INL/EXT-12-25686

Usage of Electric Vehicle Supply Equipment Along the Corridors Between the EV Project Major Cities

M. Kirkpatrick

May 2012

The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

INL/EXT-12-25686

Usage of Electric Vehicle Supply Equipment Along the Corridors Between the EV Project Major Cities

M. Kirkpatrick

May 2012

Idaho National Laboratory
Transportation Technologies
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Assistant Secretary for Energy Efficiency and Renewable Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

ABSTRACT

The EV Project consists of a nationwide collaboration between Idaho National Laboratory (INL), ECOtality North America, Nissan, General Motors, and more than 40 other city, regional and state governments, and electric utilities. The purpose of the EV Project is to demonstrate the deployment and use of approximately 14,000 Level II (208-240V) electric vehicle supply equipment (EVSE) and 300 fast chargers in 16 major cities. This research investigates the usage of all currently installed EV Project commercial EVSE along major interstate corridors. ESRI ArcMap software products are utilized to create geographic EVSE data layers for analysis and visualization of commercial EVSE usage. This research locates the crucial interstate corridors lacking sufficient commercial EVSE and targets locations for future commercial EVSE placement. The results and methods introduced in this research will be used by INL for the duration of the EV Project.

CONTENTS

FIGURES

Usage of Electric Vehicle Supply Equipment along the Corridors between the EV Project Major Cities

INTRODUCTION

Background

"INL has partnered with ECOtality North America, Nissan, General Motors, and more than 40 other city, regional and state governments, electric utilities, and other organizations to demonstrate the deployment and use of approximately 14,000 Level II (208-240V) electric vehicle supply equipment and 300 fast chargers in 16 major cities. The EV Project includes the deployment of 5,700 battery electric vehicle (BEV) Nissan Leafs and 2,600 extended range electric vehicle (EREV) General Motors Volts, that will be recharged in private residence, fleet, and public locations. All 23,000 vehicles and charging units are being equipped with meters and/or data loggers. The EV Project is the single largest deployment and evaluation project ever of electric drive vehicles and charging infrastructure. The vehicles and recharging units will operate in the below metropolitan areas:

- Phoenix and Tucson, Arizona
- Portland, Eugene, Salem, and Corvallis, Oregon
- Los Angeles, San Diego, and San Francisco, California
- Seattle, Washington
- Chattanooga, Knoxville, Memphis, and Nashville, Tennessee
- Dallas, Fort Worth, and Houston, Texas
- Washington, D.C."

(Source: "Idaho National Laboratory")

"The EV Project collects and analyzes data to characterize vehicle use in diverse topographic and climatic conditions, evaluates the effectiveness of charge infrastructure, and conducts trials of various revenue systems for commercial and public charge infrastructures. The ultimate goal of The EV Project is to take the lessons learned from the deployment of the first thousands of EVs, and the charging infrastructure supporting them, to enable the streamlined deployment of the next generation of EVs to come." (Source: "EV Project")

Problem Statement

A Geographic Information System (GIS) is a system of hardware and software used for storage, retrieval, mapping, and analysis of all types of geographic data. Spatial features are stored in a coordinate system, which references a particular location on the earth's surface. Spatial data and associated attributes in the same coordinate system can then be layered together for mapping and analysis. GIS can be used for scientific investigations, resource management, and development planning.

In this particular study, GIS is being utilized for development planning. The spatial features from the tabular data received from ECOtality are brought in as a layer using the lat/long coordinate system. This layer is combined with ESRI base maps allowing the Electric Vehicle Supply Equipment (EVSE) locations to be examined visually. The data will assist in determining where additional EVSE could be installed and also illustrate the EVSE that are available and not being used.

Electric Vehicle Supply Equipment (EVSE) is a network of public charging stations (that) gives plug-in electric vehicle drivers alternatives to home charging and can extend driving range. (Source: "U.S. DOE Energy Efficiency and Renewable Energy") Idaho National Lab (INL) is tasked to do a study on the usage patterns of the Blink EVSE located along the major interstate corridors between participating EV Project cities. In order to accomplish this task, a pre-study was completed to determine what specific EVSE should be considered to be along interstate corridors.

EVSE falling within 0.5 miles of any interstate and major highway will be considered within city limits. EVSE falling within 2 miles of any interstate or major highway outside of city limits will also be considered along interstate corridors. The focus of this study is to see if EV drivers are using the Blink EVSE chargers along the corridors to travel between EV Project cities (listed above). The Blink EVSE that are located outside of city limits will be used to support this study.

This senior project demonstrates my ability to provide a solution to an open-ended research problem. Because the EV Project is the only project of its kind to date, the research performed within this project is unique. There were no specific resources available for me to use to produce a solution other than the research skills and tools acquired throughout my education.

DATA

The commercial Blink EVSE contains an onboard data logger which records plug-in events and energy usage. The Blink EVSE then transfers streamlined data to a server located at ECOtality. ECOtality then pushes the data to INL on a weekly basis using a secure server. The data received at INL comes in comma separated value (.csv) format. The data is then loaded, processed, and stored in SQL server.

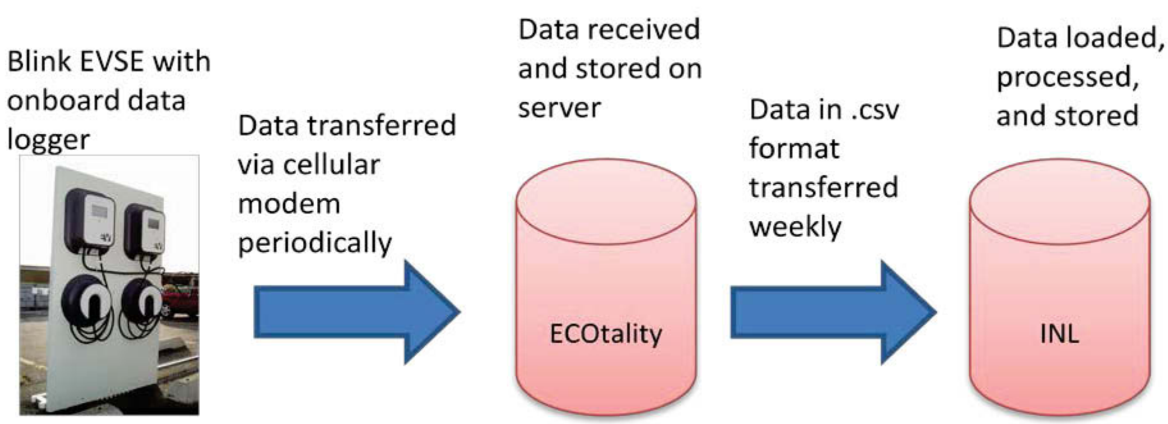

Figure 1 – Process of transferring Blink EVSE data to INL

SITE INFORMATION

The site information is limited to the interstate corridors that connect the EV Project cities, including: Seattle to Eugene, San Francisco to San Diego, Phoenix to Tucson, Dallas/Fort Worth to Houston, and Memphis to Nashville to Knoxville to Chattanooga.

