DEVELOPING A COMPREHENSIVE DATABASE OF ALTERNATIVE FUEL STATION LOCATIONS ACROSS CANADA AND THE UNITED STATES OF AMERICA[1]

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Introduction

In 1991, the National Renewable Energy Laboratory (NREL) began collecting data for the United States Department of Energy (USDOE)Alternative Fuels Data Center (AFDC).[i]Over time, the keystone dataset for the AFDC became the alternative fuels station data. Because of the long-term support of the USDOE, the locations of biodiesel, compressed natural gas (CNG), electric, ethanol, hydrogen, liquified natural gas (LNG), and propane stations have been available across the United States of America for decades. Then in 2017, NREL partnered with National Resources Canada (NRCan) to expand the dataset to include the location of those same alternative fuel stations across Canada as the Electric Charging and Alternative Fuelling Stations Locator or Localisateur de stations de recharge et de stations de ravitaillement en carburants de remplacement.[ii] On both countries' websites, users can view, get driving directions for, and conduct searches on alternative fuel stations based on specific criteria, providing the opportunity for drivers to consider a variety of fuels to enable their intra and international driving.

About the Station Locator

The alternative fuel station locators provide information for a specific audience. Rather than only targeting an individual consumer who may own one or a few cars, this tool targets audiences that care about many vehicles: fleet owners who may own, maintain and refuel vehicles; municipalities, states and provinces who may want to enable a more diverse fuel infrastructure in their region; researchers who may want to understand alternative fuel infrastructure in North America,and industrial partners who may manufacture or sell vehicles, convert vehicles to a new fuel system, or develop fuel stations. In each of these use cases, information about more than a single fuel may be needed. This is the key strength of this alternative fuel station dataset. A fleet owner may be looking at different fuel options for light-duty and heavy-duty vehicle implementations. A municipality may have air quality considerations and be evaluating a range of fuels to mitigate local emissions. A researcher may be modelingthe growth of different alternative fuels over time. An industrial partner may be breaking into a new market and want to understand the existing fuel infrastructure before introducing a new fuel station or vehicle to a region.

