	$ 3,084,800	$ 3,146,110	$ 3,208,639	$ 60,287,783
O&M (begins Year 21)									$ 3,511,497
Insurance (begins Year 21)									$ 731,562
Annual Expenditures	$ 2,795,711	$ 2,851,275	$ 2,907,944	$ 2,965,740	$ 3,024,684	$ 3,084,800	$ 3,146,110	$ 3,208,639	$ 64,530,842
Cumulative Expenditures	$ 18,462,299	$ 21,313,574	$ 24,221,518	$ 27,187,258	$ 30,211,942	$ 33,296,742	$ 36,442,852	$ 39,651,491	$ 1,219,367,073
INCOME									$ -
Energy Savings	$ 3,641,159	$ 3,767,871	$ 3,898,993	$ 4,034,678	$ 4,175,085	$ 4,320,378	$ 4,470,727	$ 4,626,308	$ 152,585,283
Annual Income	$ 3,641,159	$ 3,767,871	$ 3,898,993	$ 4,034,678	$ 4,175,085	$ 4,320,378	$ 4,470,727	$ 4,626,308	$ 152,585,283
Cumulative Income	$ 23,056,019	$ 26,823,890	$ 30,722,882	$ 34,757,560	$ 38,932,645	$ 43,253,023	$ 47,723,749	$ 52,350,057	
Annual Net Nominal	$ 845,448	$ 916,596	$ 991,048	$ 1,068,938	$ 1,150,401	$ 1,235,578	$ 1,324,617	$ 1,417,669	**$ 88,054,441**
Cumulative Net Nominal	$ 4,593,720	$ 5,510,316	$ 6,501,364	$ 7,570,302	$ 8,720,703	$ 9,956,281	$ 11,280,898	$ 12,698,567	

Assumptions: Energy production and lease payments begin 1 year after Notice to Proceed; current cost of electricity $.0816; PPA price $.065. Annual energy escalation of 4%; annual O&M and insurance escalation of 1.5%. GFS has provided illustrations of PPA repayment schedule, assuming moderate to good credit. Final eligibility, amortization and payment schedule will be determined upon formal project submission and approval.

GFS does not provide tax advice. Project owners should consult their accountant or tax professional.

Discount Rate	3.00%
NPV	**$46,486,694**

Appendix B: Solar System Pro Forma Cash Flow Over 30 Years Continued…

Power Purchase Agreement	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	30 Year Total
EXPENDITURES									
Project Cost									$ 30,000,000
Financing									$ (30,000,000)
PPA Payment	$ 3,272,411	$ 3,337,450	$ 3,403,782	$ 3,471,432	$ 3,540,426	$ 3,610,792			$ 60,287,783
O&M (begins Year 21)							$ 328,094	$ 333,015	$ 3,511,497
Insurance (begins Year 21)							$ 68,353	$ 69,378	$ 731,562
Annual Expenditures	$ 3,272,411	$ 3,337,450	$ 3,403,782	$ 3,471,432	$ 3,540,426	$ 3,610,792	$ 396,447	$ 402,393	$ 64,530,842
Cumulative Expenditures	$ 42,923,901	$ 46,261,351	$ 49,665,132	$ 53,136,564	$ 56,676,990	$ 60,287,783	$ 60,684,229	$ 61,086,623	$ 1,219,367,073
INCOME									$ -
Energy Savings	$ 4,787,304	$ 4,953,902	$ 5,126,298	$ 5,304,693	$ 5,489,296	$ 5,680,323	$ 5,877,999	$ 6,082,553	$ 152,585,283
Annual Income	$ 4,787,304	$ 4,953,902	$ 5,126,298	$ 5,304,693	$ 5,489,296	$ 5,680,323	$ 5,877,999	$ 6,082,553	$ 152,585,283
Cumulative Income	$ 57,137,361	$ 62,091,263	$ 67,217,560	$ 72,522,253	$ 78,011,549	$ 83,691,872	$ 89,569,871	$ 95,652,424	
Annual Net Nominal	$ 1,514,893	$ 1,616,452	$ 1,722,516	$ 1,833,261	$ 1,948,870	$ 2,069,531	$ 5,481,552	$ 5,680,160	**$ 88,054,441**
Cumulative Net Nominal	$ 14,213,460	$ 15,829,912	$ 17,552,428	$ 19,385,689	$ 21,334,558	$ 23,404,090	$ 28,885,642	$ 34,565,801	

Assumptions: Energy production and lease payments begin 1 year after Notice to Proceed; current cost of electricity $.0816; PPA price $.065. Annual energy escalation of 4%; annual O&M and insurance escalation of 1.5%. GFS has provided illustrations of PPA repayment schedule, assuming moderate to good credit. Final eligibility, amortization and payment schedule will be determined upon formal project submission and approval.