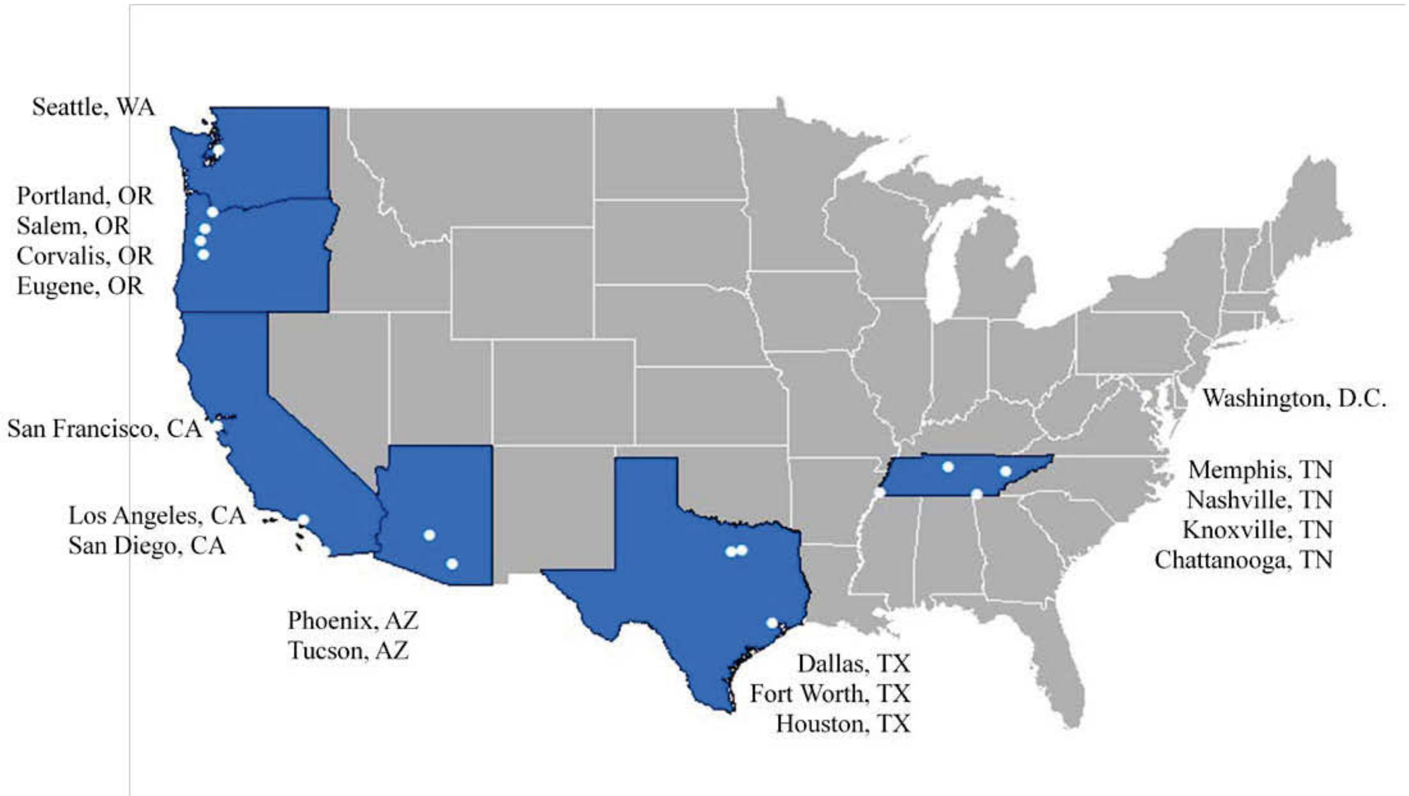

Figure 2 – EV Project cities

RESEARCH

An ESRI (the world's leading developer of GIS software) base map was used in ArcMap that included states, interstates, major roads, and city limits.

Cities

OBJECTID *	Shape *	FEATURE	NAME	ST_ABBREV	FIPS	PLACE_FIPS	POP_2000	POP2007	STATUS
166	Point	less than 10,000	Houston	AK	02170	33800	1202	1696	
685	Point	500,000 - 999,999	Seattle	WA	53033	63000	563374	593350	County Seat
1328	Point	no data	Salem	ME	23007	65305	-99999	-99999	
2150	Point	500,000 - 999,999	Portland	OR	41051	59000	529121	551302	County Seat
2347	Point	50,000 - 99,999	Portland	ME	23005	60545	64249	65935	County Seat
2391	Point	less than 10,000	Portland	ND	38097	63900	604	585	
2610	Point	10,000 - 49,999	Dallas	OR	41053	17700	12459	13855	County Seat
2652	Point	100,000 - 249,999	Salem	OR	41047	64900	136924	152039	State Capital County Seat
2738	Point	no data	Corvallis	MT	30081	17725	-99999	489	
2959	Point	10,000 - 49,999	Corvallis	OR	41003	15800	49322	51828	County Seat
3425	Point	no data	Salem	NH	33015	66580	-99999	-99999	
3542	Point	100,000 - 249,999	Eugene	OR	41039	23850	137893	145394	County Seat

1 (0 out of 109 Selected)

Interstates

OBJECTID *	Shape *	ROUTE_NUM	CLASS	NUMBER	SUFFIX	DIST_MILES	DIST_KM	Shape_Length
1	Polyline	CG8	C	G8		5.12996	8.25588	0.078384
2	Polyline	I105	I	105		19.83041	31.91401	0.362882
3	Polyline	I205	I	205		48.25566	77.66011	0.846401
4	Polyline	I215	I	215		93.43523	150.36972	1.498219
5	Polyline	I238	I	238		2.03548	3.27579	0.039176
6	Polyline	I305	I	305		4.98412	8.02118	0.094524
7	Polyline	I505	I	505		32.92274	52.98412	0.479897
8	Polyline	I515	I	515		5.68403	9.14757	0.09663
9	Polyline	I580	I	580		72.91108	117.33925	1.323339
10	Polyline	I605	I	605		27.13689	43.67268	0.415428
11	Polyline	I710	I	710		20.02547	32.22794	0.296945
12	Polyline	I780	I	780		6.33726	10.19886	0.11477

1 (0 out of 692 Selected)

Figure 3 – Example of ESRI base map attribute tables for cities and interstates

A definition query, which allows you to specify which features of a layer will draw based on a SQL query, was written in ArcMap to highlight the boundaries of the major EV Project cities.

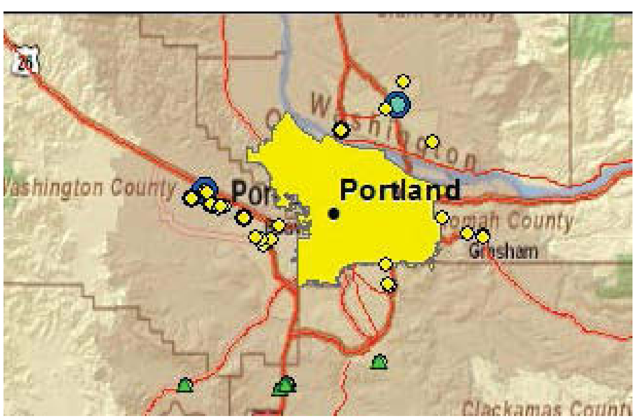

Figure 4 – Example of city limit extent query

Since the original ECOtality data had the total energy and number of charges to date, a query was run in SQL Server to limit the energy and charger data for the month of March to include all EVSE that were installed prior to March 1, 2012. This data contained the lat/long, EVSE type (commercial or residential), total energy used in March, and number of charges in March. The data was transformed into WGS_1984 geographic data of the EVSE locations using the lat/long fields.

An ArcMap definition query was created to only include the commercial chargers in that dataset. An ArcMap definition query was also created on the major highways to only include the class 1 and class 2 highways.

