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Livewire Data Platform-A Solution for Energy Efficient Mobility Systems (EEMS) Data Sharing

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National Renewable Energy Laboratory
June 23, 2022

DOE Vehicle Technologies Program
2022 Annual Merit Review and Peer Evaluation Meeting

eems066

Overview

- Timeline
  - Project start date: 10/01/2018
    - https://livewire.energy.gov/ launched June 2019
  - Project end date: 9/30/2024
  - 25% complete

- Budget
  - Total project funding (current round of funding): $5,130,000
    - DOE share: $5,130,000
  - Funding for FY 2021: $1,500,000
  - Funding for FY 2022: $1,710,000

- Partners
  - Project leads
    - National Renewable Energy Laboratory (NREL)
    - Pacific Northwest National Laboratory (PNNL)
    - Idaho National Laboratory (INL)
  - Interactions/collaborations
    - EEMS research community
    - VTO-funded FOA awardees
    - Mobility researchers

- Barriers
  - Expansive community of relevant stakeholders
  - Difficulty in sourcing empirical real-world data applicable to new mobility technologies such as connectivity and automation

What is Livewire

- A platform for sharing energy efficiency and mobility research data
- Growing catalog of transportation and mobility-related data funded by VTO and maintained by experts at NREL, INL, and PNNL
- livewire.energy.gov

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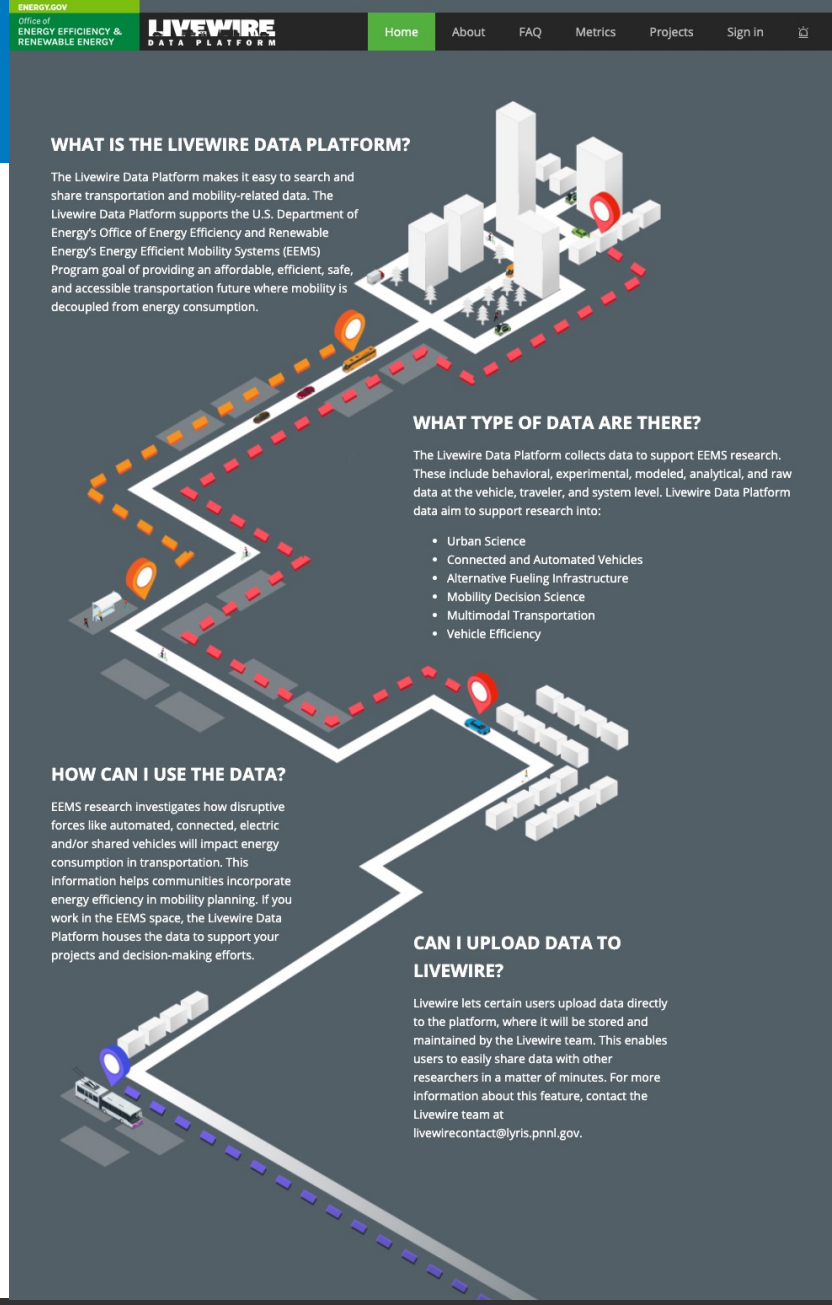


Relevance – Livewire is and will be Impactful

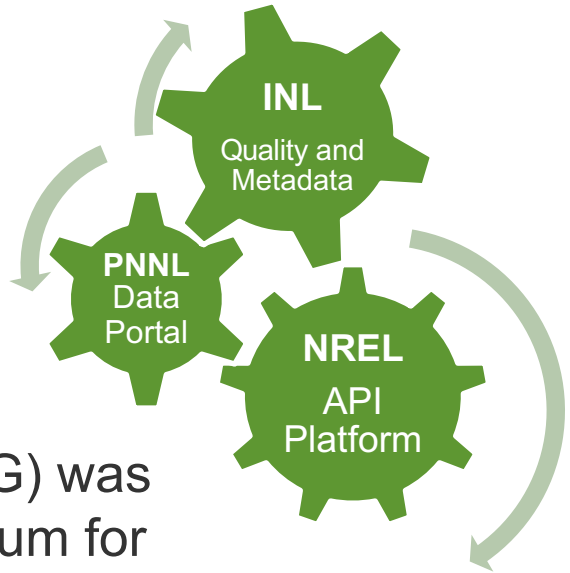
- Secure data management is an essential part of DOE's research infrastructure – it's a core capability that DOE and principal investigators (PIs) will always need. We know how to do this.
  - DOE has resources and insight to do this for all projects
  - Lower cost, better management capabilities, no silos, improved research

Livewire addresses technical and cultural challenges to enable research, collaboration, and data sharing by providing state-of-the-art data management capabilities and services

- Core services and platform capabilities include:
  - Free, secure data storage
  - Access management that allows data owners to control who sees their data
  - Data collection and preservation
  - Quality characterization
  - Detailed access and download metrics
  - Increased visibility of projects and data

Approach

- Leverage work done on successful data platforms
- First years were focused on platform development
- User-requested features followed
- After being funded in Fall 2021, Livewire is focused on:
  - Expanding access to more users
  - Growing catalog and features
  - User support



