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Exploring the **FUTURE OF MOBILITY**

Transportation Energy and Mobility Pathway Options (TEMPO) Model

TEMPO

Mobility for passengers and freight is a key element of modern society that enables our lifestyle and supports our economy. Current mobility systems depend on personally owned light-duty cars and trucks as well as trains and aircrafts for longer trips. Personal transportation costs are second only to housing, at 16% of total household expenditures.[1] Non-household transport services contribute almost $1 trillion to U.S. gross domestic product.[2]

From an energy perspective, **transportation is currently the least diversified demand sector,** with more than 90% of the energy used to move people and goods in the United States coming from petroleum.[3] As a result, transportation is responsible for almost one-third of the nation's energy use and greenhouse gas emissions.

However, the U.S. transportation systems could enter a **disruptive period** similar to that induced by the automobile in the 1900s as several trends evolve:

- After more than a century of petroleum dominance, **electric vehicles** are increasing in popularity as battery costs have declined by almost 90% over the last decade.
- Demand patterns are shifting and ownership decisions are changing due to socio-economic factors and greater availability of **new technologies and business models** such as ride hailing services, e-commerce, sharing economy, micromobility, and automated vehicles.
- **Energy and environmental ambitions** continue to promote affordable, efficient, and clean transportation solutions, which are further supported by the prospect of abundant and affordable renewable electricity.

Transformation of the transportation system—from today's petroleum base to alternative fuels —could radically change energy use and reduce emissions, but future pathways remain uncertain. To explore future mobility options and pathways, the National Renewable Energy Laboratory (NREL) developed the **Transportation Energy and Mobility Pathway Options (TEMPO)** modeling framework to better understand:

- The potential for radical transformations of transportation demand and its impact on energy use
- Interconnections with other sectors and infrastructure, particularly the electric power system
- Opportunities for transportation technology/fuel adoption across various market segments.

TEMPO is a transportation demand model that covers the entire U.S. transportation sector with an implicit spatial resolution and an hourly temporal resolution. Key features of the TEMPO model include the ability to generate long-term pathways to achieve system-level goals and explore the impacts of technological breakthroughs and behavioral changes.

TEMPO employs an innovative representation of passenger mobility demand stemming from **household-level decisions** that determine vehicle adoption/ownership and use based on socio-demographics (e.g., income, household composition), technology attributes (e.g., cost, travel time, comfort, safety, preference), geography (e.g., urban, secondary cities, rural), and household-