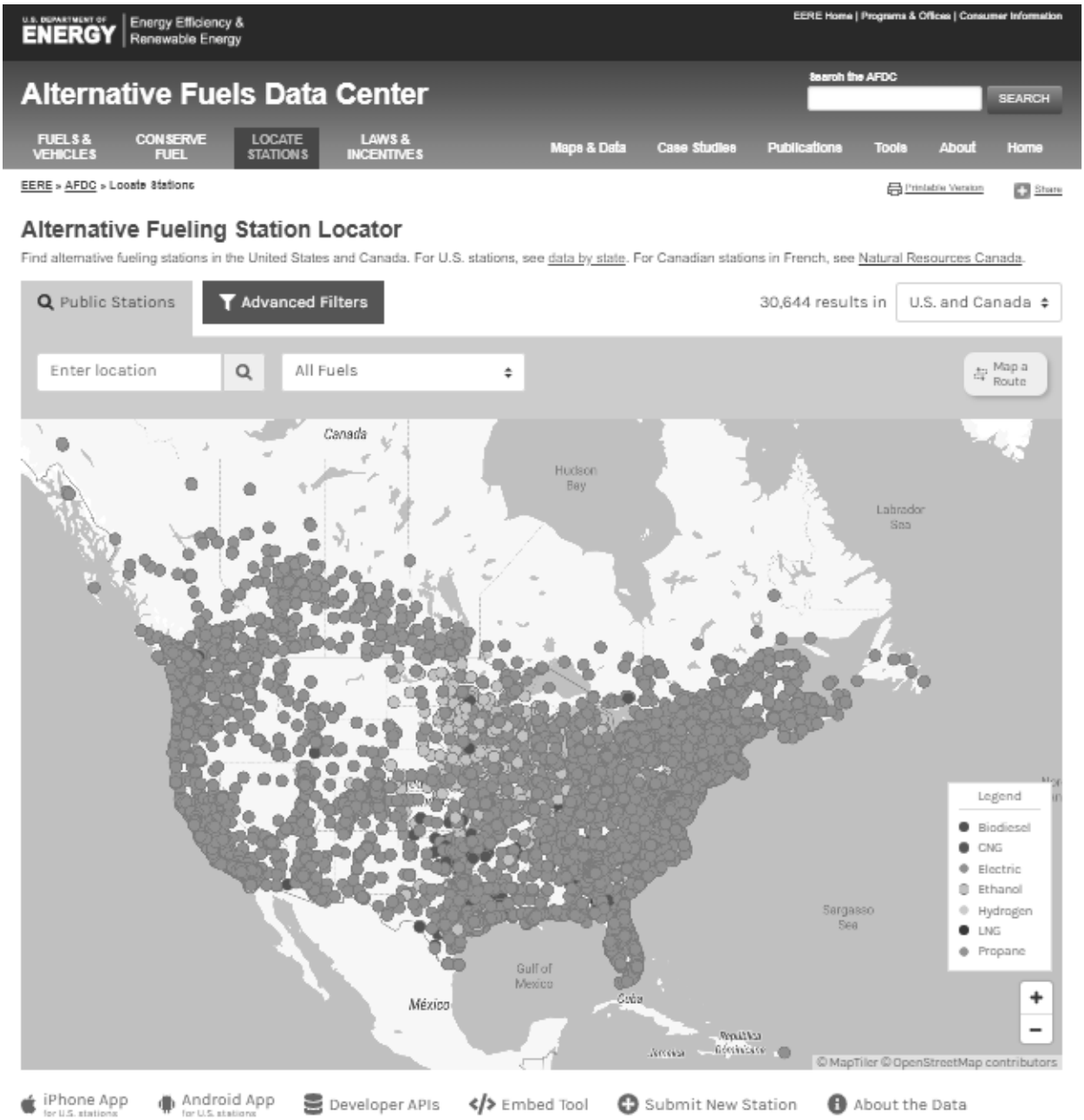
Figure 1 shows the distribution of alternative fuel stations across Canada and the United States as displayed in the AFDC Station Locator[iii]. The Locator displays the fuels, defined as alternative fuels by the United States Energy Policy Act (EPAct) of 1992,[iv]that have market-ready fueling equipment available. The market penetration of EPAct-approved alternative fuels is monitored to determine if fuels need to be added to the Locator.

The site can be viewed on a variety of devices including computers, tablets and smartphones. Users can search for a specific location and find nearby stations. Users can also view stations for all fuels or sub-select to specific fuels. Clicking on an individual station shows its details including name, address, phone number, hours, access, and other station specific information. A user can also find directions between two points and identify stations along the driving route. While the default opening screen displays just public

1Presented at the 54th Annual Meetings of the *Canadian Transportation Research Forum*, May 26-29, 2019 at Vancouver, BC

stations—stations anyone can access—the "Advanced Filters" tab allows a deeper analysis into specific countries, states, and provinces; specific fuel types and their attributes; and station details including access, owner and payment information. Querying the alternative fuel dataset by these parameters produces a count of stations, a map of station locations and the ability to download a spreadsheet of the stations that meet the selected criteria.

Figure 1 Screenshot of the AFDC Station Locator



Ensuring a variety of available data access methods is a best practice of the Station Locator, with the goal to maximize end-user compatibility. *Table 1* displays the different ways users can obtain alternative fuel data and which methods are supported in each country.

Table 1 Station data dissemination methods

Data access	Canada	United States
Web-based application	Yes	Yes
Widget for custom embeddable web-based applications	Yes	Yes
Application programming interface (CSV, JSON, XML)	Yes	Yes
Download data (CSV, JSON, XML)	No	Yes
Android App	No	Yes
iPhone App	No	Yes
Summary data table by state and fuel type	No	Yes
Summary data map by state and fuel type	No	Yes

NREL implemented the NRCanStation Locator platform with the features used by the largest number of AFDC users. The metrics of the AFDC platform informed the creation of the NRCan platform, which also enables data sharing with Canadian alternative fuel partners and application developers. The screen shot of the web-based application, seen in *Figure 2*, demonstrates auser-friendly way to access and explore data. The widget capability allows an end-user to interact with the public stations map, create a custom view specific to their needs and embed that map into any other website. For example, a user could query for electric charging stations in Montréal, QC with Level 2 and DC Fast charging. Then, the user could click the "Embed Tool" button and copy and paste the HTML code that will exactly recreate the map in their own web environment. If the user wants to create their own web map, rather than use the NRCan map, station data can be directly accessed from an application programming interface (API).[v]This API directly queries station data from the database in a computer-friendly format usable by applications, models and analysis tools.