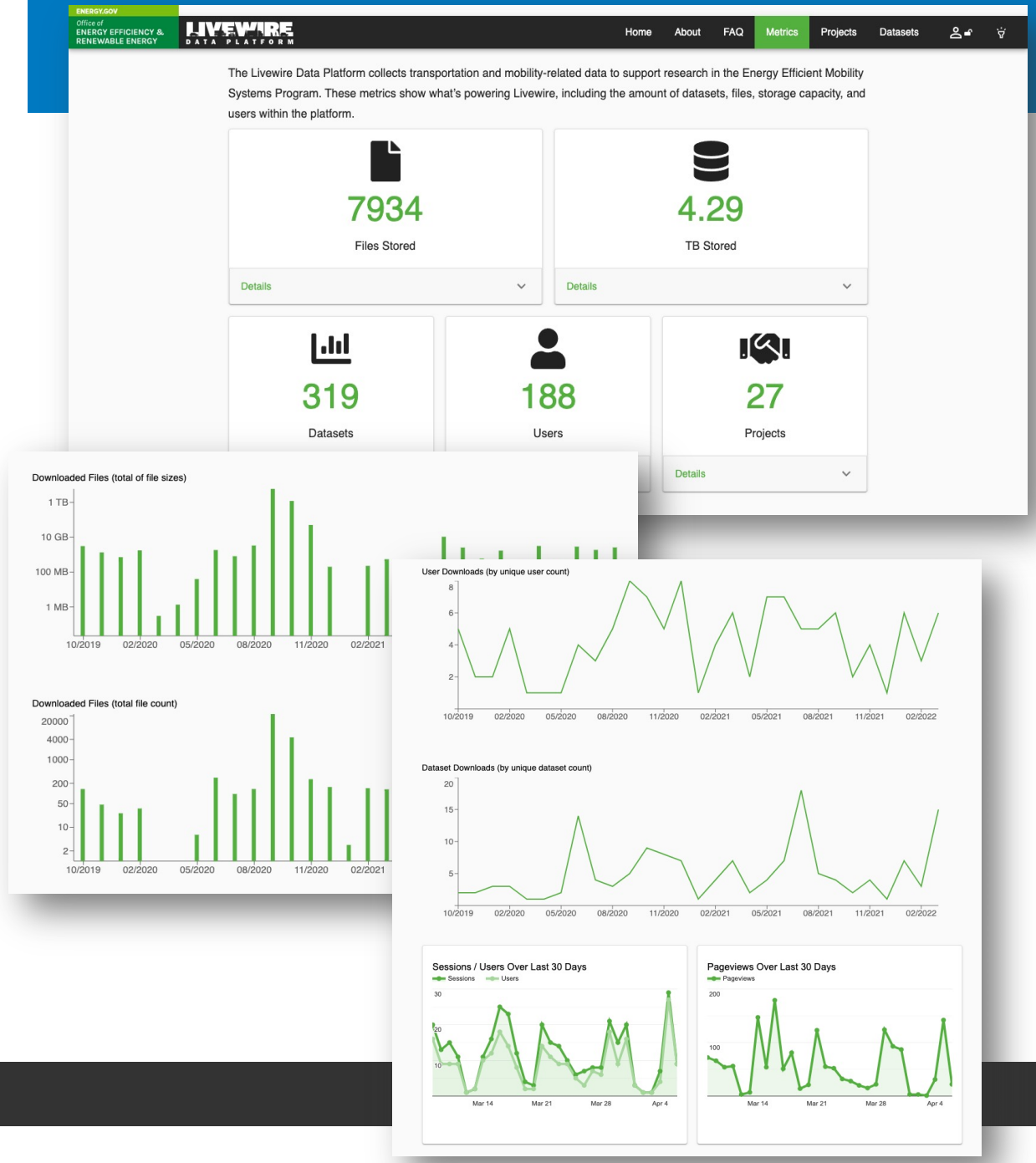
- Livewire Data Working Group (DWG) was established in 2021 to provide a forum for feedback and input from data owners and data users

Collaborate to build a data platform that users want to use

Milestones

*Milestone Name/Description	*End Date	*Type
(INL) Demonstrate continued progress on the development of tools and processes to streamline the production of detailed dataset metadata and dataset quality characterization with publication of detailed metadata and quality characterization for 40 additional datasets through the Livewire Data Platform.	3/31/22	Quarterly Progress Measure (Regular)
(PNNL) Update the user and data access capabilities to enable: · public data including assigning digital object identifiers · automatic access to community datasets for approved domains	3/31/22	Quarterly Progress Measure (Regular)
(NREL) Demonstrate progress towards the addition of data priorities identified by the DWG to the Livewire catalog. · Automated and connected light-, medium-, and heavy-duty vehicle data · Electrified vehicle and charging infrastructure data	6/30/22	Quarterly Progress Measure (Regular)
(NREL, PNNL) Add one Tier 1 (Open) dataset and report on automatic approval of users with a target of 15 users.	6/30/22	Quarterly Progress Measure (Regular)
(NREL – Fleet DNA) Define specific analysis to help quantify dataset extent in terms of vehicle parameters.	6/30/22	Quarterly Progress Measure (Regular)
(PNNL) Develop self-service capability for large or ongoing data uploads that provides guaranteed delivery, high bandwidth, and security.	9/30/22	Quarterly Progress Measure (Regular)
(INL) Demonstrate continued progress on the development of tools and processes to streamline the production of detailed dataset metadata and dataset quality characterization with publication of detailed metadata and quality characterization for 110 additional datasets through the Livewire Data Platform.	9/30/22	Quarterly Progress Measure (Regular)
(NREL – Fleet DNA) Demonstrate analysis output that leverages the Livewire developed Fleet DNA relational database.	9/30/22	Quarterly Progress Measure (Regular)
(NREL – TSDC) Summarize TSDC activities—demonstrating steady growth in included datasets, data users, and publications enabled by access to TSDC-hosted data.	9/30/22	Quarterly Progress Measure (Regular)
(NREL, PNNL, INL) Host at least one dataset used for cross-agency collaboration	9/30/22	Annual Milestone (Stretch)

Technical Accomplishments and Progress



- User-facing site improvements
  - Updated metrics page (https://livewire.energy.gov/metrics) shows impact of data shared with usage and engagement metrics
  - Updated project and dataset search pages
  - Updated Frequently Asked Questions (FAQs)
  - Additional help text and Contact Us form
- Updated design to enable embedded media and images on project and dataset pages
  - **Fulfilled FY21Q3 milestone**

Technical Accomplishments and Progress – Updated Access and Download Permissions

Tier 1 - Open

- Project page viewable by all
- Data viewable and downloadable by all (*after logging in*)
- Data must undergo review and approval

Accessible to anyone, including adversaries

Tier 2 - Privileged

- Project page viewable by all
- Data viewable and downloadable by members
  - Membership automatically granted to .gov and .mil
  - All other users request access through LDP

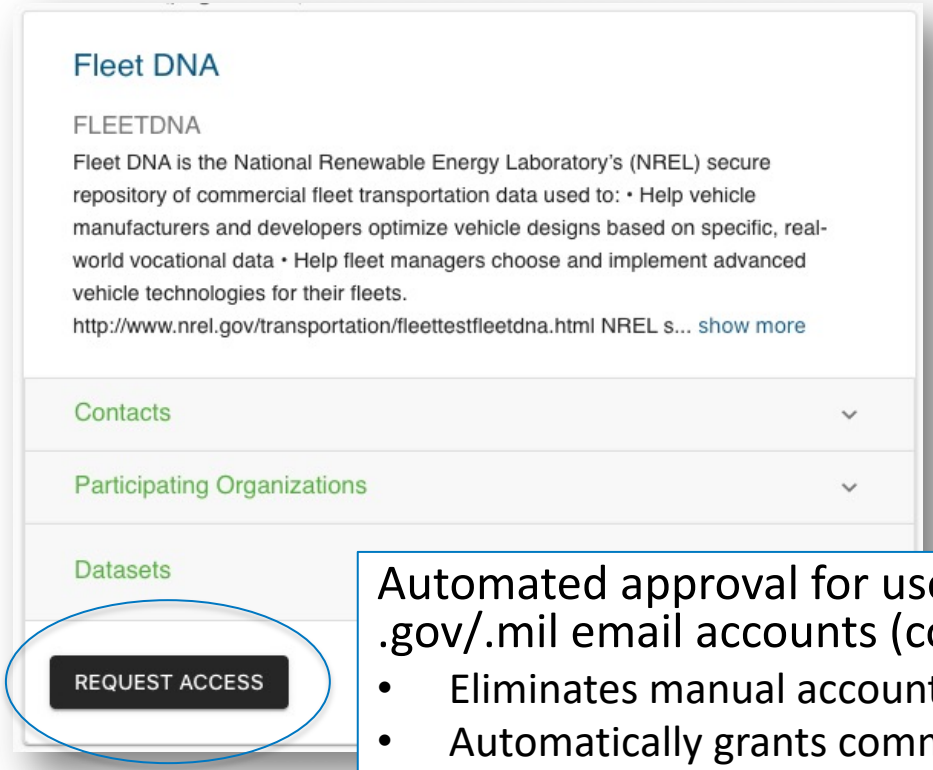
Accessible to .gov and .mil or by PI consent

Tier 3 - Restricted

- Project page *may* be viewable by project members only
- Data viewable and downloadable by project members only
  - Users request access through LDP
  - Users granted access directly by PI
- May require logging in with 2FA token