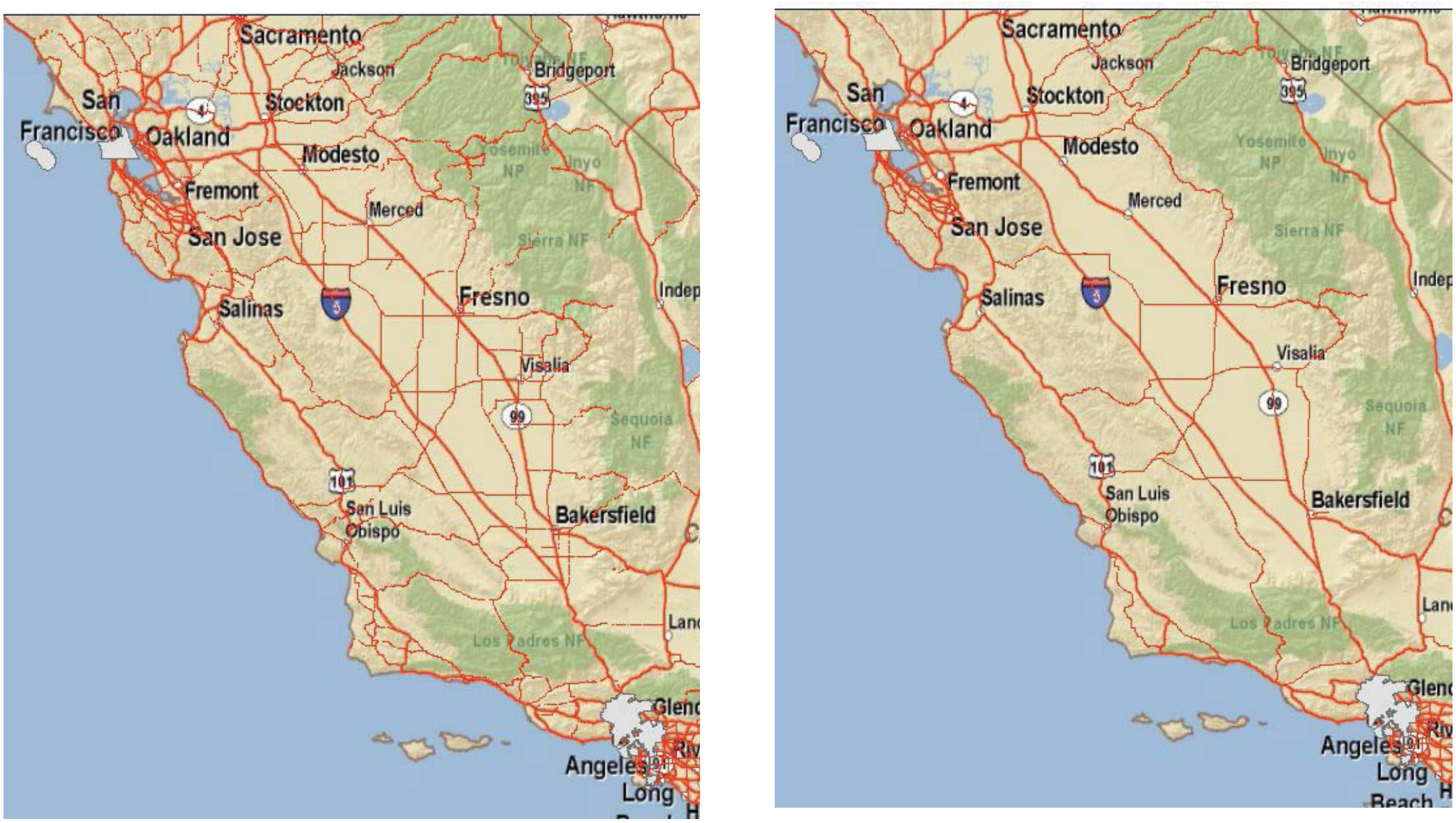

Figure 5 – Example of definition query limiting major highway layer

An ESRI ModelBuilder model was created to produce the final layer used in this analysis. A ModelBuilder Model is a model created by a user that is used to run through a series of GIS tools multiple times using different data sets.

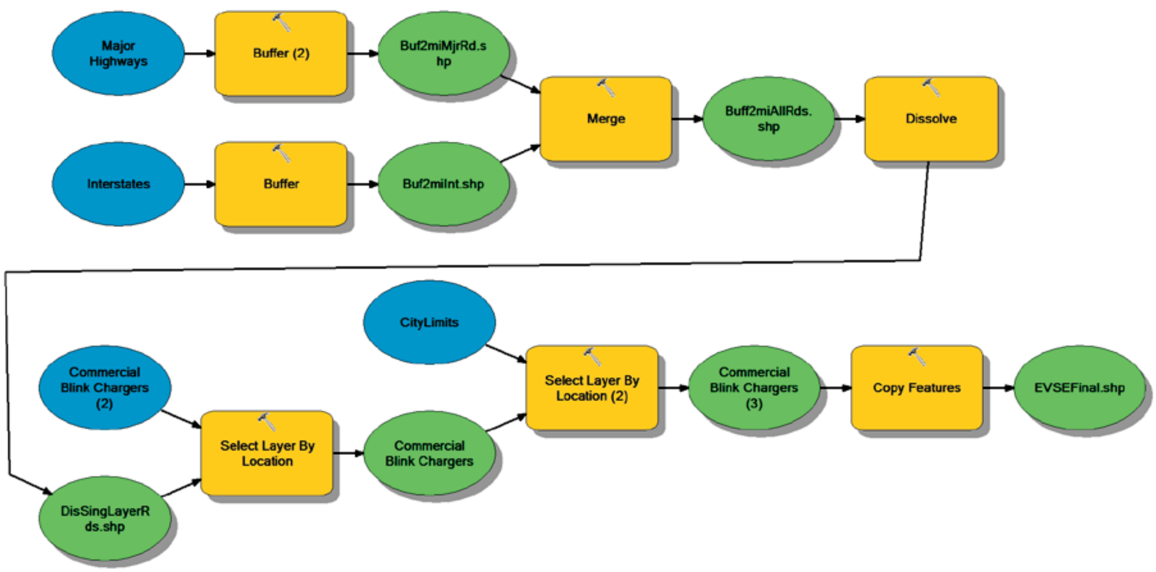

Figure 6 – Screenshot of ModelBuilder model

The processes performed by the model are as follows:

