Green Energy Feasibility Study Report

High Desert Corridor
New State Route 138/E-220
Palmdale to Apple Valley (SR-14 to SR-18)

June 2014

Parsons Transportation Group Inc.
100 West Walnut Street
Pasadena, CA 91124

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Prepared by: Randolph L Britt Date: June 16, 2014

Randy Britt
Parsons
100 West Walnut Street
Pasadena, CA 91124

Approved by: Karl Price Date: 6/18/14

Karl Price
California Department of Transportation
100 South Street, Mail Stop 16A
Los Angeles, CA 90012

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Acronyms

AB	Assembly Bill
CAHST	California High-Speed Train
Caltrans	California Department of Transportation
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CFR	*Code of Federal Regulations*
CNG	compressed natural gas
CSP	concentrated solar power
DOE	Department of Energy
DOT	Department of Transportation
EIA	Energy Information Administration
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ENV SP	Envision™ Sustainability Professional
EPA	Environmental Protection Agency
EV	electric vehicle
FHWA	Federal Highway Administration
FS	Feasibility Study
GHG	greenhouse gas
GWh	gigawatt hour
HAWT	horizontal-axis wind turbine
HDC	High Desert Corridor
HSR	High-Speed Rail
I-5	Interstate 5
I-15	Interstate 15
I-205	Interstate 205
ISI	Institute for Sustainable Infrastructure
JPA	Joint Powers Authority
kph	kilometers per hour
kW	Kilowatts
kWh	Kilowatt-hours
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LNG	liquefied natural gas
Metro	Los Angeles County Metropolitan Transportation Authority
mph	miles per hour
MTD	Montana Transportation Department
MW	Megawatts
NEPA	National Environmental Policy Act
NGV	natural gas vehicle
NREL	National Renewable Energy Laboratory
O&M	operation and maintenance
P3	public–private partnership
PGE	Portland General Electric
PPA	power purchase agreement
PPP	Public/private partnership

PSE&G	Public Service Electric and Gas Company
PV	Photovoltaic
PVNB	photovoltaic noise barrier
RE	renewable energy
REC	renewable energy credit
RFP	Request for Proposal
ROW	right-of-way
RSTIS	Regionally Significant Transportation Investment Study
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SANBAG	San Bernardino County Associated Governments
SCAG	Southern California Association of Governments
SMUD	Sacramento Municipal Utility District
SR	State Route
UV	Ultraviolet
VAWT	vertical-axis wind turbine

1 Introduction

This Green Energy Feasibility Study (FS) Report is a high-level feasibility study of potential "green" energy opportunities for the High Desert Corridor (HDC) as a joint-use transportation and energy corridor. According to the U.S. Environmental Protection Agency (EPA), Green Power [or Energy] can be defined as energy from indefinitely available resources and whose generation has zero/negligible environmental impacts, whether through reduced emissions or minimal environmental disruption. Green energy has other names, including clean or sustainable energy. Renewable energy (RE) will be the primary type of green energy discussed in this report; however, there may also be opportunities to incorporate natural gas into the corridor development.

This study researched and investigated a range of RE and natural gas alternatives and technologies, analyzed them for feasibility and suitability for the HDC, and presents a short list of recommended RE and natural gas alternatives for implementation on the HDC. Most of the stakeholders for the HDC include California Department of Transportation (Caltrans), Los Angeles County Metropolitan Transportation Authority (Metro), and Joint Powers Authority (JPA), which have been involved in the alternatives analysis process.

The HDC Project is being undertaken by Caltrans in coordination with Metro and other partner agencies. The HDC Project involves construction of a new, approximately 63-mile-long, east-west freeway/expressway and a possible toll or rail facility between State Route (SR) 14 in Los Angeles County and SR-18 in San Bernardino County. The general location of the project is illustrated in Figure 1-1. The HDC was identified as E-220 in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) and is officially designated as a high-priority corridor of the National Highway System. The project is proposed as a means of improving mobility and access for people and goods in the rapidly growing Antelope, Victor, and Apple Valley areas of Los Angeles and San Bernardino counties.

To comply with the requirements of the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA), an Environmental Impact Report/Environmental Impact Statement (EIR/EIS) is being prepared.

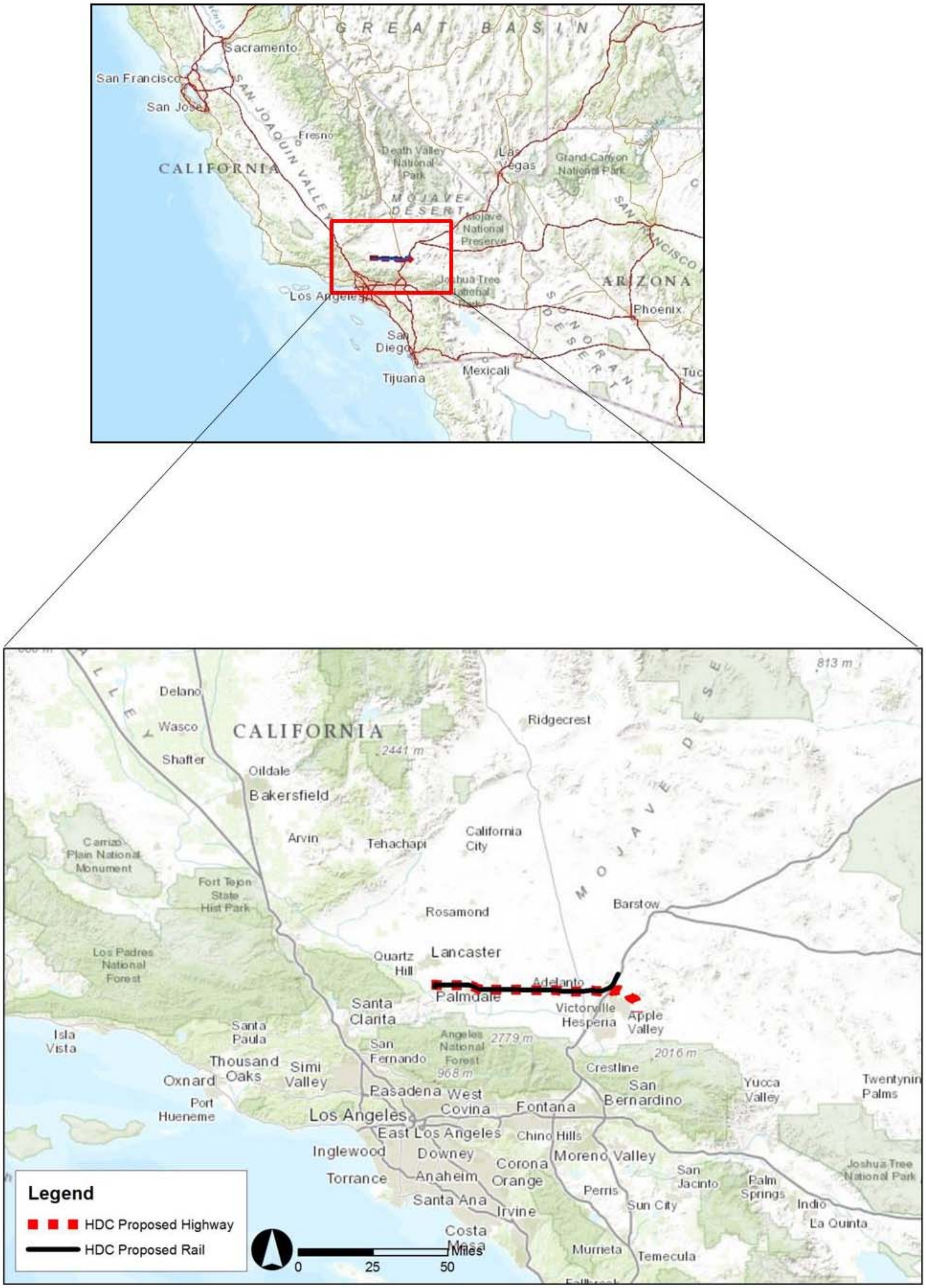


Figure 1-1: Project Location

2 Green Energy Feasibility Study Goals and Objectives

The objectives of the HDC green energy feasibility study are as follows:

- Establish a streamlined list of recommended RE alternatives for implementation on the HDC to meet the following goals:
  - Increase usage of renewable resources for energy generation to meet the State's sustainability goals.
  - Lessen reliance of nonrenewable resources such as coal, oil, and petroleum-based fuels for energy generation.
  - Reduce adverse environmental impacts (e.g., reduce greenhouse gas (GHG) emissions and carbon footprints).
  - Reduce the State's energy long-term expenditure.
- Meet the approval of the stakeholders: Caltrans, Metro, and JPA.
- Provide information regarding the various types of project financing and ownership options for the RE generation.
- Recommend viable RE alternatives that can be carried forward for further evaluation and consideration in the HDC environmental document.

3 Background of the HDC Project

3.1 Planning Background

The HDC has a long history and has been the subject of numerous previous studies. It was originally conceived in the 1970s as a metropolitan bypass to provide an alternate route for vehicles traveling from Interstate 5 (I-5) to communities to the east such as San Bernardino, Victorville, Barstow, and Las Vegas via Interstate 15 (I-15).