Accessible with PI consent

Technical Accomplishments and Progress

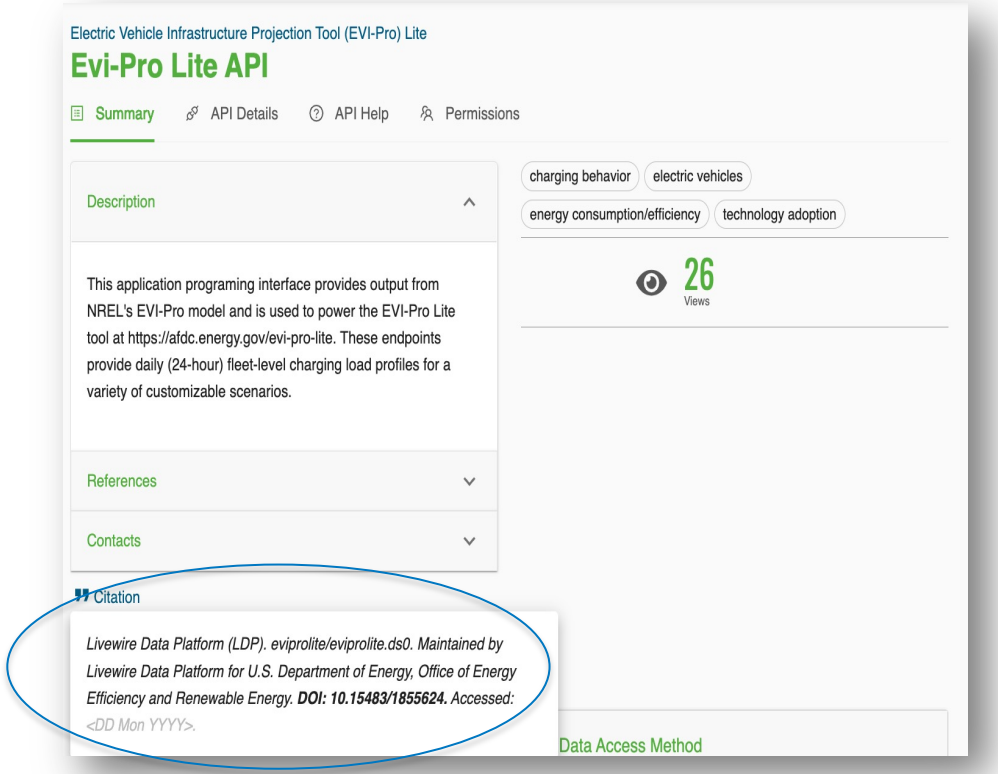


Automated approval for users with .gov/.mil email accounts (community)

- Eliminates manual account approval
- Automatically grants community members access to Tier 2 datasets
- Allows users outside the community to request access to individual projects
- Shifts responsibility of access management to project leads
- **Fulfills FY22Q2 milestone**

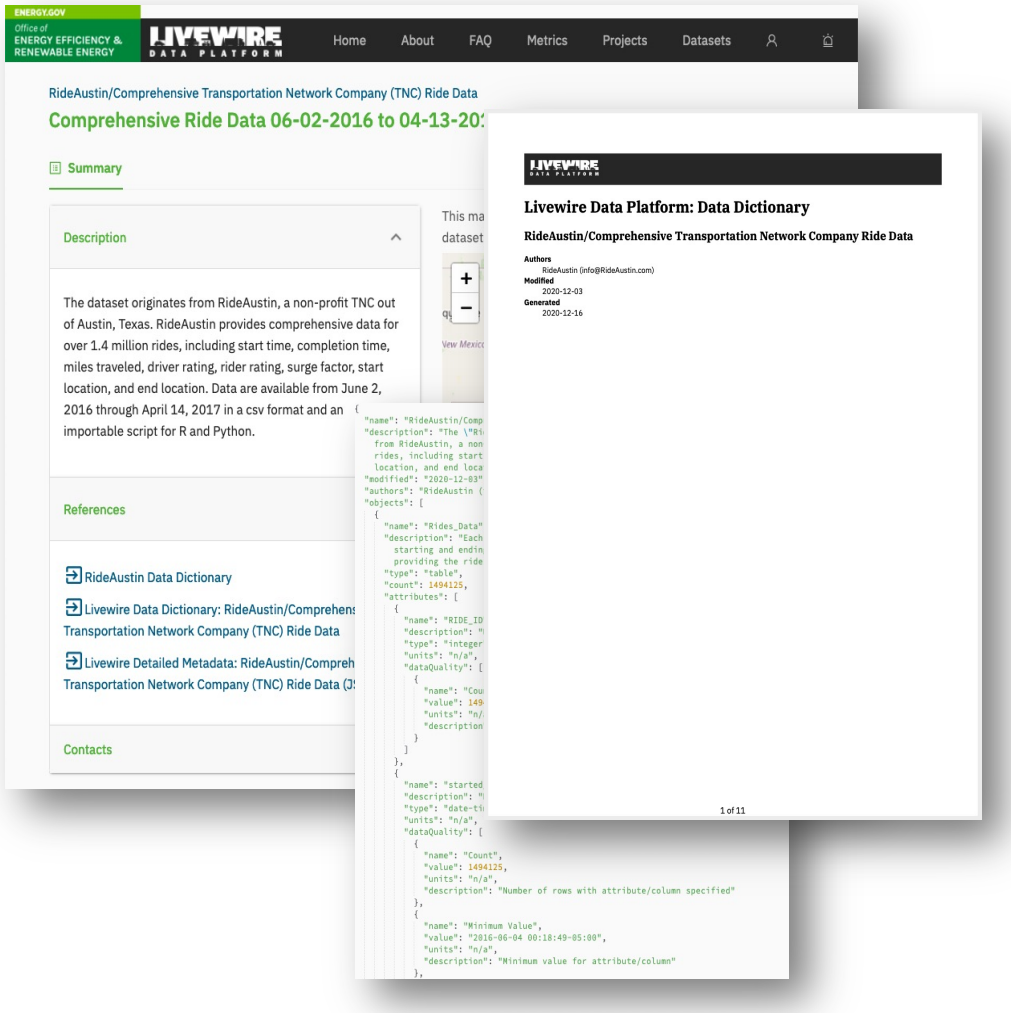
Public dataset additions

- Automatically mint Digital Object Identifiers (DOI) using DOE's OSTI E-Link web services
- Data is available to anyone, but login still required before downloading
- **Fulfills FY22Q2 milestone**

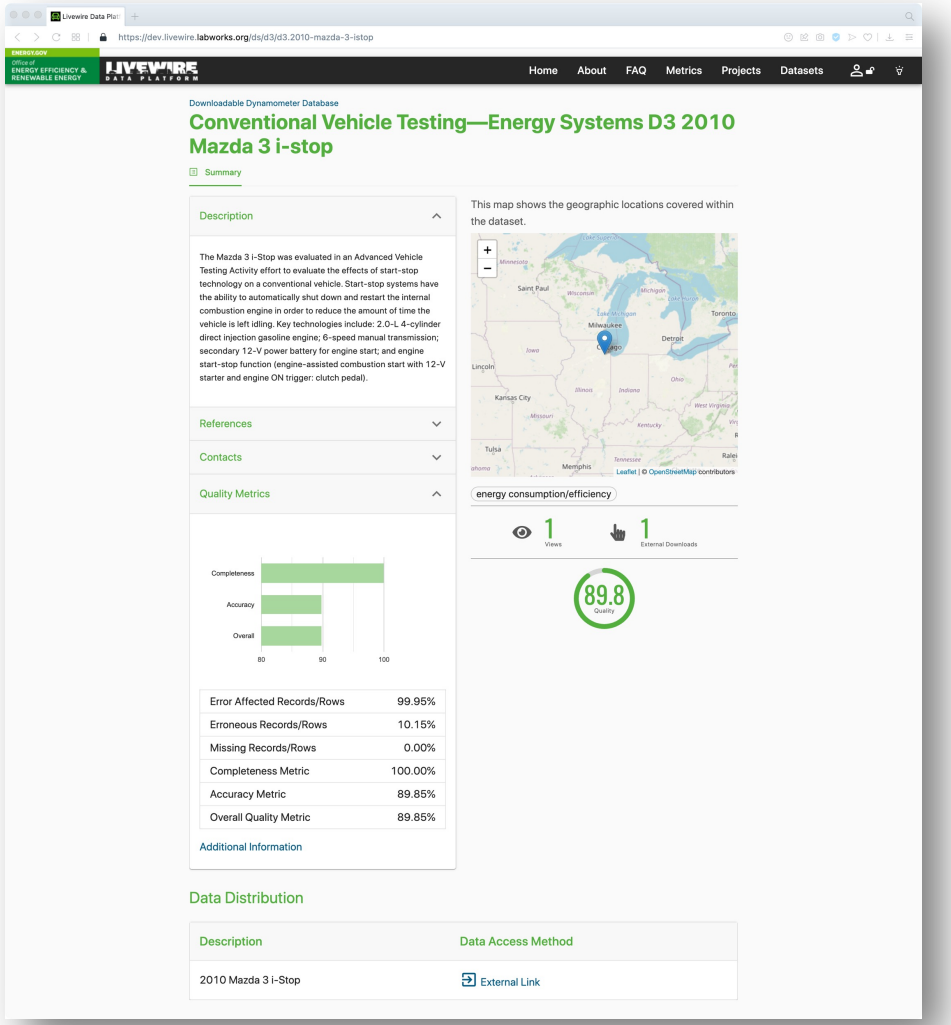


Technical Accomplishments and Progress – Detailed metadata additions

- High-level metadata contains basic information displayed on page
- Low-level (detailed) metadata provides information about a dataset, including characterization of data quality
  - Summarized graphically on LDP dataset page
  - Published as downloadable PDF and JSON dictionaries (linked as references on each dataset page)
- Significant progress has been made on the automation of tools to create detailed metadata with focus on:
  - Scalability
  - Streamlining/automation of manual processes
  - Expansion of quality metrics