The U.S.Station Locator provides the same capabilities as the Canadian Locator, with a few additional features. The U.S. Station Locator allows for data downloads into various formats, including an Excel-friendly CSV file, based on limited parameters.This provides the same functionality as the API data but is provided via a user-friendly interface. With the ever-increasing use of smart phones, NREL also built U.S. Station Locator mobile applications for both the Android and iPhone platforms. Finally, for state and federal partnersin the United States, NREL used the Station Locator API to generate easy-to-use summary tables and maps to provide high level state and U.S. data.

The Station Locator API is the backbone of all data dissemination products. The API provided to external end-users is the same API used by NREL developers to build each of the other data access productscreated and offered by NREL. Using the same API both externally and internally ensures that Station Locator partners havethe same data quality and same data experience regardless of how they access the station data.

The Station Locator data collection, validation and maintenance approach relies on a variety of sources and employs a rigorous methodologythat is evaluated annually to incorporate industry trends and changes,ensuring high quality data.NREL also adds new fields and parameters to the Station Locators periodically in response to industry evolving. For example, NREL recently started collecting EVSE power information based on requests from industry for these data. For all fuel types, data are gathered from partners and validated against existing stations in the station database. These partners can be alternative fuel advocates (e.g., the Clean Cities Coalition Network[vi]), fuel providers, fuel infrastructure owners, fuel trade associations, original equipment manufacturers, or fleet managers. Additionally, the station locators have features where users can "Submit New Station" if a station is missing or "Report a Change" if the locator provides inaccurate information. Finally, all stations in the database are contacted

at least once a year on an established schedule to verify they are still operational and providing the fuel specified. Stations that are no longer operational, no longer provide alternative fuel,or are nonresponsive to the contact efforts are removed from the database as they are identified. In addition, electric charging stations may be updated as frequently as daily when electric charging networks provide station data via their own APIs. As of 2019, the station locators import EVSE data directly from six network APIs daily. These data comprise approximately 50% of the EVSE locations in the station locators.Details on each country's methodology are available by clicking the "About the Data" or "À propos des données" link at the bottom of the web-based map.

Figure 2 Screenshot of the NRCan Station Locator

Impacts of the Station Locator

Until 2011, NREL negotiated individual agreements with each partner that needed access to station data, due tolimited demand. However, with the technological maturity of APIs —which enabled authenticated and audited data sharing—combined with an increased demand for station information, the dissemination of raw data has become the highest volume data product for the AFDC. The impact of the station data is calculated through metrics collected from all the data dissemination methods. For this paper, the station

impacts presented are from the United States AFDC application, as that is the application fully maintained by NREL making metrics easily accessible.

Table 2 displays the analytics for stations data dissemination. In Table 2, a user represents a single person or identified email (in the case of an API) who is accessing data. A pageview represents when a user has had a single stations page displayed to them, so an interaction with the Station Locator web application may contain several pageviews as the user clicks through the application. A hit is a single data access interaction via API. This hit may return data for one or many stations. A download is a large data pull containing one or all fuel types and designating two parameters: public and/or private stations and open and/or planned stations.

Table 230-day United States Station Data Analytics (1/24/2019–2/22/2019)

Data Location	**Users**	**Data Access**
AFDC including - Web-based application - Widgets - Summary data table by state and fuel type - Summary data map by state and fuel type[vii]	45,485	224,418 pageviews
Application programming interface (CSV, JSON, XML)[viii]	883	1,589,297hits
Download data (CSV, JSON, XML)	214	277 downloads
Android App	1,532	8,886 screen views
iPhone App	2,846	20,755 screen views