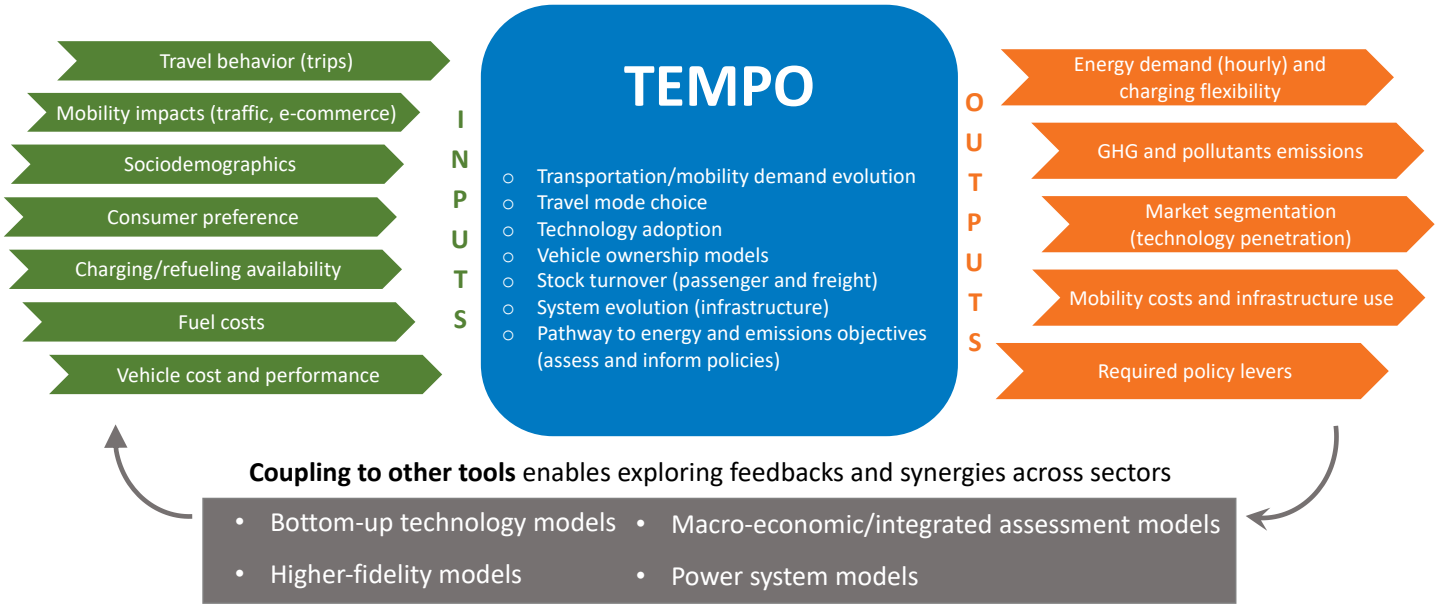
TEMPO is intended to generate future pathways to achieve system-level goals, estimate implications of different scenarios and decisions, estimate affordability and infrastructure use impacts, assess energy use and emissions implications, inform decision makers, and assess integration opportunities between transportation and energy infrastructure and supply systems.

[1] U.S. Department of Labor, Bureau of Labor Statistics, *Consumer Expenditure Survey*.

[2] U.S. Department of Transportation, Bureau of Transportation Statistics, *Freight Facts and Figures*.

[3] U.S. Department of Energy, Energy Information Administration, *U.S. Energy Facts Explained*.

TEMP*O finds pathways* to achieve energy/emissions goals and estimates implications of different scenarios and decisions



specific weekly mobility and travel requirements. This representation enables (1) a more forward-looking perspective on travelers' mobility demand and mode choice and the adoption of alternative fuel vehicles and (2) a more accurate representation of vehicle energy usage and emissions profiles than previous modeling approaches.

Furthermore, TEMPO models the **timing requirements in transportation energy usage**, which are critical to explore electrification trends that may allow for integration opportunities across sectors. In particular:

- The electric power system is undergoing profound changes as variable renewables displace conventional generation.
- Distributed generation is disrupting utility business models.
- Energy storage and smart loads, like electric vehicles, are emerging.
- The traditional system—based on the premise that generation is dispatched to match an inelastic demand—is evolving to create a system with greater participation in power system planning and operations from traditionally passive consumers.

Time-resolved energy use profiles from TEMPO can inform power system models, enabling exploration of the **synergies between transportation and power systems** and how they may improve the efficiency and economics of mobility and electric power, including fully exploiting synergies between electric vehicles and renewables.

In addition to power sector linkages, the TEMPO modeling framework also envisions a **coupling with other tools** (e.g., macro-economic, integrated assessment models, higher fidelity mobility simulators) to both inform inputs and assess the broader impacts of TEMPO results. Key outputs include dynamic passenger and freight travel demand based on future technology options and behavioral assumptions, mobility costs, utilitization of different transportation modes and refueling infrastrucutre systems, technology adoption (e.g., vehicle sales) and stock evolution, emissions, and time-resolved energy use profiles.

Transportation is ripe for **radical disruptions that can provide reliable, affordable, clean, and convenient mobility access to all** and enable a more active role of the sector in economy-wide energy transformation.

As the energy and mobility systems rapidly evolve, pathways generated with the TEMPO model can provide valuable insights on the potential transformation of the transportation sector and its energy use and emissions to inform the transition toward a sustainable future.

TEMPO

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NREL/FS-5400-78001 • October 2020