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Discount Rate	3.00%
NPV	**$46,486,694**

Power Purchase Agreement	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30	30 Year Total
EXPENDITURES									
Project Cost									$ 30,000,000
Financing									$ (30,000,000)
PPA Payment									$ 60,287,783
O&M (begins Year 21)	$ 338,011	$ 343,081	$ 348,227	$ 353,450	$ 358,752	$ 364,133	$ 369,595	$ 375,139	$ 3,511,497
Insurance (begins Year 21)	$ 70,419	$ 71,475	$ 72,547	$ 73,635	$ 74,740	$ 75,861	$ 76,999	$ 78,154	$ 731,562
Annual Expenditures	$ 408,429	$ 414,556	$ 420,774	$ 427,086	$ 433,492	$ 439,994	$ 446,594	$ 453,293	$ 64,530,842
Cumulative Expenditures	$ 61,495,052	$ 61,909,608	$ 62,330,382	$ 62,757,468	$ 63,190,960	$ 63,630,955	$ 64,077,549	$ 64,530,842	$ 1,219,367,073
INCOME									$ -
Energy Savings	$ 6,294,226	$ 6,513,265	$ 6,739,927	$ 6,974,476	$ 7,217,188	$ 7,468,346	$ 7,728,244	$ 7,997,187	$ 152,585,283
Annual Income	$ 6,294,226	$ 6,513,265	$ 6,739,927	$ 6,974,476	$ 7,217,188	$ 7,468,346	$ 7,728,244	$ 7,997,187	$ 152,585,283
Cumulative Income	$ 101,946,650	$ 108,459,915	$ 115,199,842	$ 122,174,318	$ 129,391,505	$ 136,859,851	$ 144,588,096	$ 152,585,283	
Annual Net Nominal	$ 5,885,797	$ 6,098,709	$ 6,319,152	$ 6,547,390	$ 6,783,696	$ 7,028,352	$ 7,281,650	$ 7,543,894	**$ 88,054,441**
Cumulative Net Nominal	$ 40,451,598	$ 46,550,307	$ 52,869,459	$ 59,416,850	$ 66,200,545	$ 73,228,897	$ 80,510,547	$ 88,054,441	

Assumptions: Energy production and lease payments begin 1 year after Notice to Proceed; current cost of electricity $.0816; PPA price $.065. Annual energy escalation of 4%; annual O&M and insurance escalation of 1.5%. GFS has provided illustrations of PPA repayment schedule, assuming moderate to good credit. Final eligibility, amortization and payment schedule will be determined upon formal project submission and approval.

GFS does not provide tax advice. Project owners should consult their accountant or tax professional.

Discount Rate	3.00%
NPV	**$46,486,694**

15.3 Appendix C: List of Acronyms

CAISO	California Independent System Operator
CEQA	California Environmental Quality Act
CHSRA	California High Speed Rail Authority
DOT	Department of Transportation
EIFD	Enhanced Infrastructure Finance District
EPC	Engineering, Procurement and Construction
FERC	Federal Energy Regulatory Commission
HDC	High Desert Corridor
HDCJPA	High Desert Corridor Joint Power Authority
HSR	High-Speed Rail
ITS	Intelligent Transportation Systems
LCA	Life-Cycle Assessment
LCI	Life-Cycle Inventory
NREL	National Renewable Energy Lab
P3	Public Private Partnership
PHPP	Palmdale Hybrid Power Project
PKT	Passenger Kilometer Traveled
PV	Photovoltaic
RFI	Request for Information
ROW	Right-of-Way

SCE	Southern California Edison
TRTP	Tehachapi Renewable Transmission Project
VKT	Vehicle Kilometer Traveled

15.4 Appendix D: Glossary of Technical Terms

Alternative Energy Fuel Stations: Non-conventional and advanced fuel stations, using materials other than conventional fossil fuels (petroleum oil).

Biomass: Organic matter gathered from living organisms that can be used as a source of energy when combusted or converted to other biofuel forms via thermal and biochemical methods.

California Environmental Quality Act (CEQA): Established in 1970, requires public agencies to regulate activities that may affect the quality of the environment and prevent damage to the environment.