In April 2002, Caltrans Districts 7 and 8, in partnership with Federal Highway Administration (FHWA), Southern California Association of Governments (SCAG), San Bernardino County Associated Governments (SANBAG), Metro, County of Los Angeles, County of San Bernardino, City of Palmdale, City of Lancaster, City of Adelanto, City of Hesperia, City of Victorville, and Town of Apple Valley, completed a 10-year effort that culminated in the publication of the Regionally Significant Transportation Investment Study (RSTIS) for the HDC. The RSTIS Steering Committee adopted the proposed east-west corridor as the locally preferred alternative. This corridor is depicted in Figure 3-1 at the end of this chapter.

Simultaneously, the North County Combined Highway Corridor Study was initiated to develop a multimodal transportation plan for the northern portion of Los Angeles County, addressing short-term (2010) and long-term (2025) requirements to accommodate a variety of purposes. This corridor serves large volumes of traffic for personal travel and goods movement. The North County Combined Highway Corridors Study, approved in June 2004, was conducted by Metro in cooperation with the County of Los Angeles. The east-west corridor study focused on SR-138 circulation as a key feature to reduce traffic congestion.

In 2005, the HDC, identified as E-220, was officially recognized in SAFETEA-LU Section 1305 as a high-priority corridor of the National Highway System between Los Angeles and Las Vegas via Palmdale and Victorville.

In 2006, the HDC JPA was formed to oversee the financing and construction of a 63-mile stretch of freeway corridor from SR-14 in the Palmdale/Lancaster area through the High Desert cities of Adelanto, Victorville, and Apple Valley (i.e., the HDC). Its members include County of San Bernardino, County of Los Angeles, Town of Apple Valley, and the cities of Adelanto, Victorville, Lancaster, and Palmdale.

In 2007 and 2009, environmental studies began on two small components of the HDC. The City of Victorville, with oversight from Caltrans District 8, began work on the HDC Phase 1 project in 2007. This project extended between US 395 and SR-18 on the eastern end of the corridor. On the western end, Caltrans District 7 began work in 2009 on the new SR-138 project between SR-14 and 100th Street East. During the course of conducting these studies and coordinating with regulatory and resource agencies for the proposed projects, it was determined that they should be combined into one large project, the HDC, which incorporates the two "end pieces" and fills the gap in between them.

The HDC will function as part of the collective transportation system serving local and regional travel needs in north Los Angeles County and San Bernardino County. This corridor will accommodate the substantially increased vehicle capacity demands. The geographic location of the HDC makes it an alternate corridor with potential to avoid congestion in the Los Angeles Basin by routing traffic around congested Los Angeles freeways.

Construction of the HDC is considered necessary to provide for the existing and projected traffic demand attributed to residential growth and increasing commercial developments in the Antelope, Victor, and Apple Valley areas of Los Angeles and San Bernardino counties. This growth is resulting in inadequate capacity and accessibility along the existing east-west roadways, as well as an increasing demand for goods movement and access to regional airports.

3.2 Proposed HDC Project

The proposed HDC Project is located in the High Desert area of Los Angeles and San Bernardino counties, north of the San Gabriel/San Bernardino mountains and the heavily populated areas of those two counties. The proposed project would consist of four main components: highway, rail transit, bikeway, and recommendation for green energy facilities (a subject of this feasibility report). The proposed HDC would extend west to east approximately 63 miles between SR-14 in Palmdale and SR-18 in Apple Valley.

The overall HDC Project is divided into three segments, as illustrated in Figure 3-2, at the end of this chapter.

- **Antelope Valley segment:** From SR-14 to 100th Street East in Palmdale, a distance of approximately 10 miles.
- **High Desert segment:** From Palmdale city limits to Adelanto city limits in unincorporated Los Angeles and San Bernardino counties, a distance of approximately 26 miles.
- **Victor Valley segment:** From west of Caughlin Road in Adelanto to SR-18 east of Joshua Road in Apple Valley, a distance of approximately 27 miles.

Several alternatives to the proposed project have been considered. The following build alternatives are being evaluated in the environmental document:

- Freeway/Expressway Alternative
- Freeway/Expressway Alternative with High-Speed Rail (HSR) Feeder Service Right-of-Way (ROW)
- Freeway/Tollway Alternative
- Freeway/Tollway Alternative with HSR Feeder Service ROW

The general alignments for alternatives that include either the freeway, expressway, or tollway are depicted with alignment variations and local service interchange locations in Figure 3-3, at the end of this chapter.

In 2012, an HSR feeder service component was added to the HDC Project. The HSR Feeder Service, referred to as the rail component of the project, would operate as a new HSR corridor from the existing Metrolink terminus in Palmdale to the XpressWest terminus in the city of Victorville. The HSR feeder service would provide a critical missing interregional rail link between two major infrastructure investments currently in the planning stages in southern California: (1) the California High-Speed Train (CAHST) link between Los Angeles and San Francisco, and (2) the XpressWest corridor between Victorville and Las Vegas. This feeder rail service will constitute the missing rail connection between Los Angeles and Las Vegas, linking the rail corridor between Los Angeles and Palmdale, served by the existing Metrolink Antelope Valley Line, and the future CAHST connection between Los Angeles and the Central Valley, to the future XpressWest corridor beginning in Victorville.

In addition to the alternatives outlined above, all HDC Project build alternatives would include a bicycle route, primarily extending along the corridor between major urban centers, from US 395 in Adelanto on the east to the Palmdale Transportation Center on the west, for approximately 36 miles. Green energy technologies are also planned to be incorporated into the corridor as deemed applicable.