Sharing data via a variety of methods increases the reach of data. Originally, the only data access for the alternative fuels station data was the web-based application. While this method of sharing data still provides access to the greatest number of identifiable users (45,485), the number of data interactions (224,418) is seven times less than the number of data interactions of NREL's APIs (1,589,297). Note that while the number of users of the APIs (883) is lower than the number of web users, some of those API users are disseminating their data via other websites, which in turn reaches additional users with those data interactions. Providing data via API provides a multiplicative effect on the value of data. While the data download capability may seem less impactful, with only 214 users accessing the data 277 times, an evaluation of those users shows important partners accessing data including twenty-five different educational research institutes, eleven different state and federal governments and private sector entities such as mapping companies (Here and MapQuest), electric charging networks (ChargePoint) and vehicle original equipment manufacturers (Honda, Mini USA, Ford and GM). Because of the potential impact of these data download users and their high value to the alternative fuel industry, their data usageis notable. Finally, the Android app and iPhone app provide station data to users on their smartphone, which is likely the device they will be using if they need to refuel. This usage is a fraction of the web-based usage, indicating that while users do need to find fuel on a mobile device, there is still a greater demand for station searches via a web interface, likely for planning rather than immediate refueling needs.

In addition to the self-service data access discussed previously, the Station Locator team also engages directly with many industry associations (e.g., NGVAmerica and the Renewable Fuels Association) to share and exchange data. These collaborations help stakeholders identify alternative fueling opportunities, support industry efforts to develop tools and resources that address industry challenges, and promote accurate alternative fueling data across platforms.

Station Locator Partnerships

While the usage of stations data can be quantified, to understand the true value of these data requires qualified measurement. As seen in the metrics shown previously, alternative fuel and mapping partners access NREL data regularly. While partners using NREL data is valuable, the highest value interactions enabled by these data are human-to-human partnerships across the alternative fuels arena. These partnerships lead to successful deployments of alternative fuels and vehicles. Partners include federal agencies such as Transport Canada, the United States Federal Highway Administration (FHWA), the United States National Park Service (NPS),industry associations and states and provinces. Each of these partners have used station information to develop programs that extend the reach of station data beyond the original envisioned capabilities. Details on a few of these partnerships follow.

Figure 3 United States FHWA Alternative Fuel Corridors[ix]

In 2016, the United States FHWA began a program to designate highways across the United States as alternative fuel ready.[x]The goal of this program was to formally identify and designate corridors with enough station density to ensure that a driver could reliably drive from the start to the end of a designated road using only alternative fuel. The FHWA included CNG, LNG, electricity, hydrogen, and propane in their corridor program. Figure 3shows the electric designated corridors through round 2 (2017). The corridors shown in dashed line are “pending corridors”. These roads have some fuel infrastructure installed, but there are not enough stations along the corridor to allow drivers to reliably charge. However, these are road segments ripe for opportunity because with the installation of a few more chargers the road can become a “ready corridor”.The solid lines are “ready corridors”, meaning that there are enough stations for reliable charging along that section of road. Similar maps exist for the other four fuel types.

The FHWA Alternative Fuel Corridors project does not provide funding for installing fuel infrastructure. Rather it allows states to evaluate the robustness of their alternative fuel infrastructure and identify where future investment may be needed. With this information, states can better respond to funding and partnership opportunities. On the federal level, it allows for gaps in infrastructure to be identified along the highest traveled roads in the United States. These corridors provide information for fuel partners to strategically site future stations, increasing the value of alternative fuels. The designation of these roads as alternative fuel corridors also increases driver awareness as signage indicates designated roads.

The corridor project has international implications. At the federal and state/provincial level partnerships are being developed around deploying alternative fuels. FHWA, NRCan and NREL have had discussions

with Transport Canada to considerdesignating corridors in Canada and stretching northern United States corridors into Canada. Also, the state of Maine has discussed working with bordering provinces of Quebec and New Brunswick to create corridors between the two countries.

Another effort led by the U.S. National Park Service (USNPS) aims to install charging infrastructure at U.S. National Parks. An important component of the project is to ensure that charging infrastructure at national park destinations is accessible to plug-in electric vehicle (PEV) drivers traveling to the park. Station Locator data help planners evaluate common routes from key metropolitan areas to national parks for existing charging infrastructure, which allows them to identify infrastructure gaps and make informed decisions about the PEV-accessible destinations within the USNPS system.