1. Add a 2-mile buffer around the major highways and interstates

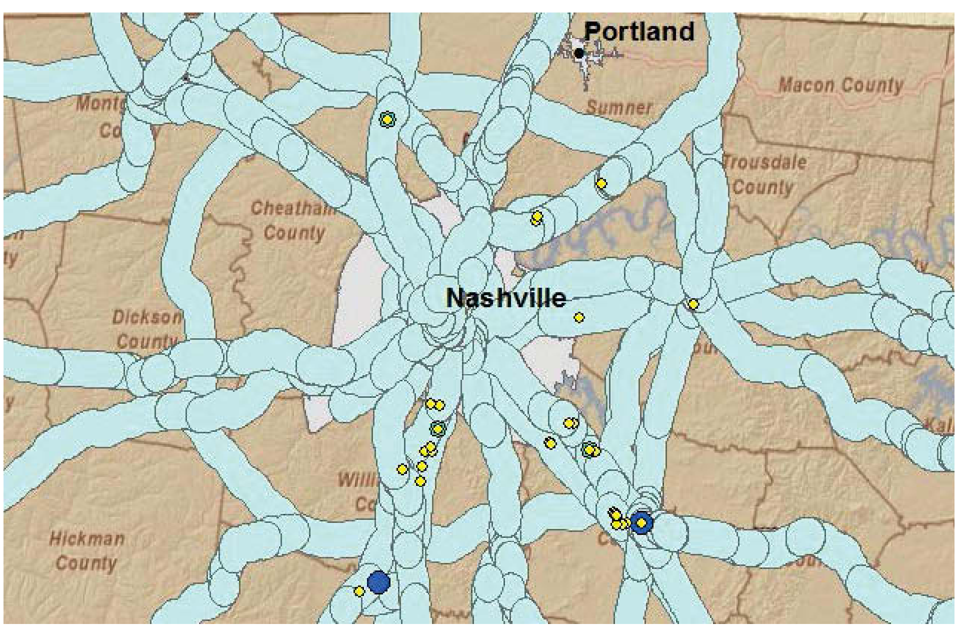

Figure 7 – Example of 2-mile buffer around interstates and major highways

2. Both buffers were merged into one layer
3. The roads layer was then dissolved into one layer

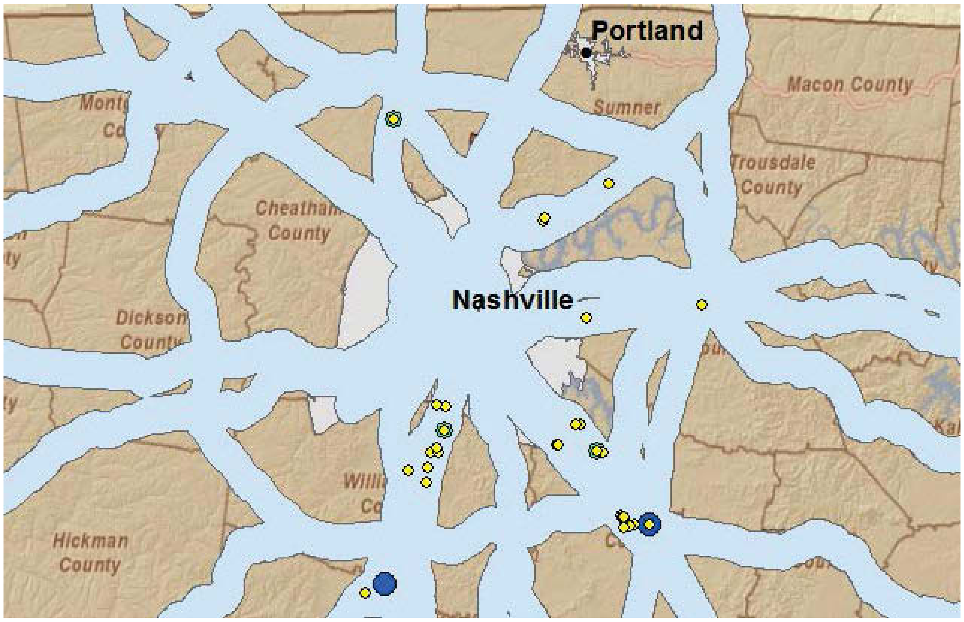

Figure 8 – Example of 2-mile buffer merged into one layer and dissolved

4. The select layer by location was then executed to include the EVSE within the 2-mile buffer of the roads

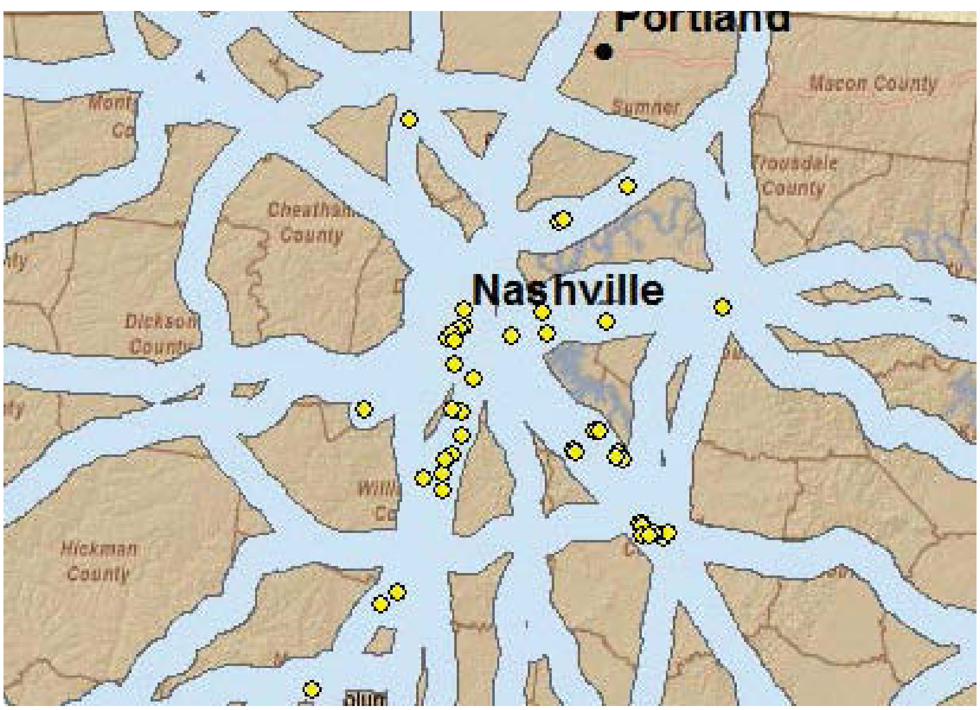

Figure 9 – Example of EVSE located within the 2-mile buffer

5. The select layer by location was executed to remove any EVSE within the city limits

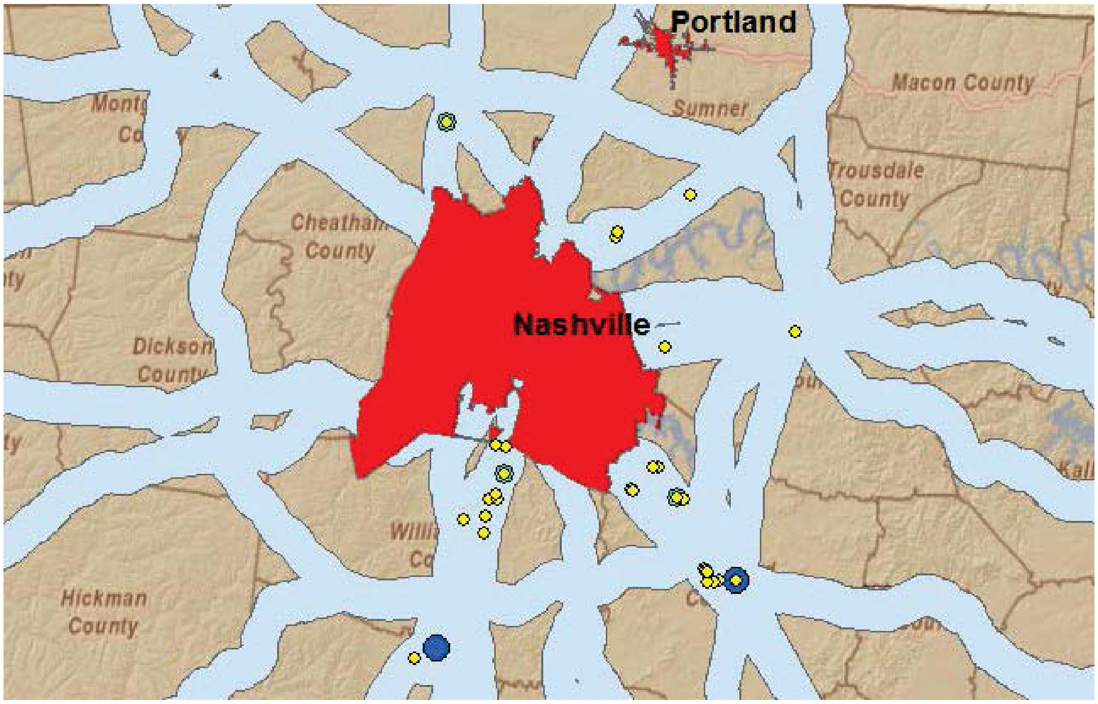

Figure 10 – Example of EVSE within 2-mile buffer and excluded from city limits

6. A new layer was created by using copy features to only include the EVSE from the selected features.

EQUIPMENT

Geographic Information System Tools

Below is a list of the tools used to create the model and a brief explanation of each tool.

Buffer – Creates buffer polygons around input features to a specified distance. An optional dissolve can be performed to combine overlapping buffers.

Merge – Combines multiple input datasets of the same data type into a single, new output dataset. This tool can combine point, line, or polygon feature classes or tables.

Dissolve – Aggregates features based on specified attributes.

Query Builder – Used to identify the features for a final selected set based on a query

Select Layer by Location – Adds, updates, or removes a layer's selection based on a spatial relationship to features in another layer.

Copy Features - Copies features from the input feature class or layer to a new feature class. If the input is a layer which has a selection, only the selected features will be copied. If the input is a geodatabase feature class or shapefile, all features will be copied.

ModelBuilder Model – Used to run through a series of GIS tools multiple times using different data sets.

Software

- ESRI ArcMap 10
- ESRI ModelBuilder10
- Microsoft SQL Server 2008

Data

ESRI – states, interstates, major roads, city limits

ECOtality – Project Blink EVSE locations and charge information

TIMELINE

Collect data – 16 hrs (Feb-March)

Create data products for analysis – 24 hrs (March)

Complete analysis – 18 hrs (March – April)

Produce report, presentation and data visualization – 23 hrs (April-May)

EVALUATION AND ANALYSIS

The two vehicles included in the EV Project are the Nissan Leaf and the Chevy Volt. The Nissan Leaf is a Battery Electric Vehicle (BEV) and has an estimated 100 mile range on a full charge. The Chevy Volt is an Extended Range Electric Vehicle (EREV), which has two sources of energy. The battery allows you to drive approximately 35 miles all electric range. Once the battery is depleted, the vehicle uses a gasoline engine to power a generator, allowing an extended range. The Volt onboard generator produces electricity providing a total of approximately 375 miles per tank of gas. Since the range of the Leaf is approximately 100 miles, drivers need to charge along the corridor to complete trips between major cities.

Figure 11 shows the corridor between Phoenix and Tucson Arizona, which is approximately 116 miles. Since the Nissan Leaf has a limited range, we will focus on that particular range along the corridors. There are two Blink EVSEs located approximately 60 miles South of Phoenix, which allows an electric vehicle to travel from Phoenix to Tucson. The data indicates that neither EVSE was used in March.

Figure 12 shows the corridors between Memphis and Nashville Tennessee. The distance from Memphis to Nashville is approximately 212 miles. There is one EVSE located along I-40, which was used twice in March, for a total of 26.59 kWh. There are also three EVSE located off of Hwy 79. One of the EVSE was used once in March with a total of 14.17 kWh, while the other two weren't in use.

Figure 13 shows the corridors between Nashville, Knoxville, and Chattanooga. The EVSE are spaced out between 30 to 60 miles with one stretch of approximately 20 miles along these three corridors. Of the eight EVSE flagged from Nashville to Knoxville, four EVSE had no charging in the month of March. The others had 3 (10.15 kWh), 1 (1.73 kWh), 2 (16.26 kWh) and 5 (12.28 kWh) charges. Between Nashville and Chattanooga, two of the four flagged EVSE had zero charging. The other two had 3 (2.75 kWh) and 7 (15.57 kWh) charges. Of the three located on the corridor between Chattanooga and Knoxville, two had no charges and one had 1(0.04 kWh) charge believed to be a glitch.

Figure 14 shows the corridors between Fort Worth, Dallas, and Houston Texas. Since the distance between Fort Worth and Dallas is about 35 miles, this corridor wasn't considered. There were no EVSE flagged between Dallas and Houston, they either may not be installed yet, or do not currently fall under the EVProject EVSE.

Figure 15 shows the corridor between Seattle, Washington and Portland, Oregon. It is about 174 miles from Seattle to Portland. There are no EVSE located along this corridor. Because of the number of vehicles in this area, this should be a main focus for installation of EVSE along this corridor.