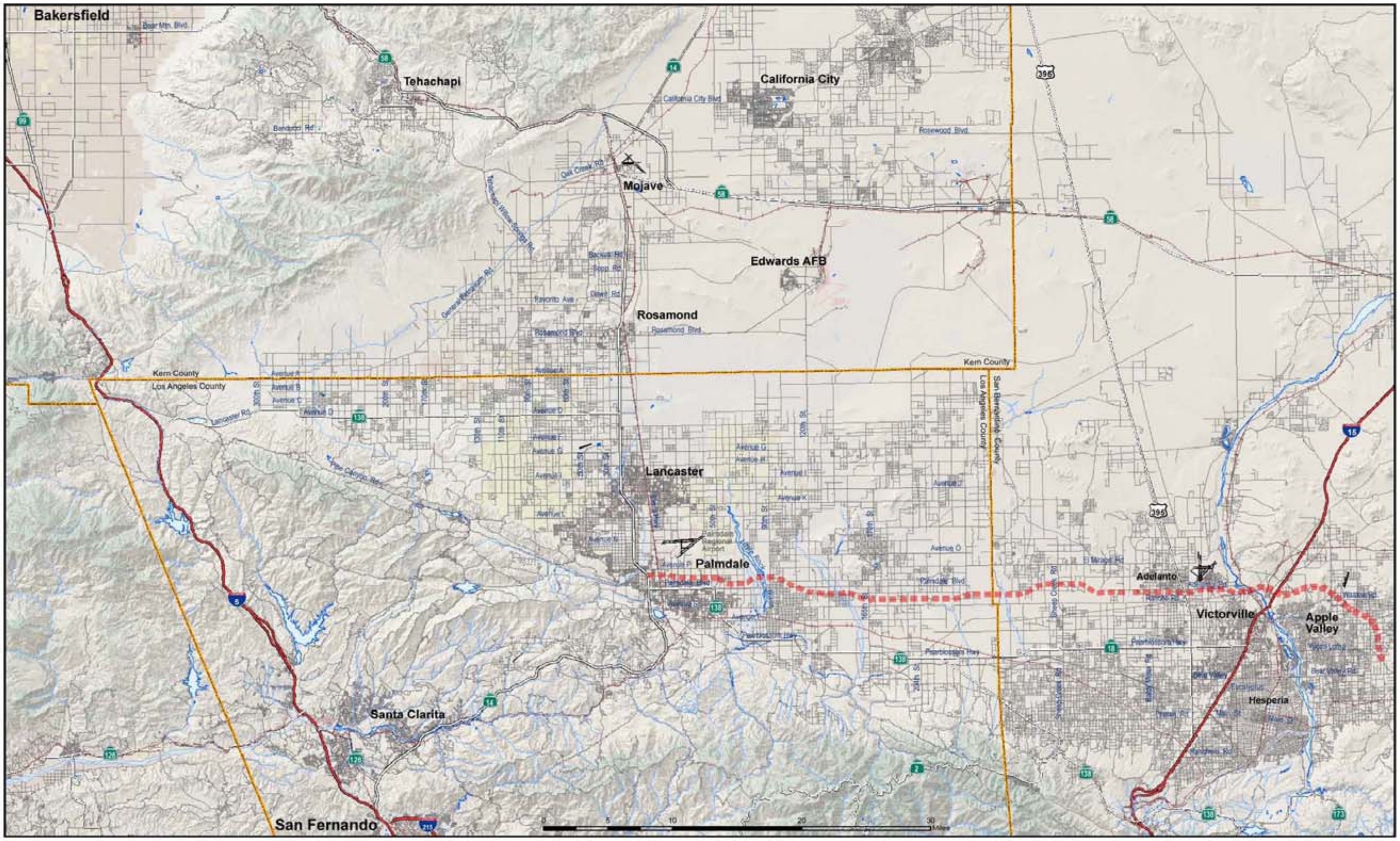
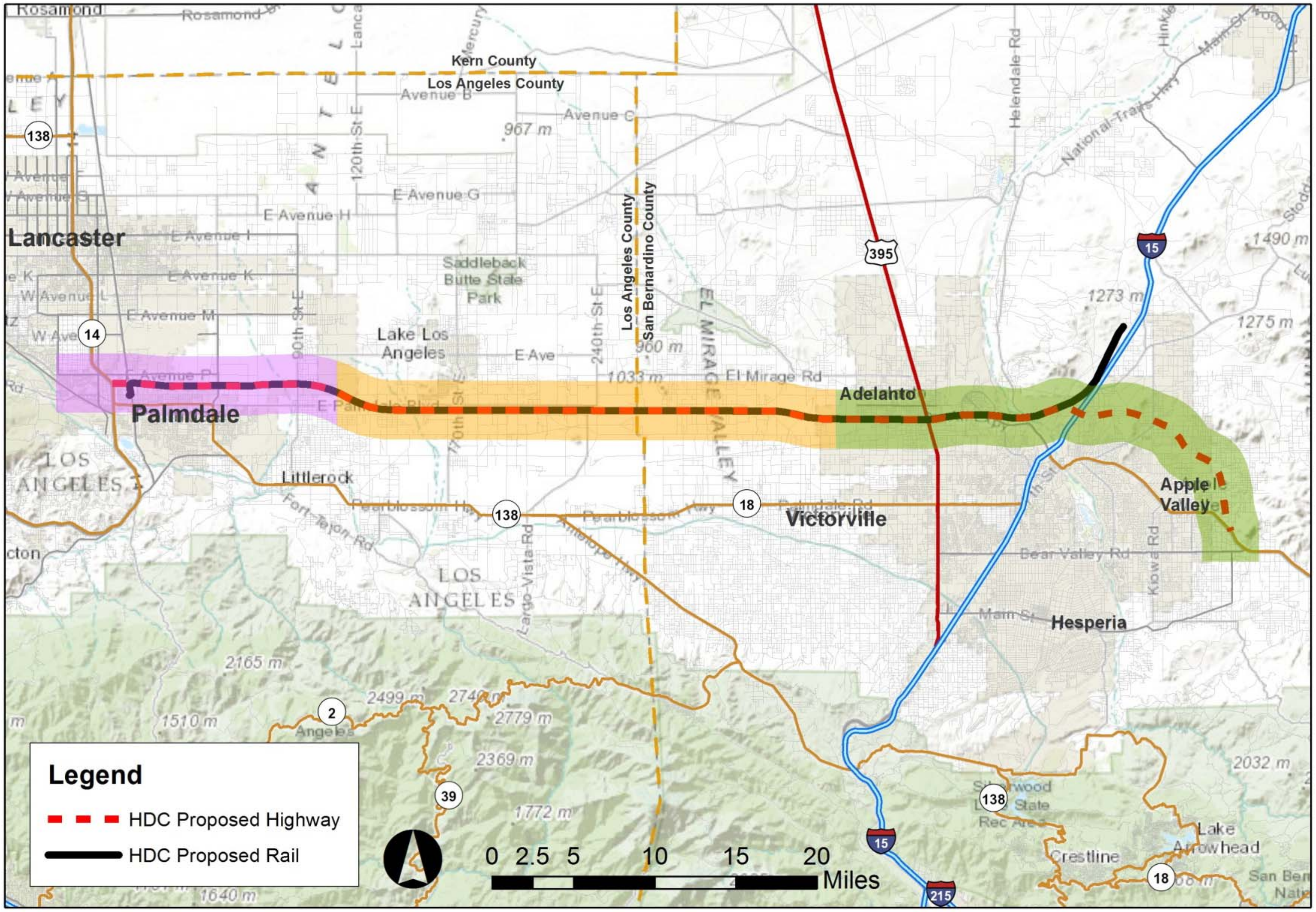


Figure 3-1: High Desert Corridor General Alignment



ANTELOPE VALLEY	HIGH DESERT	VICTOR VALLEY
Los Angeles County	**Los Angeles County–San Bernardino County**	**San Bernardino County**
Lancaster, Palmdale	Lake Los Angeles, El Mirage	Adelanto, Victorville, Apple Valley, Hesperia

Figure 3-2: High Desert Corridor Segments

Source: High Desert Corridor Traffic Study Report, 2014.

Figure 3-3: High Desert Corridor Alignments with Proposed Ramp Locations

4 Renewable Energy

Renewable energy (RE) is energy derived from a renewable resource (i.e., a source that can be regenerated without the risk of depletion). Using a renewable resource to generate electricity or heat via various forms of technology is the general process of renewable energy. The U.S. Department of Energy (DOE) classifies solar, wind, moving water (e.g., hydro or tidal), biomass, and geothermal as natural resources for RE generation [Ref. 1].

In contrast, a resource that does not have the capability to rapidly and naturally replenish is considered a nonrenewable resource. Conventional energy is derived primarily from nuclear elements (uranium) or fossil fuel-refined products, which include natural gas, coal, oil, and petroleum-based fuels (e.g., gasoline, diesel, and propane) [Ref. 2].

Natural gas is another resource analyzed in this report. Although it is not renewable, it is cleaner than other fuel-refined products.

4.1 Importance of Renewable Energy

4.1.1 Public Policy Regarding Renewable Energy

Energy security has been a major concern for the United States since the early 1970s. In October 2011, the US Energy Information Administration's (EIA) *2010 Annual Energy Review* reported that approximately 91 percent of the nation's energy supply comes from nonrenewable resources. The United States currently relies heavily on coal, foreign oil, natural gas, and nuclear fuels to meet its energy needs.

The processes of extraction, conversion, and transportation of these finite resources for the purposes of energy production are becoming increasingly costly and unsustainable [Ref. 3]. Dependence on energy derived from nonrenewable resources contributes to the eventual depletion of the nation's natural resources.

The DOE supports the premise that RE can supply a significant portion to the United States' energy needs and that it will create many public benefits, including environmental improvement, cleaner fuel options, energy security, and regional economic development benefits.

The DOE's federally funded laboratory, the National Renewable Energy Laboratory (NREL), primarily focuses on commercializing RE sources, helping meet this growing demand for cleaner energy and leveraging on the benefits of RE generation.

4.1.2 Benefits of Renewable Energy

The NREL provides additional support for the benefits of using RE and the importance of supporting research and development within this area. NREL contends that continued support for advancing RE, along with its sustainable elements, will result in the displacement of a significant portion of the conventional (i.e., fossil fuel-fired) electricity generation, thereby reducing the contribution to global warming and the related public health issues.

The use of RE offers significant economic benefits:

- Jobs are created, primarily in RE project development and construction.
- Several existing RE program incentives and tax credits are making RE projects more affordable.
- RE is a supplement to the power generated all the time.
- RE deployment reduces the need for utilities to build and run power plants, thus avoiding additional costs of generation and transmission construction that would be passed on to customers.

Energy derived from renewable resources is rapidly emerging as a viable and sustainable alternative in supplementing our nation's energy requirements [Ref. 4].

4.2 Renewable Energy Projects Help Meet Sustainability Goals

The states' departments of transportation (DOTs) are capitalizing on opportunities to generate energy from renewable sources on roadways and highways [Ref. 5]. RE generation reduces GHG statewide and helps meet the State's or state DOT's RE goals. RE projects provide an option for state DOTs to offset their carbon footprints and support legislative goals in the reduction of emissions, such as California's Assembly Bill (AB) 32. Other parallel targets can also be met as a secondary benefit (e.g., the promotion of lower emission or alternative fuel vehicles with supporting infrastructure).

California's AB 2583 is another bill to consider when meeting sustainability goals. Although not officially a law, this bill was chaptered in 2012, which is the last step before becoming a law. AB 2583 requires the State to develop a plan for equipping State-owned parking lots with electric vehicle (EV) chargers and alternative fuel infrastructure. Currently, there are only about 1,000 public charging stations in California for EVs. AB 2583 also commits California to purchase clean cars when purchasing new cars starting in 2015, with exemptions for classes of vehicles where clean cars are not available, such as fire trucks. Once this bill is a law, the HDC could incorporate EV charging stations along the corridor.

4.3 Types of Renewable Energy

The following categories are frequently identified renewable resources that have also been examined by FHWA and various states' DOTs regarding their feasibility within the highway ROW.

4.3.1 Solar

Solar energy technologies convert sunlight into usable energy while producing minimal or no emissions. The technology most commonly used along the highway ROW for solar energy generation is photovoltaic (PV) technology. Several DOTs, both nationally and internationally, have implemented PV within their highway ROW.