Technical Accomplishments and Progress – Data Quality Characterization



- Data quality characterization
  - Objective analysis of dataset for completeness, statistical outliers, likely errors, and impact of likely errors
  - Helps potential data users make choices

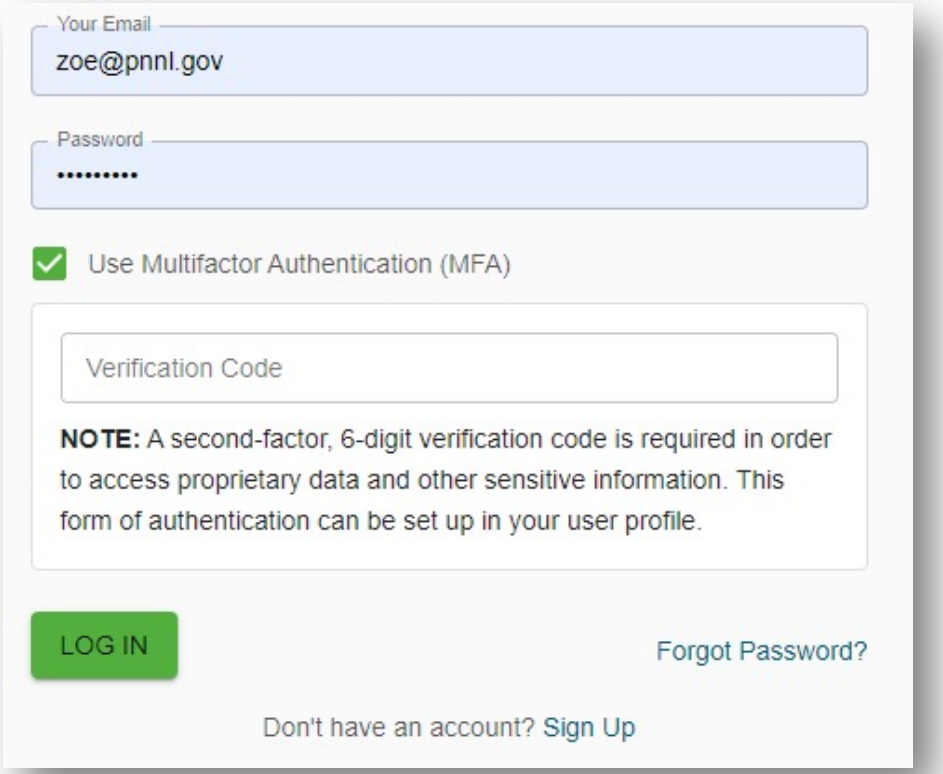
- Published detailed metadata and quality characterization for 41 datasets
  - 25 datasets from ANL's Downloadable Dynamometer Database (D3) project
  - 16 datasets from NREL's Transportation Secure Data Center (TSDC) project
  - About 13% of all Livewire datasets
  - **Fulfills FY22Q2 milestone**

Technical Accomplishments and Progress

Site security

- Streamlined automated testing methods and expanded coverage of end-to-end tests
- Added test methods for new capabilities
  - Two factor authentication
  - Downloads of past orders
- Monthly security scans and review
- Log4j vulnerability scan
- Enabled multifactor authentication (MFA), required to support proprietary and sensitive datasets
  - **Fulfilled FY21Q4 milestone**

Impact: Saves time, effort and improves availability of the site



Technical Accomplishments and Progress

Maintenance and updates

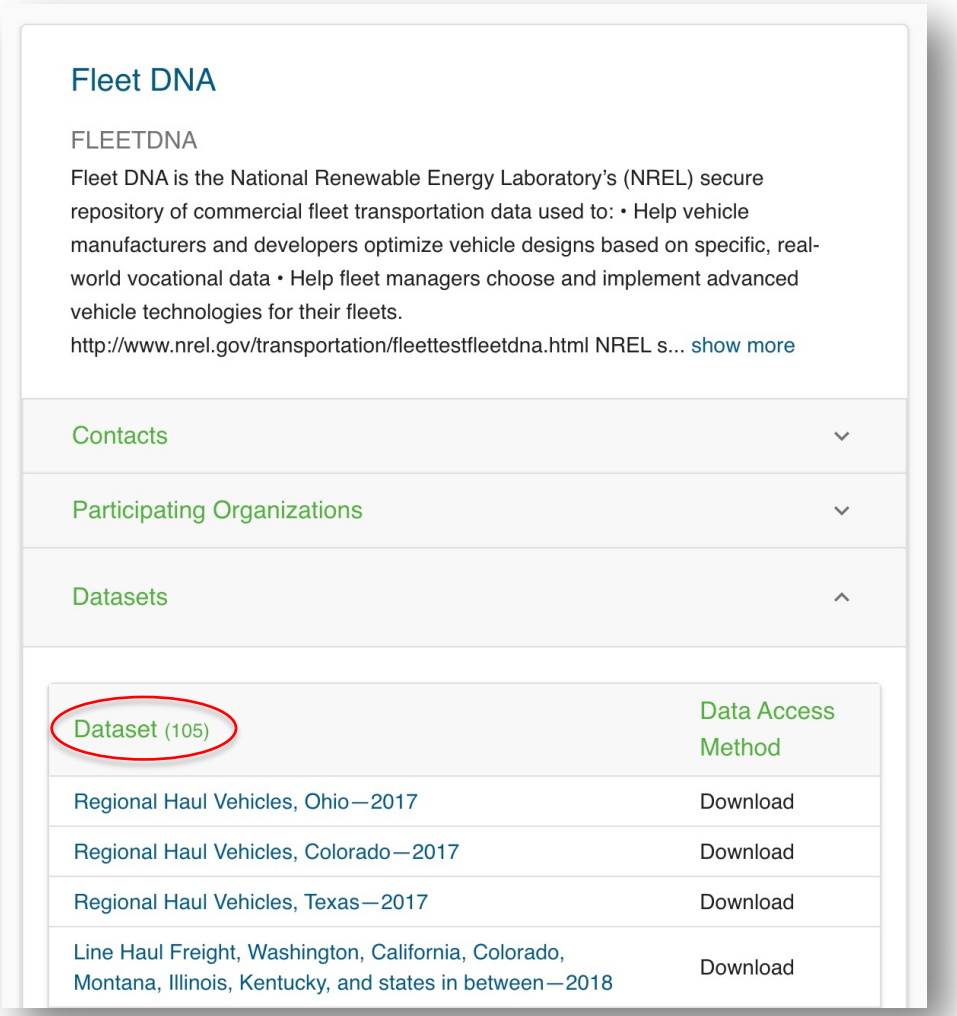
- Updated detailed metadata and quality characterization for 5 previously-processed datasets
- Migrated LDP code from internal PNNL Stash instance to *livewire-data-platform* GitHub organization
- Restructured front-end code to streamline managing core and LDP-specific changes
- Developed technical solution to improve UI responsiveness on datasets with large detailed metadata

Impact: Consistency across data, increased efficiency, improved site performance for a better user experience

Technical Accomplishments and Progress – Targeted data

- Added 75 Fleet DNA datasets broken out by vocation and location
  - Included note on data quality
  - Restricted Fleet DNA datasets
- Developed relational database for Fleet DNA
- **Fulfilled FY21Q3 milestone**

- Addressed DWG priority of adding more electrified vehicle and charging infrastructure data with the addition of data from two new projects



Responses to Previous Year Reviewers' Comments

- The reviewer was unclear who was represented in the Livewire Data Working Group from the project slide deck. It would be helpful to detail the participants in this group.
- Moving forward, the reviewer suggested that it would be good to consider expanding participation within the Livewire Data Working Group to other entities.

  Initial members of the DWG came from from five national labs (ANL, LBNL, ORNL, NREL, and INL). A broader group including PIs from university and industry partners was invited for subsequent meetings in order to further discuss the prospect of expanding Livewire's audience and solicit other feedback.

- If proprietary data are downloaded, do users need to execute non-disclosure agreements (NDAs) for those data?

  Livewire provides the mechanisms to restrict access to proprietary and other moderately sensitive data and provides capability to vet and approve users requesting access to their data. The onus is on PIs to make sure that users have signed their project NDA. Data owners and users are required to agree and accept applicable agreements (e.g., user, non-disclosure). We will provide automated methods to validate users on a quarterly basis and easy access to NDAs for PI's and users that have access to proprietary data.