Figure 16 shows the corridors between Portland and Eugene. The map shows 10 EVSE located between Portland and Salem of which 4 EVSE were not used during the month of March. The other 6 have 11 (19.56 kWh), 3 (4.38 kWh), 2 (0.70 kWh), 4 (16.99 kWh), 2 (10.02 kWh), and 3 (8.28 kWh) charges. There are also three EVSE located near Corvalis in which there was 1 (1.79 kWh) charge while the other two weren't used during March.

Figure 17 shows the corridors between San Francisco and Los Angeles. There aren't any Blink EVSE currently located between these two cities.

Figure 18 shows the corridors between Los Angeles and San Diego. Again, there aren't and Blink EVSE currently located between these two cities.

CONCLUSIONS

These maps provide a nice visualization of EVSE locations along interstate corridors. They also detail EVSE usage. The maps reveal crucial locations along the interstate corridors where additional EVSE could be installed and also shows EVSE that are available and not being used. Further analysis would need to be performed to determine if any EVSE were used to complete a drive from city to city. Additionally, this analysis should be performed monthly to observe EVSE usage over time. This may show patterns of EVSE utilization (how often used and how much energy used) and show when a new EVSE has been installed. Since not all planned commercial EVSE have been installed to date, EVSE gaps along the corridors were expected. The usage of the placed EVSE, however, may help with future EVSE placement. This is an R&D project and INL will continue to monitor the commercial EVSE usage using the process defined within this report.

The project started with a poorly defined general question, "How EVSE are or are not being used along the corridors." During the requirements gathering phase of my research I produced a list of questions to better define the original question. From the answers I received I was able to refine the general research question to "How are the Blink EVSE utilized along interstate corridors between EV Project major cities outside of city limits." I proceeded with gathering, processing, and analyzing the related data needed to answer the general research question.

Once I had the data analysis, I used ESRI ArcMap to visualize the research results. I also used ESRI ArcMap to provide a custom solution, detailed within this report that enables INL researchers to continue monitoring EVSE usage.

LESSONS LEARNED

When I first started the project, I brought in a layer of all EVSEs located along the corridors, including Blink, ChargePoint, EVSE LLC, Gridbot, RechargeAccess, Rideshare, Seama, and Shorepower. I quickly realized that this was too much information. The information made the maps messy and didn't add value. Next, I narrowed the search to only include Blink EVSEs. The maps contained Blink EVSEs that were not a part of the EV Project. These EVSEs only provided location data, but didn't tell me how they were being used. I finally decided to use the Blink

EVSEs that were a part of the EV Project, which gave me the total energy used and total number of charges for each EVSE. Although this was better, it was difficult to show the usage since the data was cumulative from the time the EVSE were installed. I further refined the search to include all EVSE installed prior to March 1, 2012 and only included data for the month of March.

EVSE located within city limits were difficult to include in my analysis because it was unclear if these EVSE were being used to travel along the corridors. Because of this, I chose to exclude the EVSE located inside the city limits of all the major project cities.

Another issue was the timing of EVSE installations; the installations did not occur as quickly as I had projected. New EVSEs are constantly being installed and our data is updated weekly. This explains areas that do not have any EVSEs located along interstate corridors. This analysis will be more robust as more data is added to the project.

REFERENCES

"American Recovery and Reinvestment Act (ARRA) - Light-Duty Electric Drive Vehicle and Charging Infrastructure Testing." *Idaho National Laboratory*. Idaho National Laboratory, 05/13/2011. Web. 4 Apr 2012. <http://avt.inl.gov/evproject.shtml>

"Overview." *The EVProject*. ECOtality, n.d. Web. 16 Apr 2012. <http://www.theevproject.com/overview.php>

"Alternative and Advanced Vehicles." *U.S. DOE Energy Efficiency and Renewable Energy*. Department of Energy, 10/17/2011. Web. 27 Apr 2012. <http://www.afdc.energy.gov/afdc/vehicles/geoevse.php>.