In addition, per Caltrans Deputy Directive 104 (DD-104), Caltrans supports the creation of new opportunities for generating solar energy within Caltrans ROW. Caltrans will promote the installation of solar energy systems, either through direct funding or by third-party providers. Installations shall not compromise the purpose and intent of highway ROWs, maintenance and operations facilities, and other property assets, and must provide a benefit to Caltrans, as well as the public it serves. Specific siting requirements must be met for solar installations along Caltrans ROW.

4.3.2 Wind

Wind has been used to produce energy through turbines. Modern wind turbines fall into two basic groups: the horizontal-axis wind turbines (HAWT) and vertical-axis wind turbines (VAWT).

- HAWTs typically have two or three blades. These wind turbines have the main rotor shaft and electrical generator at the top of a tower and are operated "upwind," with the blades facing into the wind, shown on the right of Figure 4-1.
- VAWTs, like the Darrieus model (shown on the left of Figure 4-1), have the main rotor shaft arranged vertically.

Source: http://energy.gov/eere/wind/how-do-wind-turbines-work

Figure 4-1: Modern Wind Turbines

Two main sizes of wind turbines are in use today:

- Large or utility-scale turbines can range in size from 100 kilowatts (kW) to as large as 2.5 megawatts (MW) of electricity

- Small-scale turbines are normally less than 80 feet in height and generate less than 100 kW. Architectural wind turbines are small-scale turbines that can be mounted on the top edge of a structure and normally generate 1 kW or less.

To generate sufficient energy to be effective, each of these types of wind turbines must be installed in areas that have favorable constant high-speed wind conditions. These conditions should be evaluated for any areas under consideration for wind energy development.

4.3.3 Water (Hydroelectric power)

Hydroelectric power is generated from moving water based on its flow or fall activity. The EIA reported that the use of hydroelectric power accounted for approximately 60 percent of the nation's RE generation in year 2010 [Ref. 6]. Hoover Dam, situated on the Colorado River, is an example of a hydroelectric power plant.

4.3.4 Geothermal

Geothermal energy is generated by capturing the heat produced in the earth's core and using it to make steam to turn power plant turbines. According to the DOE's geothermal mapping [Ref. 7], most geothermal reservoirs are located in the western states. Northern California's largest dry steam reservoir (The Geysers) currently produces electricity. The direct use of geothermal for energy and heating applications has been endorsed by EPA for homes and buildings because of its minimal environmental impact [Ref. 8].

4.3.5 Biomass

Biomass consists of organic material, primarily from plants and microorganisms. Examples of biomass include wood, wood waste, agricultural crops known as biomass fuel stocks, and landfill gases. The DOE also identifies municipal solid waste as a renewable biomass resource because solid waste is produced continuously.

Biomass can be converted to useable forms of energy, including methane gas and transportation fuels (e.g., ethanol and biodiesel). The uses of alternative transportation fuels are emergent and are incorporated in many sustainability plans or policies within public agencies and private organizations.

4.4 Challenges for Renewable Energy

Most renewable resources inherently produce intermittent energy (e.g., a rainy day will significantly affect solar energy production). Other challenges include energy sprawl (i.e., solar and wind each require a large footprint based on the size required to generate significant amounts of energy).

Installing RE into remote areas creates challenges in interconnection to the grid. Unless distribution centers and transmission are already near proposed RE installation, significant costs will be required to successfully complete interconnection to the grid.

To have a continuous and reliable RE supply, provisions for energy storage (e.g., battery banks to store excess energy) need to be considered. The DOE and NREL are working together to address this issue.

4.5 History of Renewable Energy Applied on Roadways

The use of RE resources for roadway applications is not uncommon within the United States. FHWA reported that the use of RE in a highway context goes as far back as the 1940s, when transportation engineers in Oregon tested the use of geothermal energy for deicing a canal bridge in Klamath Falls, Oregon [Ref. 9]. This early RE concept has progressed such that heat pipes are now considered within areas of Oregon DOT's roadway design, further improving the roadway conditions.

Within the last decade, RE generation within the highway ROW has been examined and, in some cases, has been executed. State DOTs are responding to expectations that they play a role in the RE commitments of their states. In California, all utilities have a commitment to acquire or generate 33 percent of its power from renewable resources.

Caltrans has been asked to respond to the growing demand for alternatively fueled vehicles and the development of refueling infrastructure to accommodate these vehicles.

Subsidies from government or private programs and/or utility incentives have supported and encouraged implementation that has resulted in solutions for energy offsets to power elements within the ROW, cost savings, and reducing the carbon footprint of roadways.

4.6 Governance over Utilities within Highway Right-of-Way

Within the last decade, FHWA has considered many proposals for RE implementation within the highway ROW. Most of the state DOTs had few restrictions or undefined codes or standards that addressed RE developments within their ROWs. FHWA acknowledged the need for more direction on DOT projects related to utility- or energy-related projects within the ROW.

On March 29, 2009, FHWA released a guidance document through its Office of Real Estate Services and Office of Program Administration, in response to state DOTs' growing interests in using the highway ROW. The *Guidance on Utilization for Highway Right-of-Way* [Ref. 10] discusses the applicability of federal regulations on "longitudinal accommodation, installation, operation and maintenance of public or private utilities within the Interstate System right-of-way" propositions.

Nonhighway private uses of the Interstate ROW are also subject to requirements for airspace leasing [Ref. 11]. The *Guidance* notes that as RE projects within the highway ROW become more prevalent, additional consideration of each project will be necessary to redefine governing codes and standards relating to utilities and highway ROW.

4.7 Renewable Energy Measures and Goals

In response to climate change concerns, such as the United Nations 1994 Kyoto Protocol, the U.S. Government directed EPA and other relevant agencies to develop a framework to reduce the nation's GHG emissions and contribution to climate change. The Obama Administration developed a "blueprint" that commits the federal government to environmental restoration, energy security, and sustainability. This blueprint involves unprecedented objectives relating to energy and environmental matters, including RE on public lands, Recovery Act investments, reduction of air pollution, and land conservation [Ref. 12]. While for the transportation sector, the focus of the blueprint is on improving vehicle energy consumption efficiencies and operating efficiencies on the nation's transportation network, there is a commitment to improve opportunities for RE production in multiple ways.

In 2006, California adopted AB 32, the Global Warming Solutions Act. The goal of AB 32 is to reduce California's GHG emissions to year 1990 levels by the year 2020.

California's AB 2583, as mentioned above, is another bill to consider that would require the State to develop a plan for equipping State-owned parking lots with EV chargers and alternative fuel infrastructure. AB 2583 also commits California to purchase clean cars when purchasing new cars starting in 2015, with exemptions for classes of vehicles where clean cars are not available (e.g., fire trucks).

Other countries are effectively executing RE programs. Some European countries are in the forefront in RE and sustainability projects [Ref. 13]. For example, Sweden is working to become the world's first oil-free nation, and Germany is executing its Renewable Energy Plan to phase out nuclear energy. The United Arab Emirates recently unveiled its alternative energy objectives, the World Bank has endorsed South Africa's Renewable Energy Plan, and China is executing its aggressive solar master plan and improving its solar panel efficiency ratings to restimulate the global solar market.

5 Existing Conditions

The HDC project area consists primarily of flat, open, undeveloped land with sparse, low vegetation except near the cities of Palmdale and Victorville, where there is more urbanized development. There are no shading issues (i.e., large trees, buildings, or orientation with the sun) that would limit the potential installation and productive operation of PV or solar installations in much of the project area; however, in some areas, there are floodplains that may be subject to icy conditions.

5.1 Field Review

Parsons conducted a 3-day field review of the proposed HDC project area in January 2012, which included a 1-mile radius from the proposed alignments. The field visit was designed to identify potential RE resources and applications, particularly at the interchanges proposed within the linear corridor of the HDC ROW. The investigative findings of the field visit were used to determine potential types and locations of RE-generating technologies.

During the site investigation, two Edison-owned substations, which are locations for transforming energy, were identified at East Avenue O and 90th Street and Palmdale Boulevard and 230th Street. In addition, a 2-MW private solar plant installation was in construction on East Avenue O and 90th Street. Approaching Victorville, two switching stations, which are intermediary locations between substations, are located on Powerline Road, owned by Southern California Edison and the Los Angeles Department of Water and Power, respectively.

Several large-scale government or commercially owned facilities are located within the proposed HDC Project area, particularly toward the eastern end. These large-scale facilities include a Wal-Mart distribution center, the Los Angeles County California State Prison, and a community college campus in its construction phase, with evidence of a solar installation at the intersection of Johnson and Navajo streets. Multiple aviation-related facilities exist within the HDC Project area, including the Midfield Aviation facility, Gray Butte Field airstrip, Krey Field airstrip, Victorville Federal Correctional Complex, Southern California Logistics Airport, and the Apple Valley County airstrip. The proposed HDC would cross BNSF and Amtrak rail in Victorville, as well as Amtrak rail in Palmdale. In addition, the proposed HDC would cross the Mojave River in Victorville. Large parcels of open land with limited residential properties were also observed, including small business establishments where the HDC would connect to SR-18 and Bear Valley Road. Many of these facilities could be potential green energy collaborators.