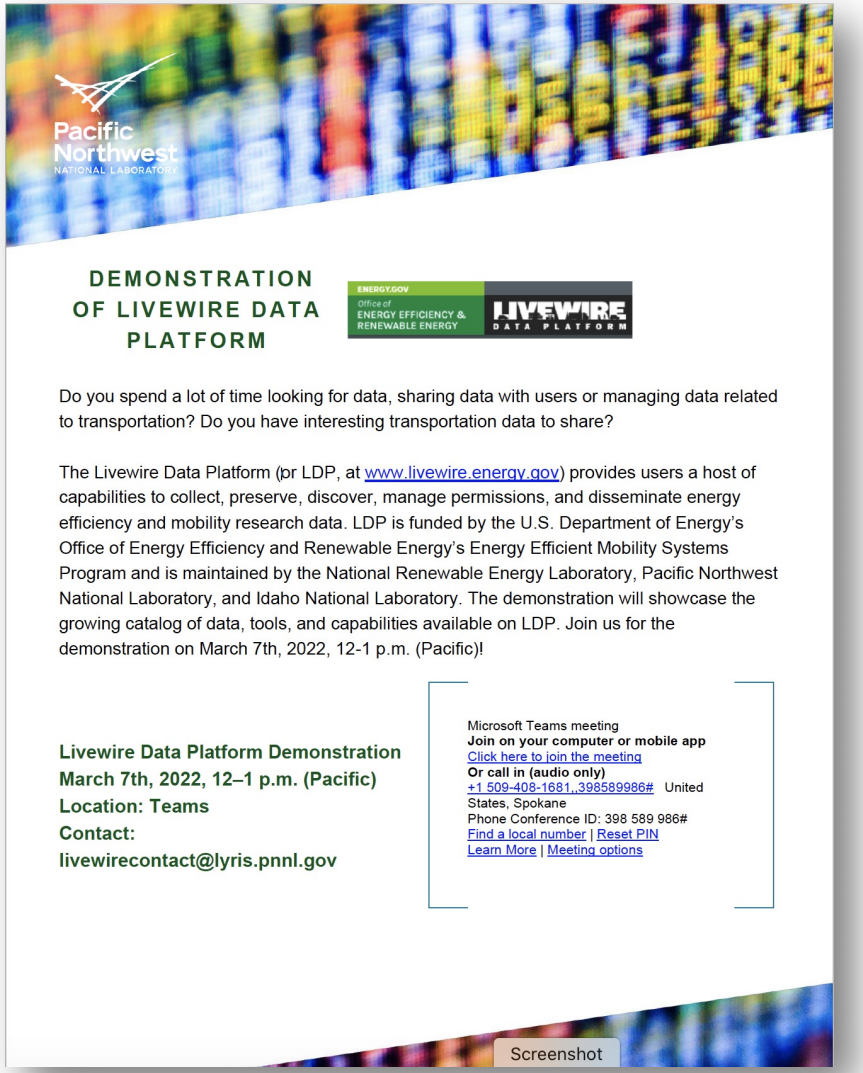
Responses to Previous Year Reviewers' Comments

- How does DOE plan on marketing the platform in order to get more subscribers and data? Will this be marketed to practitioners (state and local DOTs, other federal departments, research institutions, etc.)?

  The Livewire project team is working closely with VTO tech leads to ensure Livewire is familiar to all the projects they manage and relevant partners. We continue other periodic outreach efforts to state organizations and to mobility researchers at PNNL and continue to periodic outreaches. We attend the monthly SMART PI mobility meetings to raise awareness of LDP capabilities.

- Future work will require scaling up for larger and diverse groups. The reviewer opined that that may be challenging from a technology infrastructure, as well as a funding, perspective.

  We are pleased that DOE saw value and impact in Livewire and chose to continue to fund for an additional 3 years. The Livewire team is proactively working on solutions to facilitate rapid growth.



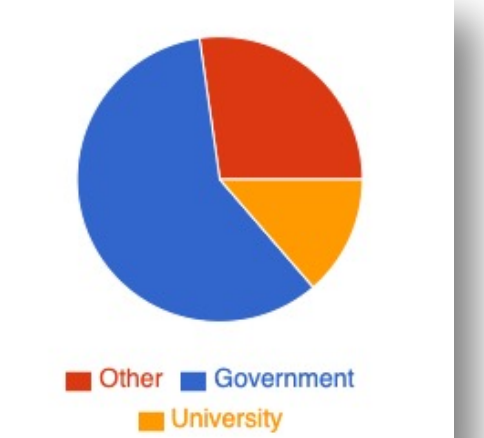
Collaboration and Coordination

- Collaboration is essential to Livewire's success
  - Strong collaboration within Livewire project team from INL, NREL, and PNNL
  - Partnership with EEMS, SMART, and TI

- Livewire Data Working Group established to help identify platform and data needs
  - Adding more automated and connected LDV and MDHD data
  - Adding more electrified vehicle and charging infrastructure data
  - Standardizing data across projects
  - Enabling querying and filtering data before downloading
  - Adding the ability to download subsets of data
  - **Addition of targeted data fulfilled FY21Q4 milestone**

- Data on Livewire and Livewire users come from more than 25 organizations, DOE, national labs, and many research partners

Participating Organizations	
U.S. Department of Energy	13
National Renewable Energy Laboratory	8
Argonne National Laboratory	4
Idaho National Laboratory	4
Lawrence Berkeley National Laboratory	3
U.S. Department of Transportation	3
PATH Program, University of California, Berkeley	2
American Center for Mobility (ACM)	1
American Public Transportation Association	1



Atlanta Regional Commission	1
Atlas Public Policy	1
CALSTART	1
Carnegie Mellon University	1
City and County of Denver	1
City of Chicago	1
City of Columbus	1
City of New York	1
City of Seattle	1
Denver Metro Clean Cities	1
EVgo	1
Empire Cities Clean Cities	1
Energetics	1
Federal Highway Administration	1

Collaboration and Coordination

- Project and data needs drive feature development and capabilities
  - Livewire team works closely with project teams and provides ongoing support
  - Each time Livewire addresses new needs presented by data owners, capabilities are streamlined and standardized and become part of the platform's core services

American Center for Mobility
CONNECTED. AUTOMATED. VALIDATED.

BERKELEY LAB

Carnegie Mellon University

VIRGINIA TECH TRANSPORTATION INSTITUTE
VIRGINIA TECH

Clean Cities

CALSTART

NASEO
National Association of State Energy Officials

"In our on-road CAV data collection project in collaboration with NREL, ANL set out to collect a large data set of production LD automated vehicles operating in various driving conditions. The data set contains over 2100 miles of driving data from two test vehicles. The aim of the project was to generate this data for a diverse audience of researchers.

[Livewire] was the perfect place to put the data to reach our potential audiences. As a new user to Livewire, we received exceptional support to organize and upload the data and get it live very quickly. We are very pleased with the prospect of getting researchers to use the data to help their research. We look forward getting feedback from data users and to the potential of new interactions with researchers that found our data on Livewire and who may want to collaborate with us further."

- Mike Duoba, ANL

Argonne NATIONAL LABORATORY

"The Livewire platform has been an intuitive and convenient way to share EV [WATTS] project data with national labs and project partners. The ability to filter and search by keywords on the platform also makes the EV Watts data available to a wider array of researchers."

- Yash Pavuluri and Ewan Prichard, Energetics

energetics
Clean Energy Consulting

Remaining Challenges and Barriers

- Livewire's API capabilities are not widely used; platform team needs to consider how to better communicate API capabilities and pursue opportunities to share via API

- More outreach to reach data users and data owners

Proposed Future Research

- Add low level metadata and quality analysis to 110 datasets by 9/30/2022 (Q4 milestone), approaching complete dataset coverage by end of FY 2024
- Develop self-service capability for large or ongoing data uploads that provides guaranteed delivery, high bandwidth, and security by 9/30/2022 (Q4 milestone)
- Expand in-platform user capabilities such as
  - data standardization
  - search within and across datasets
  - advanced querying and filtering
  - real time analysis
  - online compute services for code sharing, machine learning and data reviews
- Continue targeted outreach with goals of:
  - Cross-agency collaboration (in conversation with DOT)
  - Additional data in DWG priority areas
  - Complex data formats such as big data, AI, and streaming data
- Demonstrate growth and continued impact of TSDC and Fleet DNA

Any proposed future work is subject to change based on funding levels.

https://faginconstruction.com/

Summary

- Livewire leverages over **30 years** of experience from experts at **three national labs** to enable sharing, discovery, and preservation of transportation and mobility data
- Provides **easy** and **secure** access to a continuously growing catalog of energy efficiency and mobility data influenced by user input from the Livewire Data Working Group
- Livewire can support **proprietary data** and **NDAs**; data owners **control who can access** their data
- Livewire **removes barriers** to researchers finding and sharing the data they need *and* produce in answering important transportation questions
- Supports DOE and partner research to **reduce energy consumption, improve mobility access**, and **accelerate decarbonization** of the transportation sector by shifting the burden of data management to LDP
- Visit Livewire at https://livewire.energy.gov/