MAPS

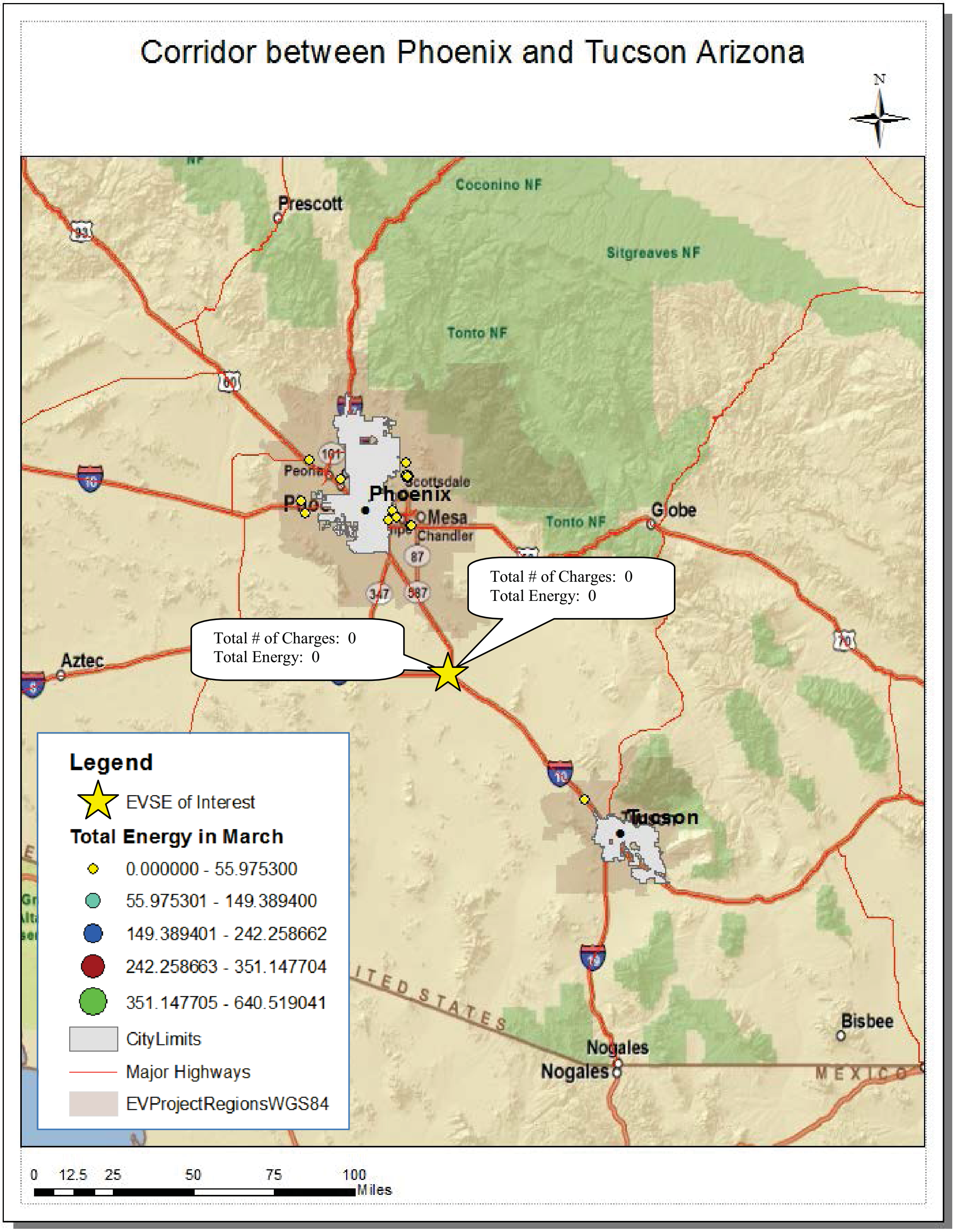

Figure 11 – Arizona map

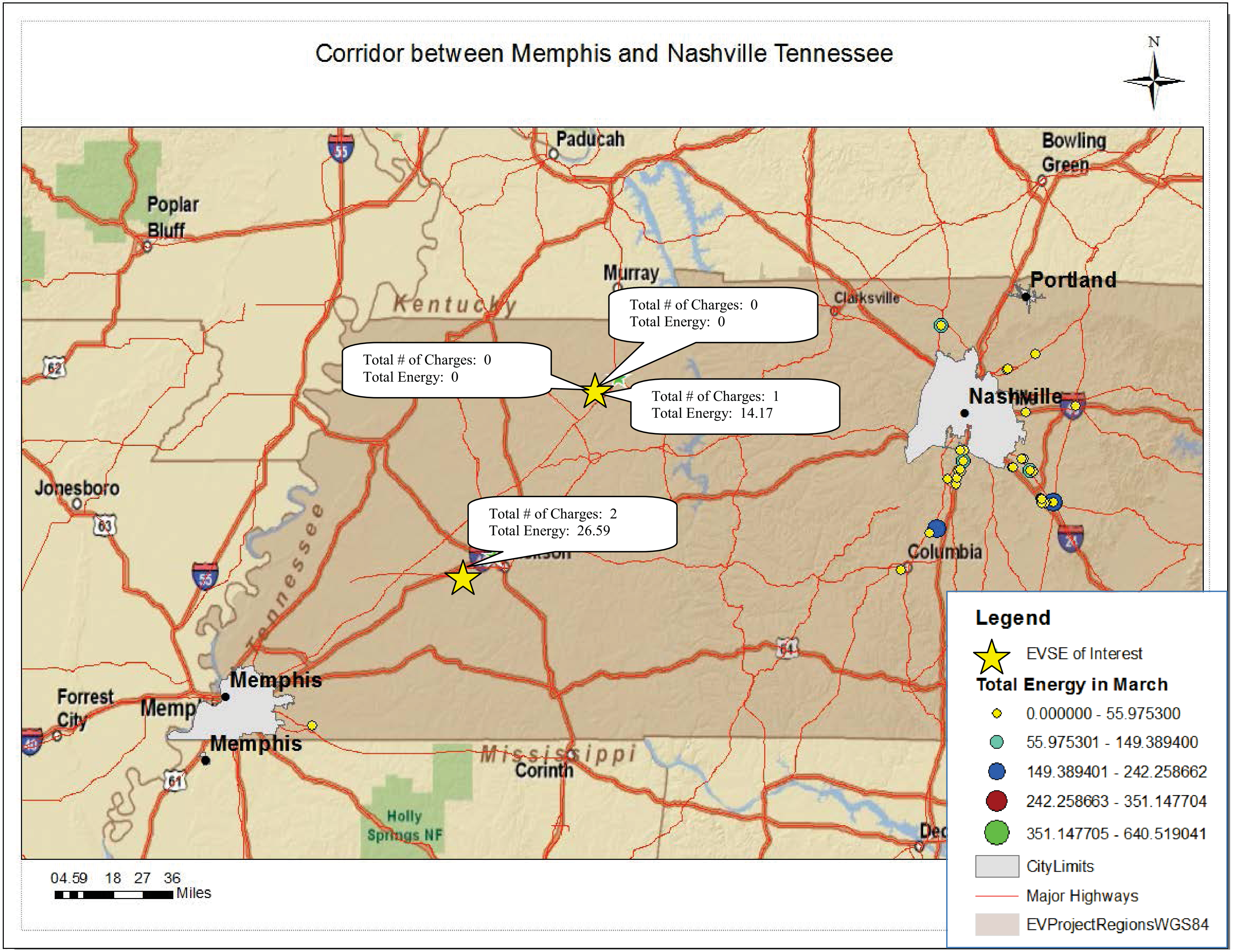

Figure 12 – West Tennessee map

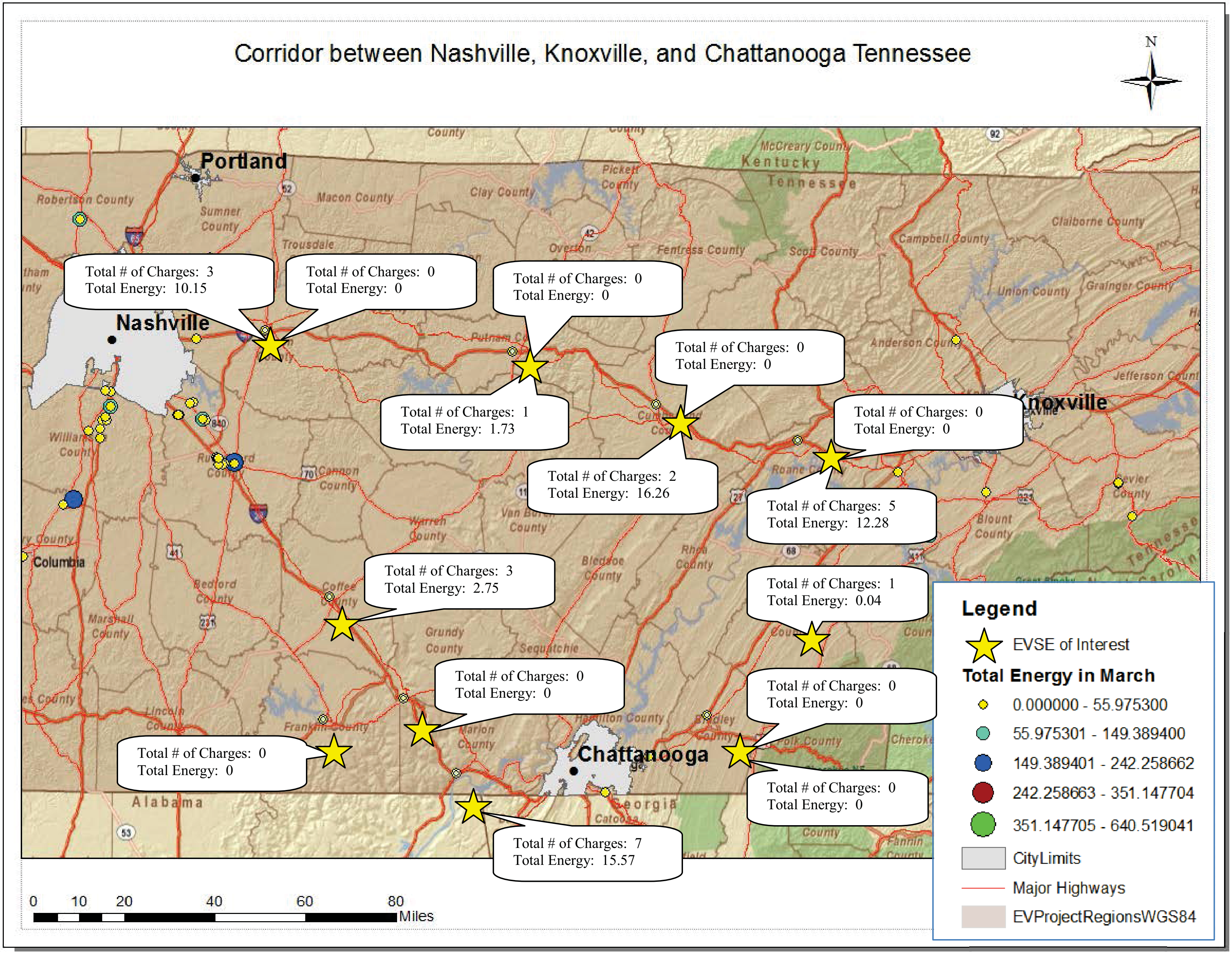

Figure 13 – East Tennessee map

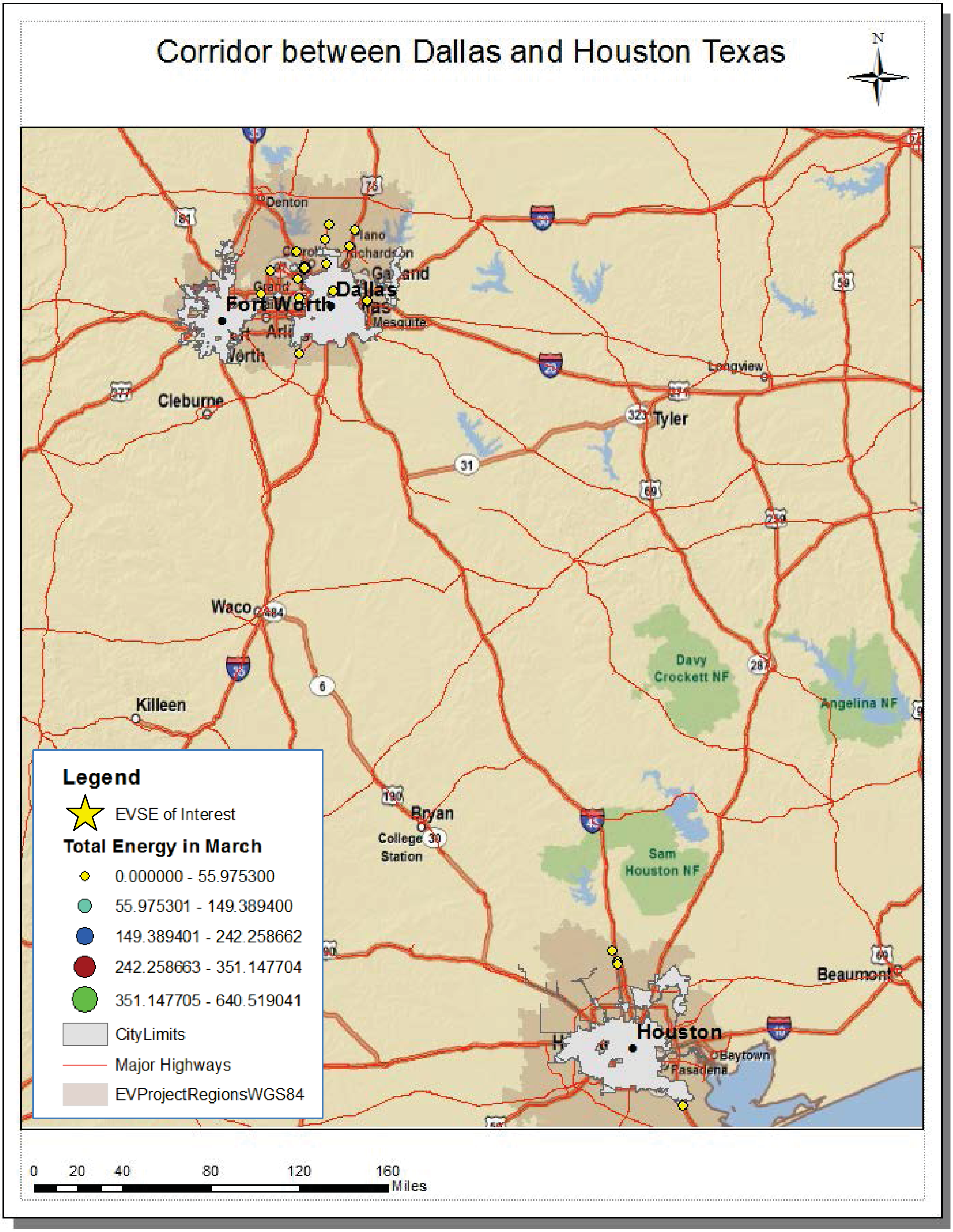

Figure 14 – Texas map

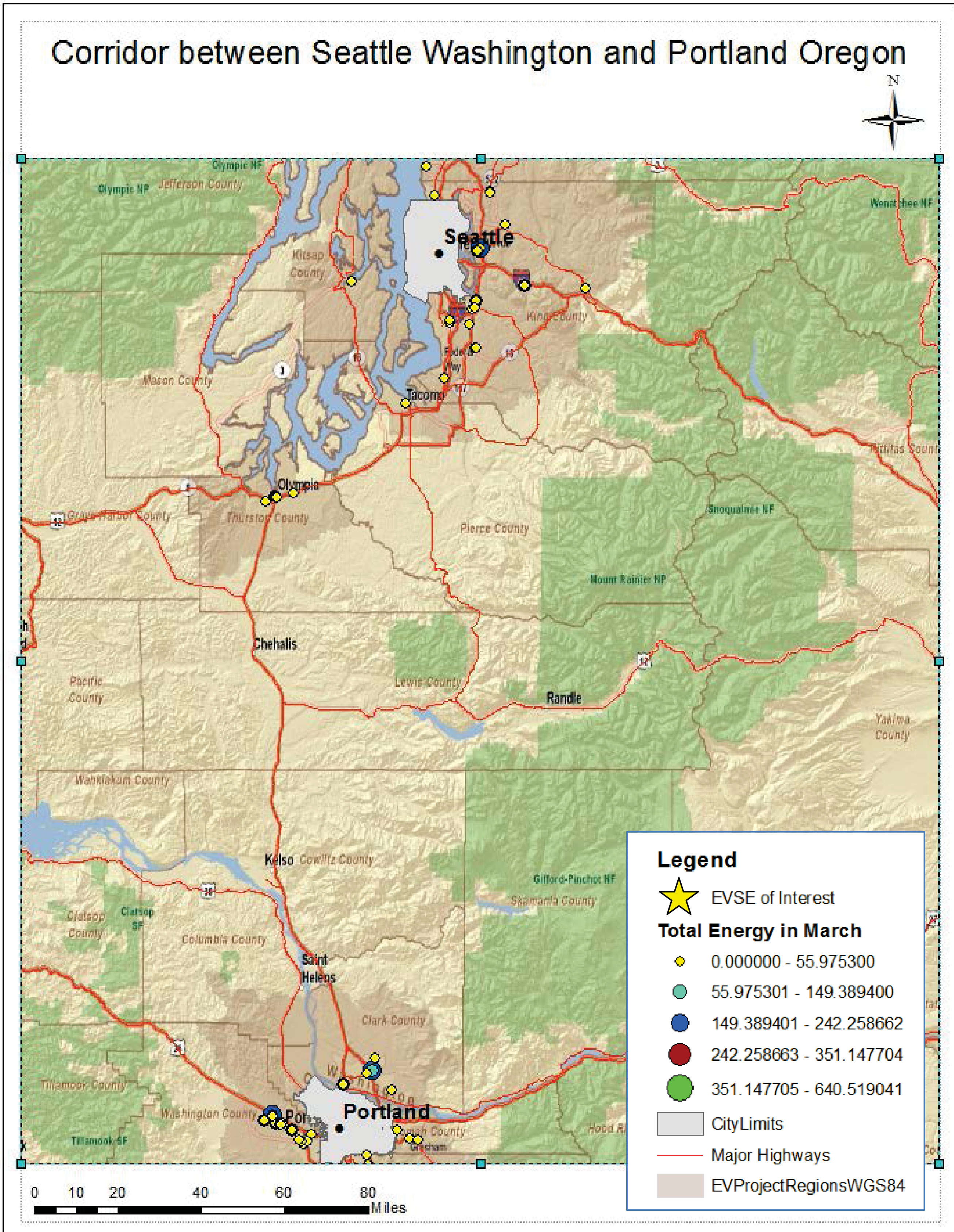