The existing terrain and its potential for flooding and ice, the proximity of energy interconnection points, and the locations of potential energy users are all issues that were raised during the field review. The regional weather conditions within the HDC Project area and the availability of land provide ideal conditions for solar development along the corridor. Wind speeds recorded at the Palmdale Regional Airport were at acceptable speeds for consideration as a RE source, and the viability and constraints in generating power through wind turbine technologies within the Antelope Valley are not discussed in this report. Potential constraints include, but are not limited to, environmental, installation, setback, and cost concerns.

6 Methodology for Developing Renewable Energy Alternatives

The following steps were taken in developing the recommended RE alternatives in this report:

- A list of RE technologies that have been implemented along roadways, both nationally and internationally, were presented to most of the stakeholders (Caltrans, Metro, and JPA) for their consideration and review. Innovative and emerging technologies were also included for discussion.
- In January 2012, a teleconference meeting was held with most of the stakeholders to discuss the types of renewable technologies and alternative energy sources that should be further investigated. The stakeholders requested that the report focus on solar, wind, alternative fuels, and utility company transmission within the HDC's ROW. The stakeholders requested that the technologies that have not been tested and implemented successfully within the highway ROW be eliminated from further evaluation.
- A 3-day field review was conducted, and aerial mapping showing the superimposed proposed HDC Project was used to examine the existing project field conditions for suitability and to locate potential sites for RE opportunities along the HDC Project. Site visits were made to every proposed interchange location that was accessible by vehicle to determine if each location represented a viable location for RE installation. RE alternatives that were not suitable for the HDC Project area conditions (e.g., climate, terrain, flooding, and wind) were removed from further evaluation.
- Additional RE alternatives were removed from consideration after analysis and evaluation of those alternatives against the constraints described below, resulting in the short list of recommended alternatives detailed in Chapter 7.
- The HDC Draft Green Energy Study was originally focused on energy efficiency, RE, and utility use of the ROW. Subsequently, Caltrans requested additional review and additional scope to the design and advised considering technologies that would be applicable 20 to 30 years from the date of this report. .That additional scope included consideration of the potential energy efficiency needs for a bicycle path; and water efficiency measures; RE offsets for the energy consumption for the HSR feeder, as well as the development of GHG and energy offsets for construction of the HDC.

The following parameters and constraints were used in the alternatives development process:

1. The project study area limits are 1 mile to the north and 1 mile to the south of the HDC centerline along the entire length of the HDC.
2. RE technologies were evaluated that:
    a. are currently in use
    b. have proven energy generation ability

   c. are appropriate for the region
   d. have favorable site conditions conducive to RE installations
   e. have demonstrated cost effectiveness
   f. are in use in other transportation authorities' ROWs
   g. are supported by the necessary utility infrastructure
   h. have public support

3. Emerging technologies and their potential application along highway ROW; these technologies are discussed in Section 8.
4. Potential impacts of the following environmental resources were considered for RE resources along the HDC:
   a. Noise
   b. Water
   c. Species preservation
   d. Land Use
5. Clear and flexible regulatory and permitting restrictions.

7 Recommended Renewable Energy Technology Alternatives for Further Consideration

The technologies and alternatives that are described below are recommended based on a review of current and applicable RE resources, preliminary financial analyses, a series of interviews with utility agencies, field review findings, and input from the stakeholders of the HDC. These recommended alternatives have been identified as reliable RE technologies through supporting case studies, and they represent opportunities for application to the HDC Project.

This report does not address quantities or specific placement of installations along the HDC at this time; however, a rendering of potential locations of the recommended technologies is provided in the Green Energy Facilities Exhibit in Appendix A.

7.1 Photovoltaic Solar Highways

Solar highway projects have been implemented or are being installed at several international and state DOT facilities and highway ROWs. Currently, the primary technology used for generating solar power within the state DOTs is PV technology. The PV panels are usually fixed in place or on solar tracking systems designed to optimize the location's solar radiance conditions.

The Oregon DOT installed a 100-kW solar PV system using approximately 8,000 square feet of footprint with the technology available at the time, producing an estimated 100,000 kilowatt-hours (kWh) per year. This can potentially offset their energy usage at an interchange requiring 400,000 kWh annually by more than 30 percent.

In California, a 100-kW system would produce up to 160.000 kWh annually. The solar energy produced in California may be used directly by a property owner to power energy-using devices; more commonly, however, it is injected into the grid to offset energy used in a net-metering program approved by the State of California. .

Solar energy generation usually requires significant amounts of land or building roof space and is best suited for areas in which energy does not have to travel far to access the grid. It is therefore ideal for interchanges, utility substations, and (most commonly) urban areas; and it is suited to the HDC Project.

7.1.1 Solar Applications on Barrier Walls

As the installations of PV technology expand within the transportation sector, integrating PV into roadway structure design has been considered along the highway ROW.

Solar projects have been implemented by transportation authorities since the 1980s in European countries and Australia (Figure 7-1), and most recently in Canada [Ref. 14].

Figure 7-1: Soundwall in Germany
Source: http://www.photovoltaik.eu/typo3temp/pics/92b3a2e7eb.jpg

7.1.1.1 Solar Panels on Soundwalls

Photovoltaic noise barriers (PVNBs) along motorways and railways offer an innovative option for the application of PV within the ROW [Ref. 15]. Installation of solar soundwalls along the business/residential communities in selected areas of Palmdale, Lancaster, and Victorville, would provide the following benefits:

- noise mitigation
- power for lighting/ signage within the HDC
- visual impact mitigation.

7.1.1.2 Solar Panels on Median Barriers

Similar to the PVNB, the application of solar panels on top of the highway median barrier could be a renewable energy alternative. The feasibility of the project would depend on the roadway median barrier requirements and the panel orientation to effectively produce solar energy; however, further engineering and analysis would be required to verify if the project is cost effective for the HDC.

Figure 7-2: PV Panels on Solar Wall on Melbourne's M-80 (Western Ring Road)
Source: www.goingsolar.com.au

Going Solar, a design and installation company specializing in innovative solar electricity (based in Australia), has installed PV panels on a solar wall on Melbourne's M80 (Western Ring Road) (Figure 7-2) for Vic Roads to help offset energy consumption for the railway stations along the new Region Rail Link in Melbourne's West.

7.1.2 Solar Applications on the Right-of Way and Interchanges

Viable recommendations for land use that is typical for the ROW or an interchange include installing solar assests. Installing solar systems in underutilized large parcels of land would provide the following benefits:

- Attract investors and/or public/private partnerships (PPP) to lease the land for RE installations
- Offer revenue-generating project opportunities
- Help offset the energy needed for the HDC or HSR

According to data provided in the Energy Technical Report, the HSR Feeder Service's annual energy usage is estimated to be approximately 31,000,000 kWh. Installing approximately 20 MW of solar panels in selected areas of the HDC ROW could potentially meet the energy usage for the HSR feeder service and possibly conform with the California High Speed Rail Authority program's electrification of trains.

Certain applications/uses of solar energy power may benefit with combined installation of battery storage. Nearby SCE substations may need to be retrofitted to accommodate the increased generation capacity or new substations may need to be installed nearby to support the solar asset.

7.1.2.1 Solar Lighting and Signage

Solar street signage and lighting devices are readily available and have been installed in a variety of locations and roadway projects both nationally and internationally. Various solar energy panels have been used in traffic stops, intersections, parking lots, and to power information boards.

Solar-powered street lighting (Figure 7-3) and signage are a recommended RE measure for all proposed HDC interchanges. Various technologies are available for demonstration and as pilot programs.

Figure 7-3: GridFree™ UE Solar Lights Solar Street Lighting
Source: Solar Street Lighting website, http://www.solarstreetlightsusa.com

Electricity for the HDC interchanges is expected to be provided by SCE. Solar-powered lighting offers the following benefits:

- Produce electricity during the day, supplying power onto SCE's grid or storing directly to a battery,
- Supply power needed to light the interchanges at night.

The benefits of solar lighting and signage include the fact that interconnection applications or permits are not required. The devices or equipment are turnkey systems. Ideally, the devices are adjustable and adaptable to DOT specifications. To ensure reliability, battery back-ups are available; however, there may be a maintenance concern for the cost and downtime to replace the batteries.

Figure 7-4: Solar Panels

Public Service Electric and Gas Company (PSE&G) has installed solar panels (Figure 7-4) on 200,000 utility poles and street lights in about 300 communities in New Jersey as part of its Solar 4 All Program.

7.2 Grid-Neutral Energy Train Stations for HSR

In consideration of the California High-Speed Rail Authority's 2029 HSR system plan, there are currently two projected train stations identified within the HDC's HSR design. It is anticipated that the proposed station platform in Palmdale, which will connect and support the California High-Speed Rail Authority's system, would be shared with Metrolink's current transit station (Palmdale Transit Center). The only other stop would be in Victorville, adjacent to the Desert Xpress high-speed train station, currently referred to as the XpressWest Victorville Station.

From an energy-savings standpoint, the following installation elements are recommended for a sustainable train station design:

- Energy-efficient lighting
- Energy-efficient mechanical systems
- Implementation of daylight-harvesting strategies to minimize energy load requirements
- Installation of a solar system to offset the electrical energy needs of the train station and potentially a portion of the HSR's needs

Cost analysis and evaluation of energy returns will be presented in the Financial Analysis report, depending on available industry data on the selected measures.