Thank You

www.nrel.gov

NREL/PR-5400-82773

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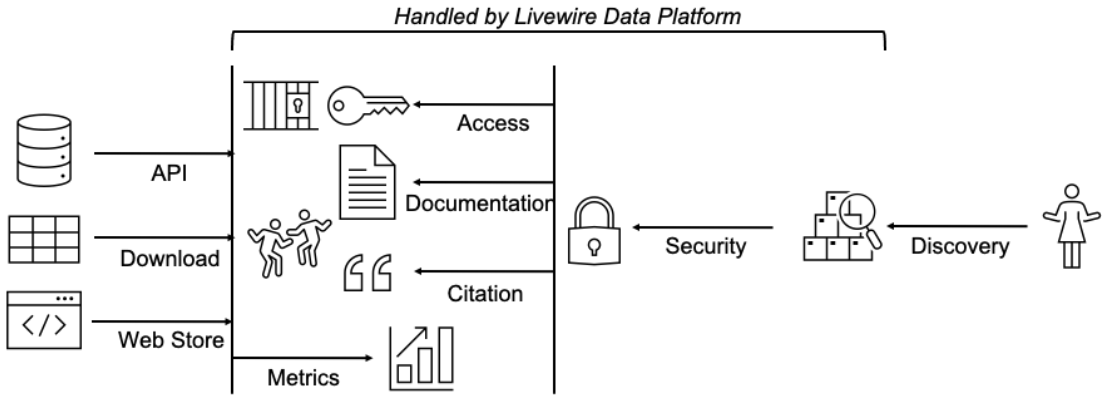
Technical Backup Slides

(Include this “divider” slide if you are including backup technical slides [maximum of five]. These backup technical slides will be available for your presentation and will be included in Web PDF files released to the public.)

Core services and benefits of sharing data via Livewire

- Storage
  - Livewire can host up to 10 TB of data per project at no cost, but also supports other methods for sharing data
- Secure data platform
  - Livewire adheres to federal security standards, handles authorization and authentication
- Access management and control
  - Data owners can restrict at project or dataset level
  - Can store data that requires NDA
- Detailed metrics on downloads and API usage

- Increased visibility of projects and data
  - Livewire can display digital object identifiers
  - Livewire can provide citation guidance/standard language



Data download

Drones, Delivery Robots, Driverless Cars, and Intelligent Curbs for Increasing Energy Productivity of First/Last Mile Goods Movement

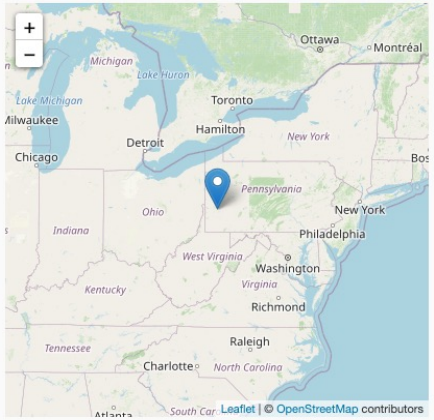
Energy Use of Drone, Delivery Robot, Driverless Car, and Intelligent Curb Optimization

Summary

Description

The dataset originates from a Carnegie Mellon University project on "Drones, Delivery Robots, Driverless Cars, and Intelligent Curbs for Increasing Energy Productivity of First/Last Mile Goods Movement" funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy's Vehicle Technologies Office (VTO). The project began in FY2019 and will continue to FY2022. Data include energy use of drone flights carrying various payloads at a 10 Hz resolution, energy use of delivery robots and driverless cars, and curb use optimization. In addition, local and network-wide energy impacts of those different first/last mile technologies will be estimated.

This map shows the geographic locations covered within the dataset.