California High Speed Rail Authority (CHSRA): A state agency run by a Board of Governors, established to begin formal planning in preparation of California High Speed Rail.

Capital Cost: The total cost needed to bring a project to a commercially operable status.

Clean Energy: Energy that is collected from renewable resources such as sunlight, wind, or geothermal heat.

Clean natural gas-fired combined-cycle combustion: Using natural gas to heat an assembly of engines that work together and in turn usually drives electrical generators.

Clustered solar system: Cost effective design of grouping large solar panels.

Degradation rate: The rate at which a solar system will wear down.

Department of Transportation (DOT): Municipal agency that oversees transportation planning, design, construction, maintenance and operations.

Double/single-axis tracker system: A device that orients solar panels toward the Sun.

Economies of scale: Cost advantages gained by an increased level of production.
Energy footprint: A measure of land required to absorb the CO_2 emissions.

Energy kites: A kite system that has energy-harvesting parts that fly transverse to the direction of the wind.

Energy transmission line: The movement of electrical energy from a generating site to an electrical substation.

Engineering, Procurement and Construction (EPC): A contracting arrangement where the contractor is responsible for all activities - from design, procurement, construction, to commissioning and handover of the project.

Enhanced Infrastructure Finance District (EIFD): Allows for infrastructure development funded by tax increment revenue.

Fossil fuel: A natural fuel such as coal or gas, formed from the remains of living organisms.

Geothermal: A source of clean and sustainable energy generated from heat in the Earth.

Greenhouse gas emissions: Gases that trap heat in the atmosphere, and absorb and emit radiation within the thermal infrared range.

High-road standards: An approach in which infrastructure projects are expected to deliver multiple benefits.

Hydrogen fueling stations: Fueling stations intended to power hydrogen vehicles.

Hydropower: Power generated from the energy of falling or fast running water.

Industry forum: A meeting coordinated by gathering industry experts and asking for feedback.

Intelligent Transportation Systems (ITS): An application which aims to provide advanced services relating to different modes of transport and traffic.

Interoperability: The extent to which systems can exchange data, and interpret that shared data.

Life-Cycle Assessment (LCA): A technique to assess environmental impacts associated with all the stages of a product's life.

Life-Cycle Inventory (LCI): Analysis involves creating an inventory of flows from and to nature for a product system.

Lifetime maintenance costs: A total of all other costs relating to the project over

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its expected lifetime, in addition to the amount paid to acquire it.

Long-run assets: The value of a company's property, equipment and other capital assets, minus depreciation.

National Renewable Energy Lab (NREL): A government-owned facility specializing in renewable energy and energy efficiency research and development.

Net present value: Present values of cash outflows subtracted from the present values of cash inflows over a period of time to calculate profit.

Operation costs: The expenses which are related to the operation of the equipment or facility.

Passenger Kilometer Traveled (PKT): Calculated by dividing total distance travelled in a given period, by the number of passengers.

Passenger load: Measures the capacity utilization of public transport services.

Photovoltaic: Solar cells that convert sunlight directly into electricity.

Prevailing wage: The hourly wage paid in the largest city in each county, to the majority of workers.

Public Private Partnership (P3): A cooperative arrangement between two or more public and private sectors.

Rainwater capture systems: The accumulation of rainwater for reuse.

Regional power grid: An interconnected network that generates power and delivers electricity from producers to consumers.

Request for Information (RFI): Standard business process for collecting written information about various suppliers.

Right-of-Way (ROW): A right to make a way over a piece of land.

Rooftop solar: Solar panels mounted on the rooftop of residential or commercial buildings to generate electricity.

Solar energy: Energy that is produced from radiant light and heat from the sun.

Solar farms: Solar panels clustered for generating a large amount of electricity.

Solar panels: Panels which generate electricity by absorbing sunlight.

Southern California Edison (SCE): The primary electricity supply company for much of Southern California.

Tax increment financing (TIF): Public financing method that is used as a subsidy for redevelopment.

Utility substations: Electrical power may flow through a utility substation located between where the power is generated and the consumer.

Vehicle Kilometer Traveled (VKT): A measure of traffic flow, calculated by multiplying the number of vehicles on a given road or traffic network by the average length of their trips.

Water-conscious infrastructure: Infrastructure that reduces water wastage.

Wind turbines: A device that converts the wind's kinetic energy into electrical energy.

15.5 Appendix E: List of Figures

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15.6 Appendix F: List of Tables