Additional solar systems could be installed within a parking area if a park-and-ride lot is available for the HSR.

Because the California High-Speed Rail Authority is planning to work with cities on future HSR stations to create "station communities," the Palmdale and Victorville stations are candidates for achieving grid neutrality.

Challenges for Solar Photovoltaic Technologies

For the HDC Project, many issues should be considered and addressed when evaluating the application of solar PV technology:

- Land availability
- Current site conditions that must be addressed in the environmental document
- Identification of all "soft costs" (e.g., permits, ancillary studies, and utility interconnection requirements)
- Allowance for full public review and comment periods
- Power purchase agreement (PPA) negotiations that can be lengthy and complicated
- Identifying and securing funding sources

7.3 Alternatively Fueled Vehicle Refueling Stations

Federal energy policies are addressing vehicle-generated GHG concerns through energy technology and transportation operation measures. Consequently, state and regional air quality management districts, investor-owned and municipal utilities, and vehicle manufacturers have been involved in the research and development of several new vehicle technologies and the infrastructure that will be needed to support these technologies.

Promoting the use and viability of alternatively fueled vehicles by providing refueling stations at the interchanges along the HDC would support the goals for a "green energy" HDC, as well as abiding by AB 2583, discussed above. Having those refueling stations (Figure 7-5) powered by RE would provide even greater benefit and an impressive commitment to RE objectives.

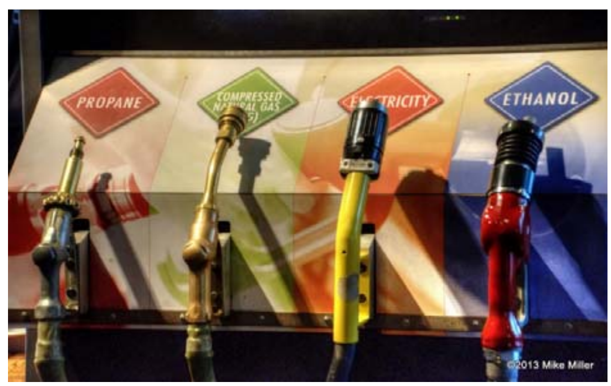


Figure 7-5: Alternatively Fueled Vehicle Refueling Station
(Source: http://www.convoyautorepair.com/fuel-system/beyond-diesel-alternative-fuels)

According to FHWA's report [Ref. 14] on the accommodation of alternative fuels, if highway ROW were to allow for alternative fuel distribution, one or more of the following fuels could be considered:

- Electricity
- Hydrogen
- Biofuels (e.g., biodiesel)
- Natural gas (e.g., propane, compressed natural gas [CNG], and liquefied natural gas [LNG])

Federal and state subsidies have encouraged the development of alternative fuels technology and its use. Because electricity can be generated onsite through solar shade structures (Figure 7-6), the opportunities for creating RE-powered EV stations within the highway ROW are greater than for the installation of other alternative fuels listed above. The HDC presents an opportunity to construct EV charging stations powered by solar shade structures at rest stops and service areas.

Figure 7-6: Honda Solar Powered EV Charging Station
Source: http://www.gizmag.com/honda-solar-powered-ev-charging-station/17326/

The states of Oregon, Washington, and California have formed the West Coast Green Highway initiative. These states have jointly applied for federal funding to support development of the Alternative Fuels Corridor Project along I-5. The project involves commercializing State-owned ROW or highway rest areas and installing privately owned alternative fueling stations [Ref. 15]. Oregon DOT has recently received funding to support its effort in electrifying I-5 for the Alternative Fuels Corridor Project.

To ensure the success of such programs, any alternative refueling stations considered within the highway ROW or interchanges would have to meet customer expectations of reliability, ease of access, and affordability.

Although EV charging station installations are gaining momentum, it is worth noting that because natural gas has been moderate in price in California and can be easily stored, more growth should be anticipated within CNG programs.

Note that there has been a recent increase in the use of natural gas vehicles (NGVs) due to lower costs of natural gas, incentives, and regulatory requirements passed by policy makers for fleet vehicles in California. The benefits include:

- Lower-cost domestic fuel in comparison to gasoline
- Lower emissions, and
- Overall reduction of GHG contribution.

Similar to the need to develop EV charging station infrastructure, the development of CNG refueling stations should be considered at the interchanges along the HDC. The California Fuel Cell Partnership recently gained more support and is accelerating in the installation of hydrogen refueling stations to promote a market for zero-emission fuel cell vehicles [Ref. 16].

Depending on the need and demand of alternative refueling stations, CNG, LNG, EV, biofuels, and propane stations could be installed at selected or all proposed interchanges.

7.4 Utility Utilization of Corridor Right-of-Way

7.4.1 Natural Gas Pipelines and Electricity Transmission Lines

A study of the utilization of the HDC's ROW for utilities was requested by the stakeholders for consideration as a means to offset the cost of construction of the corridor. Preliminary discussions with the respective utilities indicated an interest in using the ROW for transmission of natural gas and electricity. Formal proposals would have to be developed to receive confirmation from these utility companies.

Properties adjacent to the HDC ROW will be reviewed further for partnering opportunities with each utility serving the areas along the corridor. Meetings between the stakeholders of the HDC and the utilities are recommended to discuss the potential opportunity.

Note also that there has been an increased interest from Southern California Gas Company (The Gas Company) in developing CNG and LNG stations in interchanges along the corridor that would prompt them to develop plans for CNG infrastructure along the HDC ROW. A utility (i.e., electricity, gas, water) corridor running along the north and south of the HDC within the ROW is anticipated to:

- Support future businesses and residential communities; and
- Provide reliable utility services across cities within the HDC.

7.4.2 Guidance and Considerations

Under Title 23 *Code of Federal Regulations* (CFR) Part 645, specific requirements will have to be considered regarding the private uses of the Interstate ROW relating to utility companies. One of the objectives in regulating the location of utilities within the ROW is to ensure that such nonhighway-required activities do not affect Caltrans' responsibility to safely maintain and operate the public highway.

7.5 Sustainable Technology Alternatives for Bicycle Path

As discussed in Section 6, the HDC Project would incorporate a bicycle facility in each build alternative, extending along the corridor between major urban centers, from the Palmdale Transportation Center (39000 Clock Tower Plaza Drive East) on the west to US 395 in Adelanto on the east. Cyclists traveling from Palmdale to Adelanto should be able to access a planned future bicycle network in the Victor and Apple valleys. Recommended sustainable technology alternatives for the bike path surface include solar pathways (see Section 8.3) and semi-permeable paving surfaces that use sustainable materials/techniques to allow movement of stormwater through the surface.

Overhead solar lighting systems (see Section 7.1.2.1), solar bollard lighting (Figure 7-7) and path-embedded solar light-emitting diode (LED) lighting will providesustainable lighting for the bicycle path.

Figure 7-7: Solar Bollard Lighting
Source: http://www.solarcynergy.com/

In addition, upcoming technologies, including ultraviolet (UV)-powered path lighting developed by UK company Pro-Teq, should be considered as a possible alternative to street lighting (Figure 7-8). According to the company, the patented, quick-drying, water-resistant, spray-on, elastomeric coating absorbs UV light during the day and releases it at night, when particles are able to adjust to the available natural light, and glow with the appropriate level of intensity.

Figure 7-8: UV-Powered Path Lighting
Source: http://www.pro-teqsurfacing.com/

7.6 Other Potential Technology Considerations

Technological advances in the automotive industry are increasing at a rapid pace and may need to be considered during design of the HDC. In September 2012, California became the third state to allow the use of self-driven cars (i.e., driverless) for testing purposes. Certain technologies may or may not directly impact the road's infrastructure, but they may provide opportunities to integrate other technologies to support smart automobiles in the future (e.g., charging/computer stations) [Ref. 22, 23, 24].

7.7 Envision™ and Application to HDC

Envision™ is a sustainable infrastructure rating system that provides a holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects. It evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle [Ref. 25].

This rating system is gaining increasing recognition and being used by DOTs, water treatment plants, and several public/private entities during the project design phase to meet sustainability goals, make informed decisions regarding investment of scarce resources, include community priorities in civil infrastructure projects, and gain public recognition for high levels of achievement in sustainability. The Envision™ tools can help assess costs and benefits over the project lifecycle, evaluate environmental benefits, use outcome-based objectives, and ultimately, reach higher levels of sustainability achievement for horizontal infrastructure projects similar to the Leadership in Energy and Environmental Design (LEED) rating system for vertical infrastructure projects. This verification system can serve as a valuable tool for the HDC Project in quantifying GHG emissions, based on the technologies selected for implementation, and development of GHG and energy offsets for construction and operation of the corridor.