drones | UAVs | first/last mile | package delivery

References

M100 Flight Sheet

Data Description Dictionary

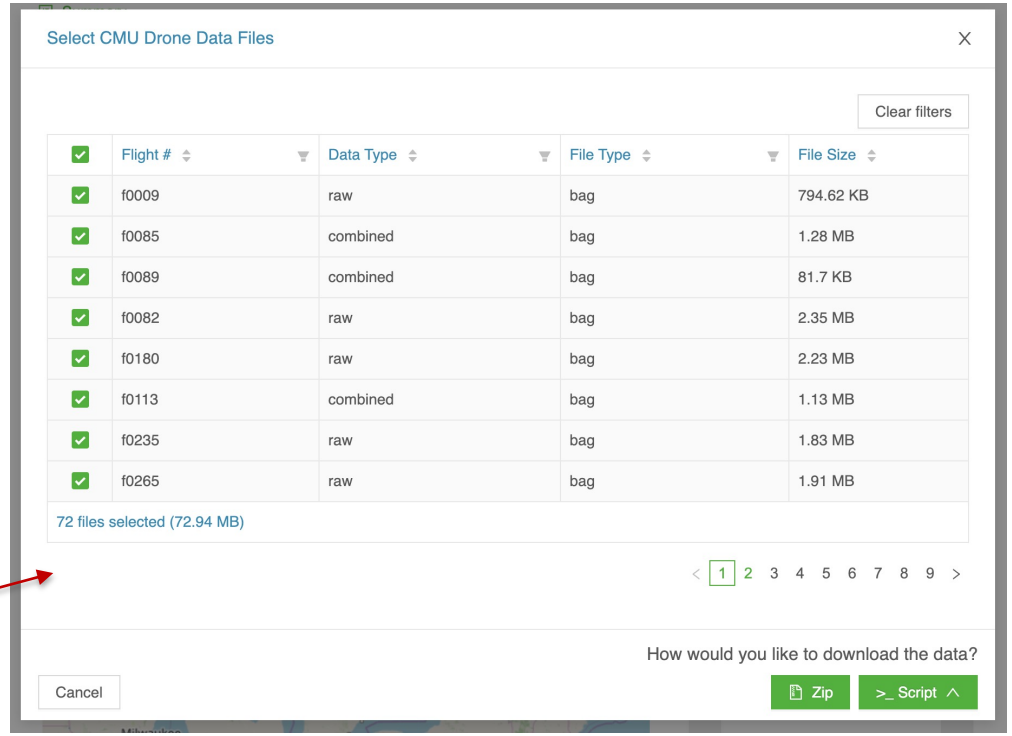
Contacts

Name	Role	Email
Costa Samaras	Project PI	csamaras@cmu.edu

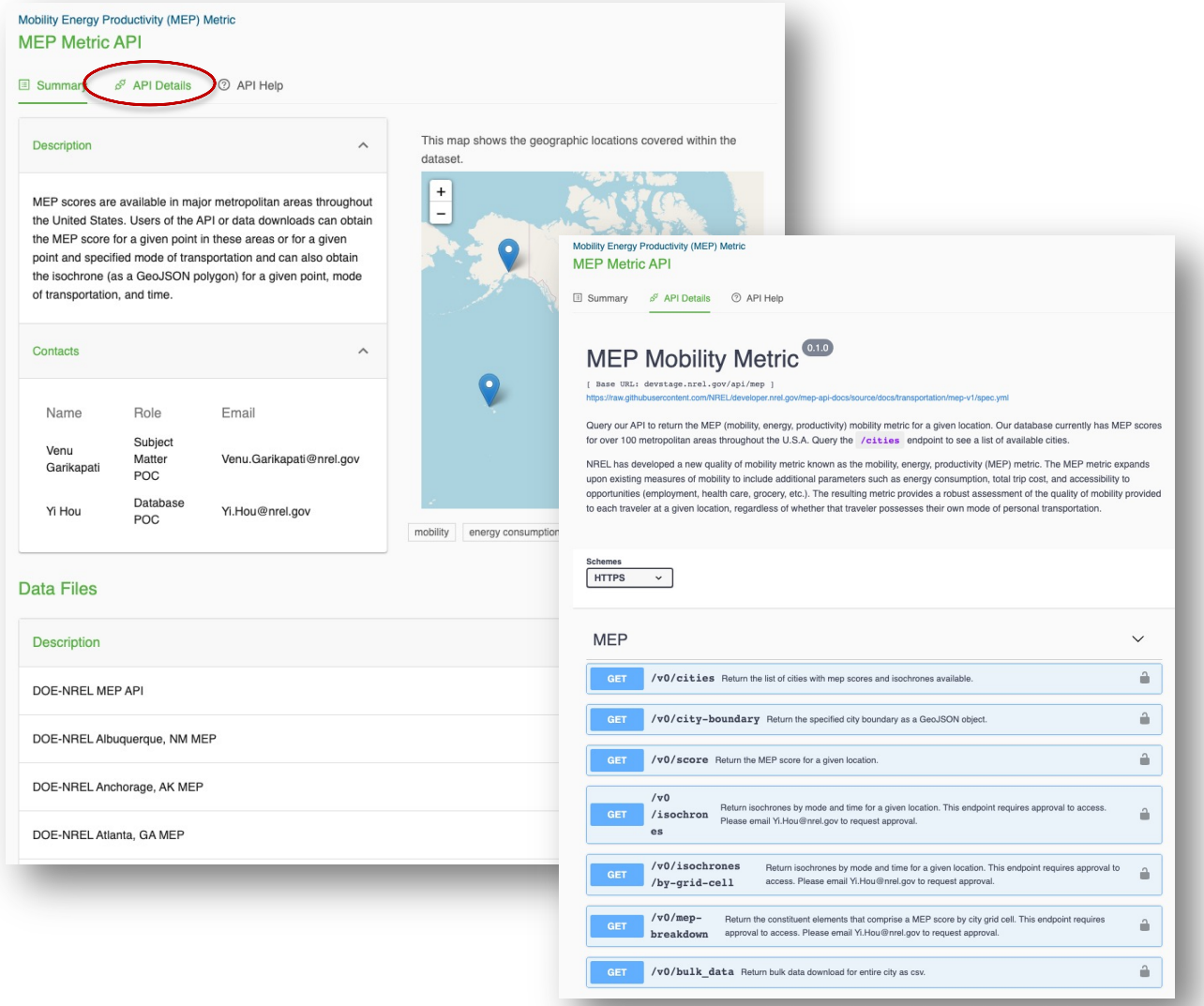
Data Files

Description	Data Access
CMU M100 Drone Data	Multi-Download

Data hosted on the Livewire Data Platform can be sorted, filtered, and downloaded directly by logged-in users.



Using Livewire with APIs

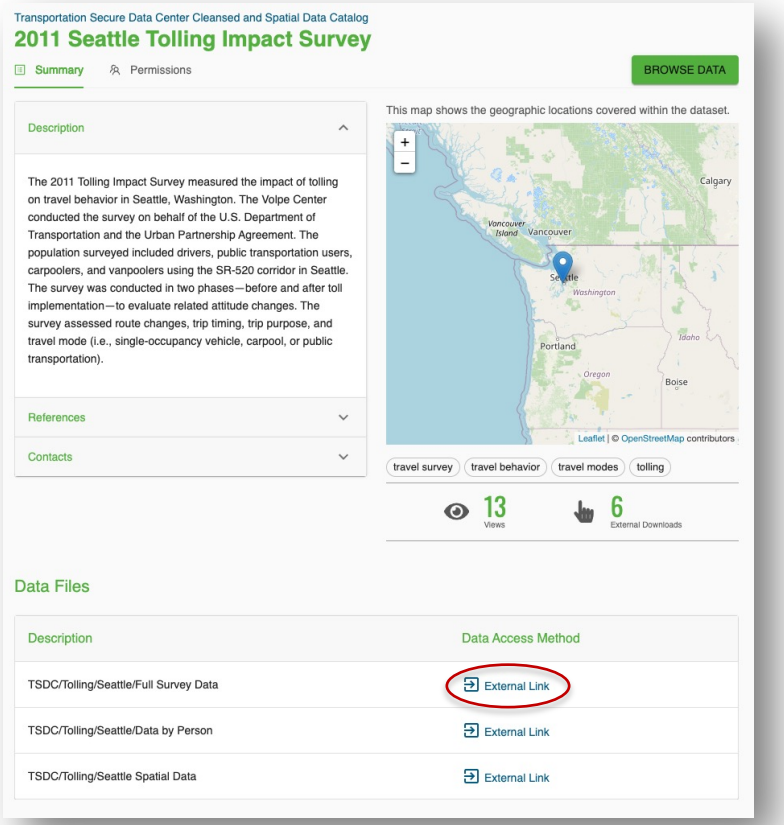


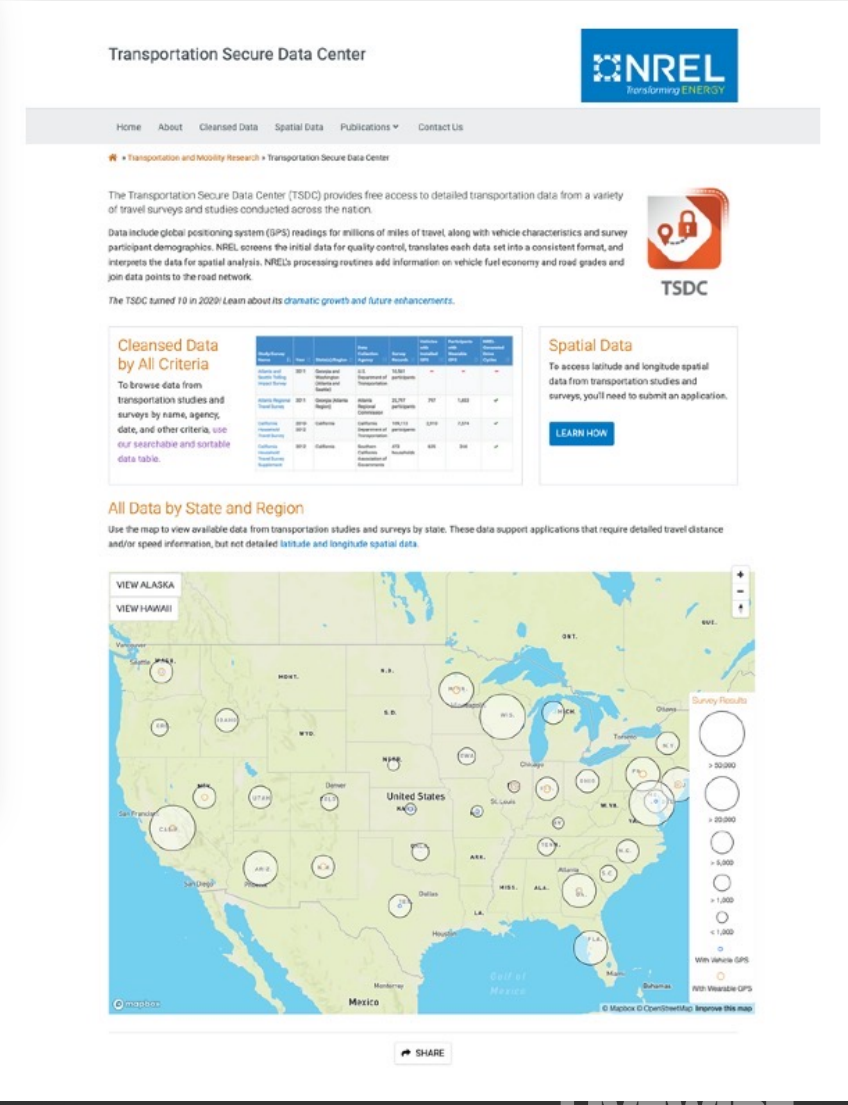
- An API, or application programming interface, is a way for one application to provide data from its database to another in a standardized, machine-readable format.
- Accessing data via API automatically updates a user's content as database content changes
- Each endpoint represents a specific collection of data that a user can access

Link to existing webpage

When data is stored or shared elsewhere, Livewire can link to that URL

- Projects and datasets still have landing pages on Livewire
- Data is discoverable