NREL is also working with the state of California to extend the understanding of alternative fuels. Two projects help researchers analyze how stations are used today and how stations have been used historically. In 2017, the California Energy Commission (CEC) began working with NREL and electric charging station providers to gather charger utilization data in California. These data—which provide information about when individual chargers have cars connected andwhen they are delivering electricity to cars—provide real-world information about how chargers work in the field, how much electricity is needed and when the electricity is needed. These data will help California understand highly used stations and their impacts on the grid. They will also help develop realistic charger models for future state and regional planning. In 2019, NREL and CEC will begin collaborating to analyze six years of United States station data. This dataset, mined from the AFDC, will show how stations have changed over time. These data will help increase understanding about what makes a station long lived, what trends exist in stations opening and closing, how station equipment is upgraded and what stations are short lived. While CEC is funding analysis in the state of California, the dataset created will produce the ability to evaluate stations in the United States from 2013 and stations in Canada from 2018.

Other states and municipalities continue to use Station Locator data in their PEV-readiness planning. For example, the Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite tool[xi] provides a general way to estimate how much electric vehicle charging might be needed at the city- and state-level and compares those projections with existing charging infrastructure sourced from the Station Locator. The underlying EVI-Pro model is used by NREL researchers for detailed projections on required infrastructure at the city, state, or national levels and can include siting recommendations. The siting recommendations consider existing infrastructure provided by the Station Locator.

Conclusion

NREL has provided alternative fuel station data to tens of millions of users. However, these data areeven more valuable becausethey are both usable to end-users and enable collaboration and partnerships between alternative fuel entities. The creation of the NRCan station locator in 2018 is a textbook example of how the scope of the AFDC has grown far beyond its initial vision in 1991. In the past few years, the AFDC has grown to enable drivers in Canada to find alternative fuel stations; it has powered the creation of corridors across the United States; and it willallow researchers in California to better understand the usage and longevity of alternative fuel stations. The value of these data stretches beyond current partnerships and projects. Until alternative fuels and traditional fuels are fungible, the alternative fuel station data will continue to serve as a catalyst for creating new partnerships and new products that will enable the adoption of new technologies across the United States and Canada.

Endnotes

[i]"Alternative Fuels Data Center." (2019). US Department of Energy. Accessed February 24, 2019: https://afdc.energy.gov/.
[ii]"Electric Charging and Alternative Fuelling Stations Locator." (2019). Natural Resources Canada. Accessed February 24, 2019: https://www.nrcan.gc.ca/energy/transportation/personal/20487#/find/nearest.
[iii]"Alternative Fueling Station Locator." (2019). US Department of Energy. Accessed February 24, 2019: https://afdc.energy.gov/stations/.
[iv]"Alternative Fuels Data Center – Key Federal Legislation." (2019). US Department of Energy. Accessed February 25, 2019: https://afdc.energy.gov/laws/key_legislation.
[v]"Alternative Fuel Stations." (2019). National Renewable Energy Laboratory. Accessed February 24, 2019: https://developer.nrel.gov/docs/transportation/alt-fuel-stations-v1/.
[vi]"Clean Cities Coalition Network." (2019). U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. Accessed February 24, 2019: https://cleancities.energy.gov/
[vii]"Google Analytics." (2019). Google. Accessed February 23, 2019: https://analytics.google.com/analytics/web/#/.
[viii]"API Umbrella." (2019). General Services Administration. Accessed February 23, 2019:https://api.data.gov/admin/#/stats/users.
[ix]"Electric Vehicle (EV-Round 1 and 2)." (2019). U.S. Department of Transportation Federal Highways Administration. Accessed February 23, 2019: https://hepgis.fhwa.dot.gov/fhwagis/ViewMap.aspx?map=Highway+Information|Electric+Vehicle+(EV-Round+1+and+2).
[x]"Alternative Fuel Corridors." (2019) U.S. Department of Transportation Federal Highways Administration. Accessed February 23, 2019: https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/.
[xi]"Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite." (2019) U.S. Department of Energy Alternative Fuels Data Center. Accessed February 23, 2019: https://afdc.energy.gov/evi-pro-lite

This work was supported by the U.S. Department of Energy under Contract No. DE-AC36-08GO28308 with Alliance for Sustainable Energy, LLC, the operator of the National Renewable Energy Laboratory, and Natural Resources Canada Office of Energy Efficiency under agreement ACTC24NRCAN. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.