Given the increased interest from public/private sector and regulatory agencies in this rating system, and the high likelihood of the use of this system as standard practice in the future, it would be effective for personnel trained in the use of the Envision™ rating system to be an integral part of the HDC Project team. This would allow the team to obtain guidance in achieving higher levels of sustainability, document project sustainability accomplishments, and submit the project for recognition. It is recommended that project team members working on the sustainability component of the HDC design obtain the Envision™ Sustainability Professional (ENV SP) certification so they are trained in the use of the rating system and credentialed by Institute for Sustainable Infrastructure (ISI).

7.8 Water Conservation/Efficiency Measures

Water conservation/efficiency measures should be implemented primarily through drought-resistant planting, xeriscapaing, drip irrigation, and the use of recycled water for irrigation to the greatest extent possible.

7.9 Case Studies

7.9.1 Oregon Department of Transportation Solar Highway Demonstration Project

In 2008, the Oregon DOT installed the "first solar highway" within the United States in partnership with its investor-owned utility company, Portland General Electric (PGE). The solar installation is located in Tualatin, Oregon, within the boundaries of the I-5 and I-205 interchange. According to Oregon DOT, this demonstration project is sized at 104 kW and consists of a 594-panel, ground-mounted, solar array system (Figure 7-9). The PV system reportedly produces nearly 112,000 kilowatt-hours (kWh) annually, feeding the utility grid during the day to offset one-third of the interchange's electricity requirements for its lighting and road signs during the evening hours.

Figure 7-9: Oregon DOT's Solar Highway Demonstration Project
Source: Oregon DOT Website: http://www.oregon.gov/ODOT/

The financing company is SunWay 1, and the Oregon DOT maintains the property outside the fenced array and acts as procurer of the green energy.

Figure 7-10: Oregon DOT's Baldock Solar Highway Project
Source: Oregon DOT Website: http://www.oregon.gov/ODOT/

After the success of Oregon DOT's solar highway demonstration project, a second PV installation project was started in 2011. This larger system is located within the Baldock Safety Rest Area on I-5 (Figure 7-10). According to ODOT's Highway Project Director, the Baldock Solar Highway installation began operating in January 2012. This installation is also a ground-mounted system with an anticipated annual generation of 1.94 million kWh produced by a 1.75-MW, 6,994-panel solar array.

Figure 7-11: Artist's Rendering of West Linn, Oregon Site
Source: A. Hamilton, ODOT Solar Highway Project Director

Another proposed location for a solar highway installation is being considered for West Linn, Oregon (Figure 7-11) and is in the planning stages of development.

7.9.2 Other Solar Installation Projects

Other solar installation projects use different business models. For example, the Ohio DOT, in partnership with the University of Toledo, received federal funding to install a solar array within the ROW for innovative research while offsetting current energy use to light downtown Toledo's Veteran's Glass City Skyway (Figure 7-12) [Ref. 17].

Figure 7-12: Veteran's Glass City Skyway 100-kW Solar Array and Lighted Pylon
Source: Ohio DOT's Office of Public Communications

Caltrans has been involved in the preplanning phases of solar projects. These projects are in various phases of review (i.e., predevelopment, innovative technology review, feasibility analysis, environmental review, and financial analysis) for installation within Caltrans facilities and/or highway ROW.

In 2010, the California Transportation Commission selected Republic Solar Highways to develop solar energy projects within the Caltrans' ROW for interchanges in Santa Clara County. The project involved Caltrans entering into a P3 agreement with Republic Cloverleaf Solar, LLC (Republic) for a total of 15 MW in solar installations at seven interchanges along Highway 101.

Republic, together with General Electric, will develop, install, own, maintain, and operate the systems; the solar energy produced would be sold directly to the utility. The agreement involves an airspace development lease and a revenue-sharing operations agreement. The airspace lease agreement would allow for the installation of RE facilities on otherwise unleasable ROW, while establishing a new revenue source for the State [Ref. 18]. Several technical and environmental impact studies were necessary for the public review process. According to Republic, the project is in the final stages of environmental review. Federal funding is involved; therefore, the project required a NEPA review, in addition to the CEQA requirements that have already been completed. Completion of the environmental review has been delayed to investigate whether the endangered red-legged frog inhabits one of the proposed solar sites.

Figure 7-13: Yawkey Station
References: http://www.boston.com/news/local/massachusetts/articles/2010/11/15/mass_officials_hail_1st_solar_powered_train_stop/ http://www.boston.com/yourtown/news/fenway-kenmore/2014/03/yawkey_to_be_bostons_first_zero_net_energy_station.html

A renovated project at Yawkey Station (Figure 7-13) in Boston, MA, has been designed to be a "zero net energy" commuter rail station by 2017. The all-solar-powered commuter rail station will feature a solar array that will produce enough power necessary to service the station and a shared-use parking structure. The solar-designed parking structure is expected to produce enough electricity to serve the station's need.

7.9.3 Photovoltaic Noise Barriers

The original Tullamarine-Calder Interchange in Australia (Figure 7-14) was noted to be prone to traffic accidents because of the confluence of two major urban freeways and the need to traverse several lanes of traffic to reach an exit ramp. A major reconstruction project reconfigured the interchange.

Figure 7-14: Tullamarine–Calder Interchange, Australia
Source: http://www.goingsolar.com.au/php/

Sustainability was an integral part of the design approach. Going Solar, an RE installation firm, and the design team incorporated 210 solar panels into the freeway walls, offsetting about 10 percent of the annual interchange lighting power demand, reducing carbon dioxide emissions, and providing a 500-meter sound barrier for the nearby residential areas [Ref. 19]. This particular application could be a viable option for the HDC.

The case study reported the following benefit:

- Public awareness is enhanced by a public display that indicates the power generated from solar technology.

7.9.4 Wind Technologies

The former Massachusetts Turnpike Authority, now part of MassDOT, analyzed potential wind turbine sites along the Massachusetts Turnpike, a 138-mile highway extending across the state from east to west, in support of the State's Leading by Example Program that established GHG emissions reduction and RE targets for all of the State's agencies. One of the sites the Turnpike Authority examined was a 68-acre property it owned in the western part of the State.

Over 13 months, the Turnpike Authority conducted a feasibility study, collecting wind speed and other site condition information. It was ultimately determined that the site was suitable for wind power development, and in April 2009, the former Turnpike Authority issued a Request for Proposal (RFP) for a long-term lease for wind turbine development at the service area. Solaya Energy, LLC was selected to develop what was planned to be a nearly 400-foot-tall, 1.5-MW wind turbine; however, in May 2011, registered voters at a Town of Blandford open town meeting defeated a wind power zoning bylaw that would have allowed development of the proposed turbine, putting the future of this project in question [Ref. 20].

In 2008, the Montana Transportation Department (MTD) began an evaluation of a tower-mounted wind turbine for the generation of supplemental power for the Anaconda Rest Area (Figure 7-12). The three-blade turbine is deployed on a 98-foot-tall free-standing lattice tower.

It costs approximately $68,000 to construct. Annual status reports have shown that limited maintenance issues have arisen, noise levels have been at a minimum, and the unit supplements approximately 20 percent of the annual power consumption of the rest area.

If the HDC design includes service/rest areas and/or train stop parking lots within the 63-mile stretch, utility-scale (large) wind turbines may be installed to offset the power of the HSR feeder similar to the projects mentioned above [Ref. 21].

8 Renewable Energy Technology Alternatives Considered but Not Recommended

Several other RE alternatives were considered for application along the HDC and its adjacent land. The following alternatives were withdrawn based on the stakeholders' input, the technology's availability, the utilization rate of the technology, cost effectiveness, and other issues related to the use of the technology. These alternatives and the rationale for their withdrawal are described below.

8.1 Wind Power

Although state DOTs have examined the feasibility of installing wind turbines in the highway ROW and within DOT facilities, wind energy projects have not been as widely implemented as solar energy. Based on the research and other DOTs' experience, wind turbines are not recommended for consideration in conjunction with construction of the HDC Project for the following reasons:

- Standard restrictions on wind turbine construction recommend setbacks of at least 1.5 times the hub height from buildings, roads, and transmission lines. This restriction effectively eliminates the use of all mid- to high-output wind turbines, particularly in the ROW.
- Small wind turbines are not yet financially viable under current market conditions; the cost is higher per watt than PV installations, and utility companies are not offering incentives for wind installations.
- Environmental concerns include impacts that lead to soil erosion, especially to surface roads, and disturbance of avian life.

Typically, the highway ROW design does not accommodate utility-scale turbines; however, recent advances in designs for smaller and micro-wind turbine technologies are emerging.

Figure 8-1: Induced Wind Turbines on Highway Median
Source: www.medianwind.com

The induced wind turbine is a recent wind-harnessing technology that is situated within the road, on top of the highway's concrete median (Figure 8-1). This innovative technology harnesses wind from moving vehicles within the roadway. Power is sent to substations located at 1-mile intervals [Ref. 26], which would be a costly measure to implement along the 63-mile stretch of the HDC.

An Arizona State University student has proposed a novel way of recapturing energy expended by vehicles moving at high speeds on our nation's

Figure 8-2: Horizontal Wind Turbines Mounted above the Roadway
Source: www.archinect.com

highways. The proposal would involve mounting horizontal wind turbines above the roadway (Figure 8-2) that would be driven by the moving air generated by the passing traffic. The electricity generated by spinning these turbines could be fed back into the grid. The student's analysis indicates that based on vehicle speeds of 70 miles per hour (mph), each turbine could produce 9,600 kWh per year [Ref. 27].