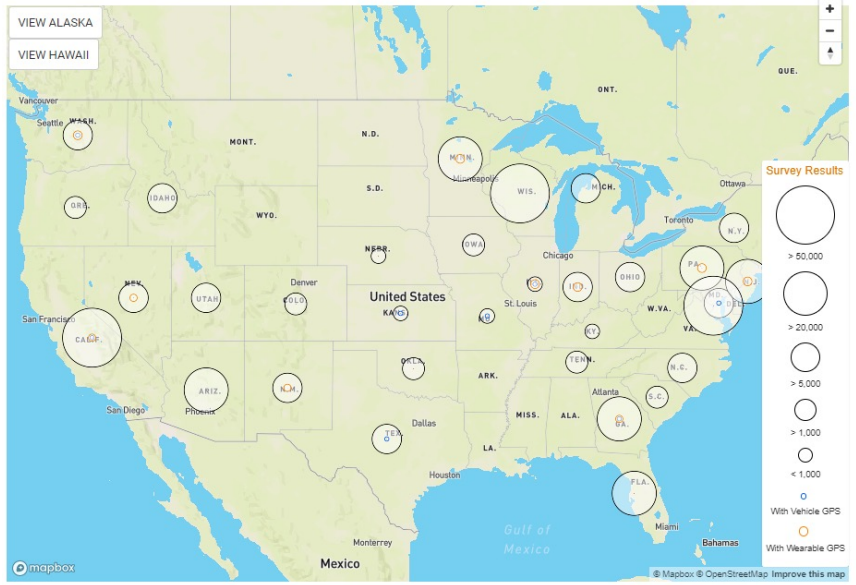


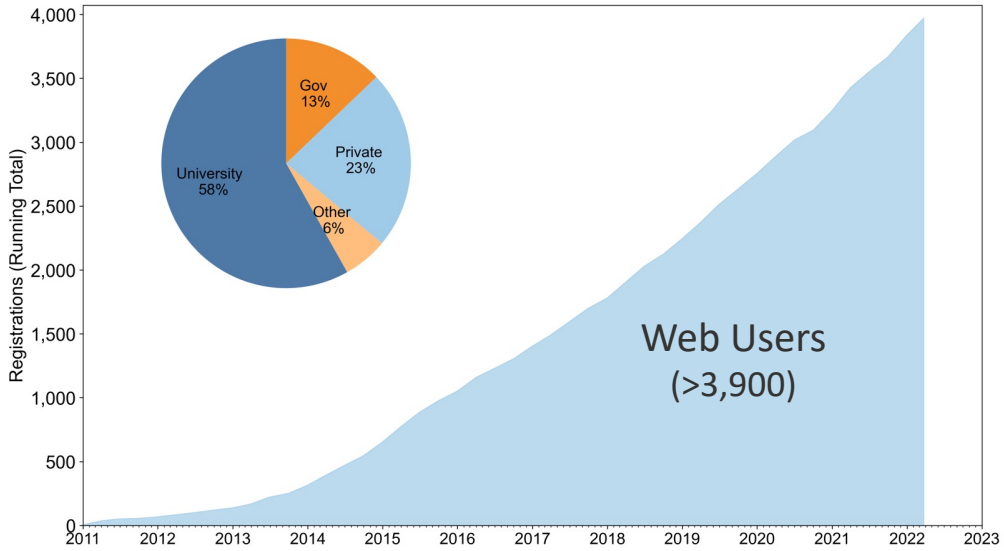


Additional Accomplishments: Scope and Growth of the TSDC

TSDC

Includes hundreds of surveys / studies and millions of miles of travel data from across the U.S.

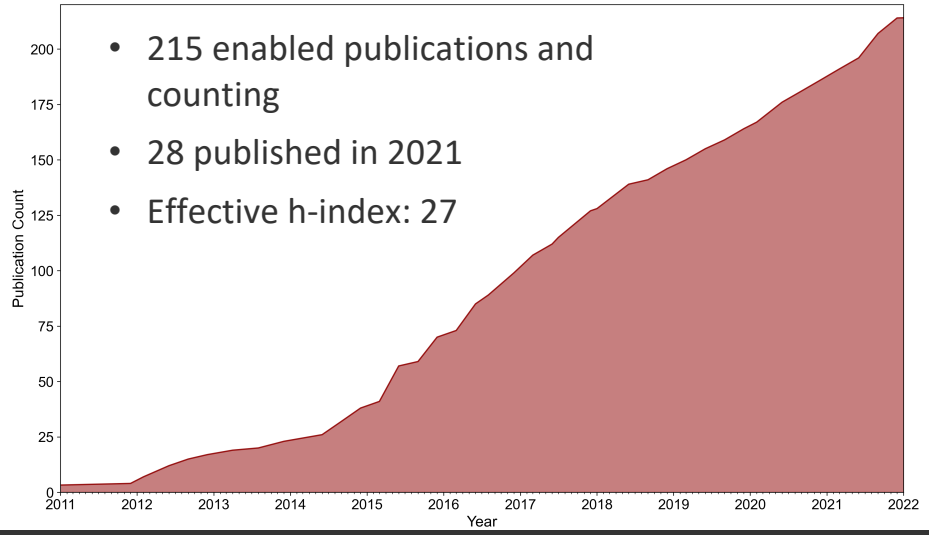


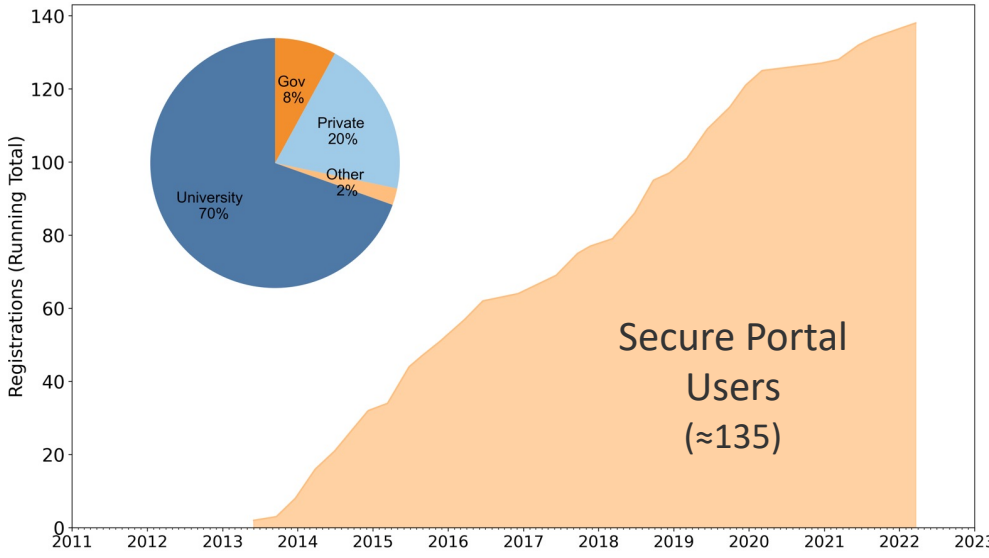


2021

1. A Review of Data Sources for Electric Vehicle Integration Studies
   Authors: Lisa Calearo, Mattia Marinelli, and Charalampos Ziras
   Journal: *Renewable and Sustainable Energy Reviews* (November 2021)
2. Driving Conditions-Driven Energy Management Strategies for Hybrid Electric Vehicles: A Review
   Authors: Teng Liu, Wenhao Tan, Xiaolin Tang, Jinwei Zhang, Yang Xing, Dongpu Cao
   Journal: *Renewable and Sustainable Energy Reviews* (November 2021)
3. The Value of Vehicle-to-Grid in a Decarbonizing California Grid
   Authors: Meiye Wang and Michael Craig
   Journal: *Journal of Power Sources* (November 2021)
4. Adapting Time Headway in Cooperative Adaptive Cruise Control to Network Reliability
   Authors: Adil Alsuhaim, Anjan Rayamajhi, James Westall, and Jim Martin
   Journal: *IEEE Transactions on Vehicular Technology* (October 2021)
5. Centralised Coordination of EVs Charging and PV Active Power Curtailment over Multiple Aggregators in Low Voltage Networks
   Authors: Andrés Felipe Cortés Borray, Julia Merino, Esther Torres, Alejandro Garcés, and Javier Mazón
   Journal: *Sustainable Energy, Grids and Networks* (September 2021)
6. Quantifying the Impact of Driving Style Changes on Light-Duty Vehicle Fuel Consumption
   Authors: Marco Miotti, Zachary A. Needell, Sankaran Ramakrishnan, John Heywood, and Jessika E. Trancik
   Journal: *Transportation Research Part D: Transport and Environment* (September 2021)
7. Real-Time Highly Resolved Spatial-Temporal Vehicle Energy Consumption Estimation Using Machine Learning and Probe Data
   Authors: Joseph Severino, Yi Hou, Ambarish Nag, Jacob Holden, Lei Zhu, Juliette Ugirumurera, Stanley Young, Wesley Jones, and Jibonananda Sanyal
   Journal: *Transportation Research Record: Journal of the Transportation Research Board* (September 2021)
8. Stated Preference Analysis of Automated Vehicles Among California Residents Using Probabilistic Inferences
   Authors: Jimoku Hinda Salum, Boniphace Kutela, Angela E. Kitali, and Emmanuel Kidando
   Journal: *Transportation Research Record: Journal of the Transportation Research Board* (September 2021)
9. Optimal Transport Based Drift Detection for Sensor Streams: Method and Applications in Transportation
   Authors: Arnab Kumar Laha and Shikha Verma
   Report: Indian Institute of Management, Ahmedabad (September 2021)
10. Modeling Consumer Affinity Towards Adopting Partially and Fully Automated Vehicles – The Role of Preference Heterogeneity at Different Geographic Levels
    Authors: Behram Wali, Paolo Santi, and Carlo Ratti
    Journal: *Transportation Research Part C: Emerging Technologies* (August 2021)

- 215 enabled publications and counting
- 28 published in 2021
- Effective h-index: 27





LIVEWIRE DATA PLATFORM