Figure 15 – Washington and Oregon map

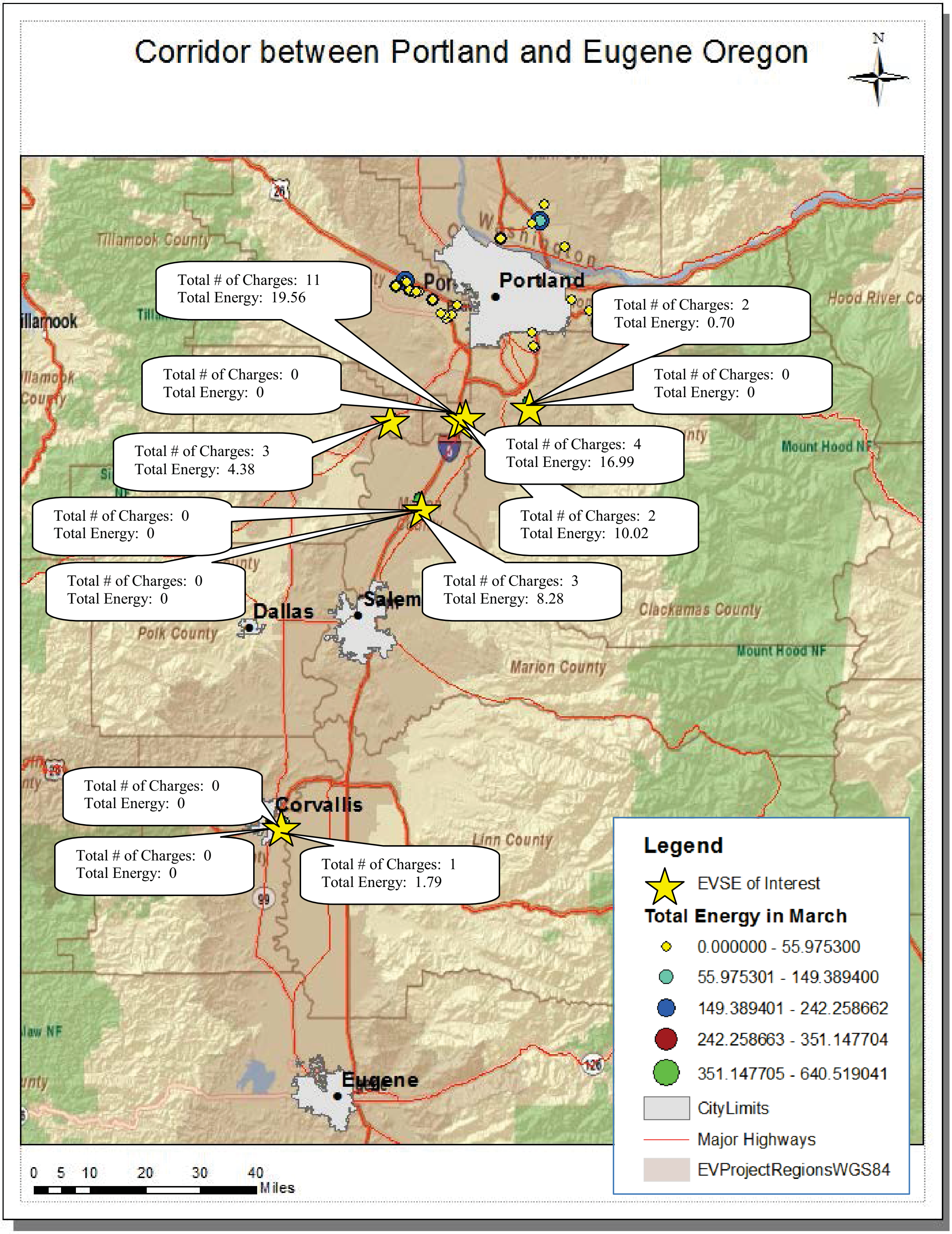

Figure 16 – Oregon map

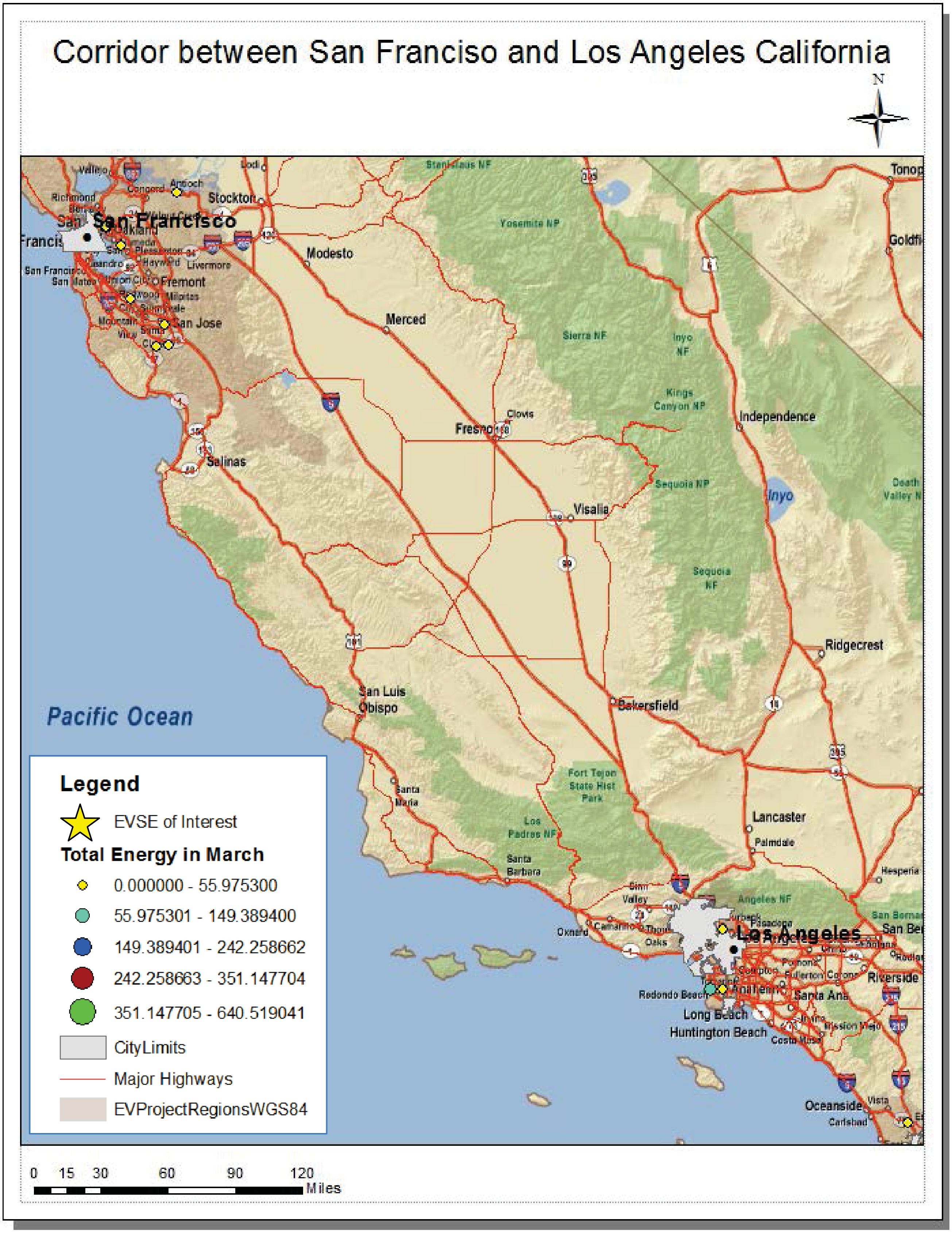

Figure 17 – San Francisco to Los Angeles California map

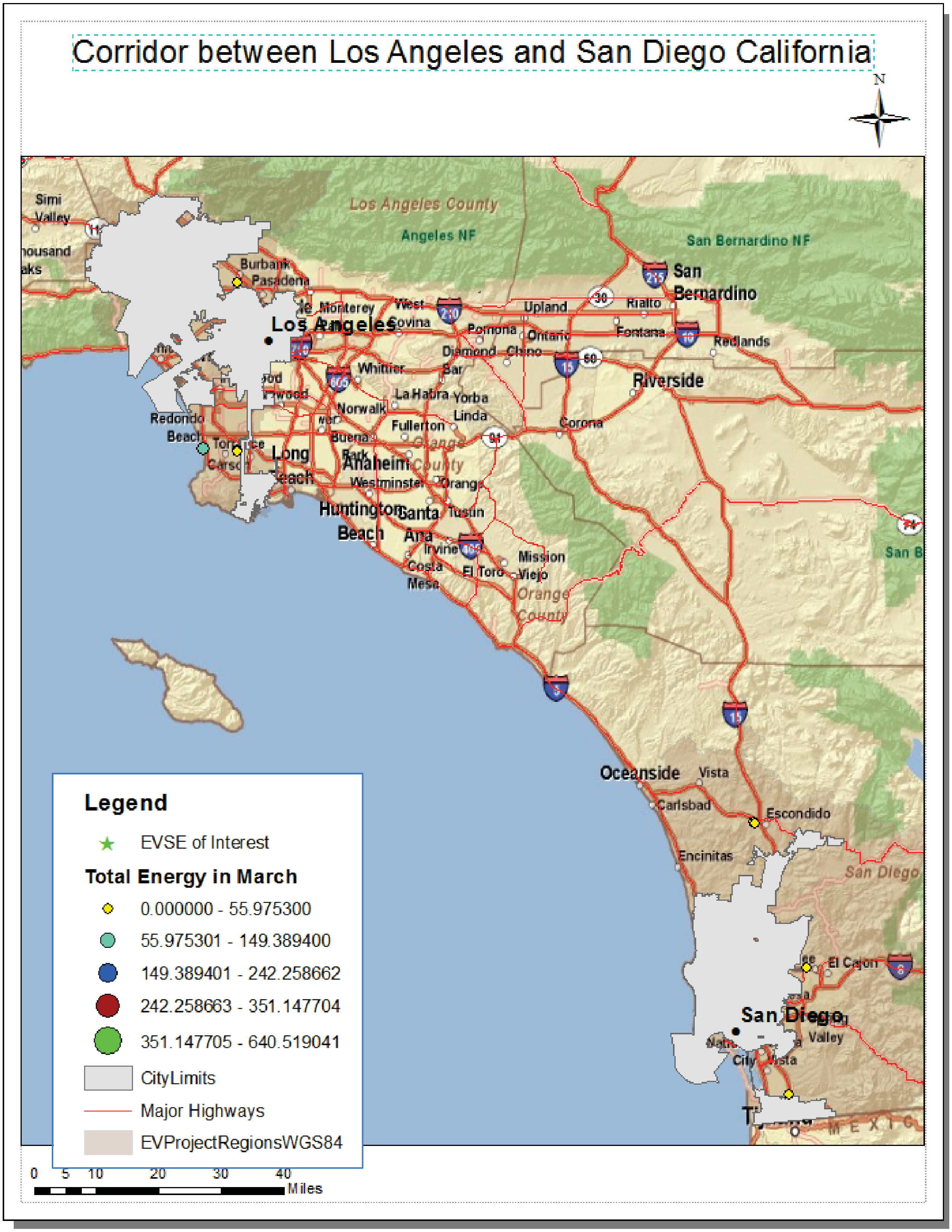

Figure 18 – Los Angeles to San Diego California map

Appendix A

Data Model

State attributes: State_Name, State_abbreviation

Interstate attributes: Route_Num, Class

Highway attributes: Name, type, class, Hwy_type

EVSE attributes: Latitude, Longitude, EnrolledDate, EVSELevel, EVSEType, totalEnergy, numberCharges

NOTE: The raw and geographic EVSE data is covered by an NDA between INL and ECOtality, I am unable to provide a copy of the data.