In the future, wind technology advancements, if proven effective, may provide more opportunities to be incorporated along or in the roadway design.

8.2 Concentrated Solar Power

Concentrated solar power (CSP) land requirements can range from 1 to 3 square miles, and these projects require long-term planning [Ref. 28]. The HDC's ROW would not meet the space requirements and line-of-sight restrictions of a CSP system; therefore, this alternative is not recommended unless one or more of the HDC stakeholders requests further research.

8.3 Solar Road

The solar road is a promising, emerging technology that has received much attention and government and public support. A solar roadway is a road surface that generates electricity by solar power PVs. FHWA is funding the research and development of a solar roadway. In 2009, Solar Roadways received a contract from FHWA under the Small Business Innovation Research to build the first-ever solar road panel prototype (Figure 8-3).

Figure 8-3: Solar Roadway Innovation
Source: YERT

In 2011, Solar Roadways was awarded Phase II funding to continue the engineering development and testing of this innovative technology [Ref. 29]. In 2013, the company successfully tested its latest prototype (a Solar Roadways parking lot laid next to their electronics lab) and is currently raising funds to gear up production. The solar panels prevented snow and ice accumulation this past winter and are producing the expected amount of power (the parking lot is equivalent to a 3,600 Watt solar array). In addition, the panels passed load testing for vehicles weighing up to 125 tons without breakage. The textured glass surface was traction tested and capable of stopping a vehicle traveling 128 kilometers per hour (kph) on a wet surface in the required amount of distance. According to Solar Roadways, the applicability of this technology to motorways, parking lots, pavements, and playgrounds could transform the existing motorway infrastructure and prevent accidents [Ref. 30].

Because this concept has not yet been installed on a roadway, solar roads are not recommended at this time.

8.4 Piezoelectric Energy Harvesting Systems

Piezoelectric roads harvest traffic energy to generate electricity by converting mechanical energy to electrical energy. The mechanical energy is derived from the compression stress created during vehicle travel on the road [Ref. 31].

Innowattech demonstrated its technology on a 6.2-mile stretch of road near Haifa, Israel. This technology was installed in 2013 in Italy, as was a small prototype on just 33 feet of Israel's Road Four north of Hadera on the coastal plain. A study conducted by Rex Garland at Stanford University concluded that there is currently a significant cap on the generating capacity of this alternative. The generating capacity of piezoelectric devices can be over-approximated by assuming that the vibrations in the road are caused by traffic alone and that each "vibration event" from one vehicle is independent of another (i.e., the vibrations are sufficiently dampened before the next vehicle passes) [Ref. 32].

California's 43rd Assembly District proposed AB 306, *Piezoelectric Energy Generation in Roads* [Ref. 33]. The Bill was approved and then vetoed in December 2011. This bill would have required the California Energy Commission (CEC) to conduct research on generating electricity using piezoelectric transducers under roadways or railways, which the State and CEC could not fiscally support [Ref. 34].

Innowattech has extended their research and development to now include railways. This technology should be considered during design of the HSR feeder train and assessed whether this alternative is mainstream and financially feasible for design integration.

8.5 Bioenergy

Bioenergy is an RE derived from sources of biomass, such as organic material. Biofuel derived from plant materials is among the most rapidly growing RE technologies. State agencies are beginning to explore the potential for bioenergy generation along highway ROWs. Michigan, North Carolina, Tennessee, and Utah have invested in research on raising crops for biofuels through the Freeways to Fuel National Alliance to grow crops that can be processed into biofuels [Ref. 35].

Based on the research and an overview of the resources available for the vicinity of both Apple Valley and Antelope Valley, bioenergy is not recommended for the HDC. Regulatory issues are restrictive, the permitting process is complex, and the cost to collect massive amounts of biomass inhibits the implementation of bioenergy projects at an effective scale.

8.6 Geothermal Power

Geothermal power generation will not be considered in this report due to the general lack of this resource in the project area.

8.7 Solar Tunnel

Europe's first solar tunnel began operation in June 2011. A 2-mile portion of the train track within the Paris–Amsterdam train service route is enclosed in a solar panel-covered tunnel in Antwerp, Belgium (Figure 8-4) [Ref. 36]. A 16,000-solar-panel system was placed on 50,000 square meters of roof on the tunnel that serves conventional and high-speed trains.

Figure 8-4: Solar Tunnel, Belgium
Source: Engadget Transportation

The solar energy produced provides power to the stations, including Belgium's Antwerp Central Station. The solar tunnel also provides a secondary benefit: it shields the train from falling tree debris from the surrounding forest and provides a noise barrier for nearby residences.

This design was engineered for HSR and onsite energy use. The system is expected to generate 3.3 GWh yearly, about the annual electric consumption of 1,000 homes in Belgium, and cut carbon dioxide emissions by 2,400 tons per year.

This application is not recommended at this time: the concept for roadway application would require additional information to enable the stakeholders to conduct engineering and financial reviews to determine its feasibility for the HDC.

9 Financing Options and Feasibility

9.1 Project Financing Options

Several ownership options are available to finance RE projects. To determine which model would work for a specific project, it is important to develop an understanding of the current available business models and how the other projects described in this report were financed.

To date, several types of business models have been proposed and/or used to finance RE projects:

- **Capital Purchase of Renewable Energy Facility.** In this model, the DOT purchases the installation with available cash on hand, takes full responsibility for operation and maintenance (O&M) of the facility, and reaps the full benefits of the available utility incentives, energy savings, and renewable energy credits (RECs).
- **Power Purchase Agreement.** In a PPA, the DOT acts as a "host" to allow a solar project developer to install a solar array on its property, and the DOT may elect to purchase the energy produced by the array over a 20- to 25-year period. Although specific contracts would have to be negotiated, most PPAs are selling energy at rates lower than the utility company rates.

  The DOT may also elect to allow the solar developer to install the array on its property and sell the energy to a third party, providing the DOT with a land lease payment.

  In either instance, the developer, not the DOT, would be responsible for O&M, and the developer would receive the benefits of the available utility incentives, tax credits, and RECs, which it may pass on to the DOT in the form of lower energy pricing.
- **Tax-Exempt Municipal Lease.** These leases are available only to public entities; they provide an option for a developer to complete an installation on the DOT's behalf, and the DOT makes lease payments that can be structured to be less than or equal to existing utility costs. In this model, the DOT has ownership responsibilities for O&M and receives the benefits of the utility incentives, energy savings, and RECs; the developer receives the tax incentives.
- **Bond Financing.** Bond financing can be executed in several ways and can provide a low-cost financing vehicle for the DOT to have direct ownership of the RE facility.

9.2 Financial Feasibility

Financial details for all recommended projects will be provided in the subsequent report (June 2014). The following steps will be taken in developing the financial analysis:

- Conduct an analysis of current and projected utility rates over the next 25 years.
- Provide current and projected installed costs for each recommended measure.
- Estimate the projected life of each recommended measure.

- Estimate the O&M costs over the life of the project.
- Project any regulatory impacts over the life of the project.
- Identify incentives, tax credits, and grants that may be available when needed to support financing of the project.
- Provide an analysis showing both the simple return on investment and a more complex approach that incorporates net present values and a full life-cycle cost analysis.
- Describe the potential exit strategies at the end of the project life and their related cost impacts.

See the HDC Green Energy Feasibility Study Report Financial Analysis of Recommended Measures for further financial analysis.

10 Summary and Conclusions

The continuing increases in the cost of energy, coupled with the negative environmental impacts of conventional energy production, clearly indicate the need to support the advancement of RE technologies.

The recommendations presented in this report provide the stakeholders and the public an outlook for RE-generating installations, referencing the existing and reputable renewable technologies to date.

The recommended RE technologies considered in the HDC are listed below. The technologies that appear to have the greatest potential for success and achievement of the goals and objectives are solar installations at specific points throughout the HDC ROW, within nearby utility distribution access, and near planned energy loads. Locations and applications such as:

- Solar on soundwalls along the ROW at nearby residential or business areas
- Solar on top of median barriers within the highway
- Alternative fueling stations at specific points throughout the HDC, EV charging stations, and biodiesel, CNG, and LNG fueling stations
- Solar lighting and signage at all locations throughout the HDC
- Solar carports for EV charging stations
- Solar-powered street lighting at interchanges
- Solar panel installations to offset the energy use of electric trains

Solar lighting and pathways for bicycle path. In addition, the opportunity for the installation of utility transmission lines for electricity and/or natural gas along the ROW should be considered.

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Appendix A Potential Locations for Green/Renewable Energy Installation

REV	DATE	BY	CHK	APP	DESCRIPTION	
						DESIGNED BY
						DRAWN BY
						CHECKED BY
						IN CHARGE
						DATE

PARSONS

DRAFT

GREEN ENERGY FACILITIES EXHIBIT

CONTRACT NO.
DRAWING NO.
SCALE
SHEET NO.

$USER$ $DATE$ $TIME$ $FILE$