



**U.S. Department of Energy
Advanced Research Projects Agency – Energy
Request for Information (RFI)
DE-FOA-0001424
on
Advanced Telepresence Technology**

Objective:

ARPA-E seeks input from researchers from a broad range of disciplines, including the physical, computer, and social sciences and all engineering disciplines, regarding the development and adoptability of advanced telepresence technologies in the context of reducing the energy use associated with transportation.

These may include, but are not limited to, advanced technologies and concepts relating to 2D or 3D telecommunications, virtual or augmented reality, brain-computer interface, robotics for telelabor, and any other mixed reality technologies.

Any opportunities for development and potential technical solutions that might be of interest to ARPA-E would require a demonstrable path to reducing the amount that people use energy in the transportation sector.

Of essential importance is the argument that, whatever the technology or concept is, an individual *would prefer it* to the energy-intensive status quo. This would therefore relegate the potential emissions reductions and fuel import reductions as positive externalities, not primary motivations.

The information you provide may be used by ARPA-E in support of program planning. **THIS IS A REQUEST FOR INFORMATION ONLY. THIS NOTICE DOES NOT CONSTITUTE A FUNDING OPPORTUNITY ANNOUNCEMENT (FOA). NO FOA EXISTS AT THIS TIME.**

Background:

Nearly one-third of the energy-related emissions in the United States emanates from the activities of the transportation sector¹.

An unavoidable aspect of nearly all present-day transportation technologies is that the energy source must be carried onboard the vehicle. Gasoline powers most automobiles; diesel powers most heavy-duty trucks; and jet fuel powers most airplanes².

The dominance of these liquid fuels in the transportation sector is a result of their enormous energy density and low cost. At 32 MJ/l, the energy density of gasoline is more than an order of magnitude

¹ <http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html>

² http://www.eia.gov/Energyexplained/?page=us_energy_transportation



higher than that of lithium-ion batteries and nearly 1000 times higher than uncompressed natural gas³.

There is substantial opportunity to improve upon the existing transportation supply chain in order to reduce the energy use in transportation. In its short history, ARPA-E has made several such investments, focusing on electric vehicle batteries, natural gas tanks and compressors, lightweighting, and alternative fuel production methods with low lifecycle emissions⁴. These programs sought to create transformative changes within the present paradigm of automobiles and liquid transportation fuels or batteries, and have made several important contributions to date.

Another viable approach is to consider how we could satisfy, with much lower energy intensity technologies, the fundamental reasons for which we move around in the first place. This approach would involve changing the present paradigm for transportation.

A high level dichotomy of transportation energy expense is that of moving things versus moving people.

1. Freight transportation results from a desire to have cargo physically exist in a place where it is not presently. This type of transportation is responsible for ~30% or 278 GW (8 quadrillion BTU/yr) of transportation energy expenditures⁵, and is not the focus of this Request for Information.
2. When people are transported, however, it is their *presence* that is desired for one reason or another. Passenger transportation is responsible for ~70% or 568 GW (17 quads/yr) of transportation energy consumption^{5,6}.

This RFI requests information related to the second element of the dichotomy. “Presence” here is to be understood as both *perceptual* and *physical*. Our perception of presence is the understanding that we derive through the eyes, ears, nose, mouth, and dermis, as processed by the human brain. Our physical presence is our ability to use our bodies to interact with the physical environment. Both of these types of presence are very important, and in some cases very difficult to deconvolute.

For purposes of discussing the energy-presence nexus, we propose a trichotomy based on high-level objectives of passenger transportation. Passenger transportation can be broken down into these three objectives:

1. *Communication*: We move from one place to another predominantly to convey or consume information, e.g. business trip, drive to office, etc.
2. *Labor*: We move from one place to another predominantly to interact physically with the environment, e.g. drive to factory, farm or restaurant, etc.
3. *Experience*: We move from one place to another predominantly to “experience”, e.g. trip to the beach, the Pantheon, or a religious gathering.

We are interested to know to what extent advances in low-energy telepresence technologies can meet

³ https://en.wikipedia.org/wiki/Energy_density

⁴ If further interested in ARPA-E transportation-related programs, [visit our webpage](#) and search for BEEST, AMPED, MOVE, RANGE, LITECAR, Electrofuels, PETRO, REMOTE, TRANSNET, or METALS.

⁵ Freight Facts and Figures 2013. U.S. Department of Transportation. 2011 data.

http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/13factsfigures/pdfs/fff2013_highres.pdf

⁶ Transportation Energy Data Book: Edition 33-2014



the objectives of reducing physical transportation used for addressing the needs of human presence. For example, how could recent advances in the field of robotics contribute to performing labor at a distance (telelabor)? Or, how could the monumental advances in performance-per-cost in computing power, screens, and cameras satisfy modes of communication that modern telecommunications cannot?

As noted above, the purpose of the inquiry is to identify key factors that would need to be addressed for telepresence technologies to reduce the need for passenger transportation, and thus reduce the associated energy use.

Figure 1 shows the breakdown of transportation energy consumption in the United States for 2011. In an attempt to ascertain how much energy the U.S. uses for each of the objectives outlined above, we relied heavily on the National Household Transportation Survey⁷.

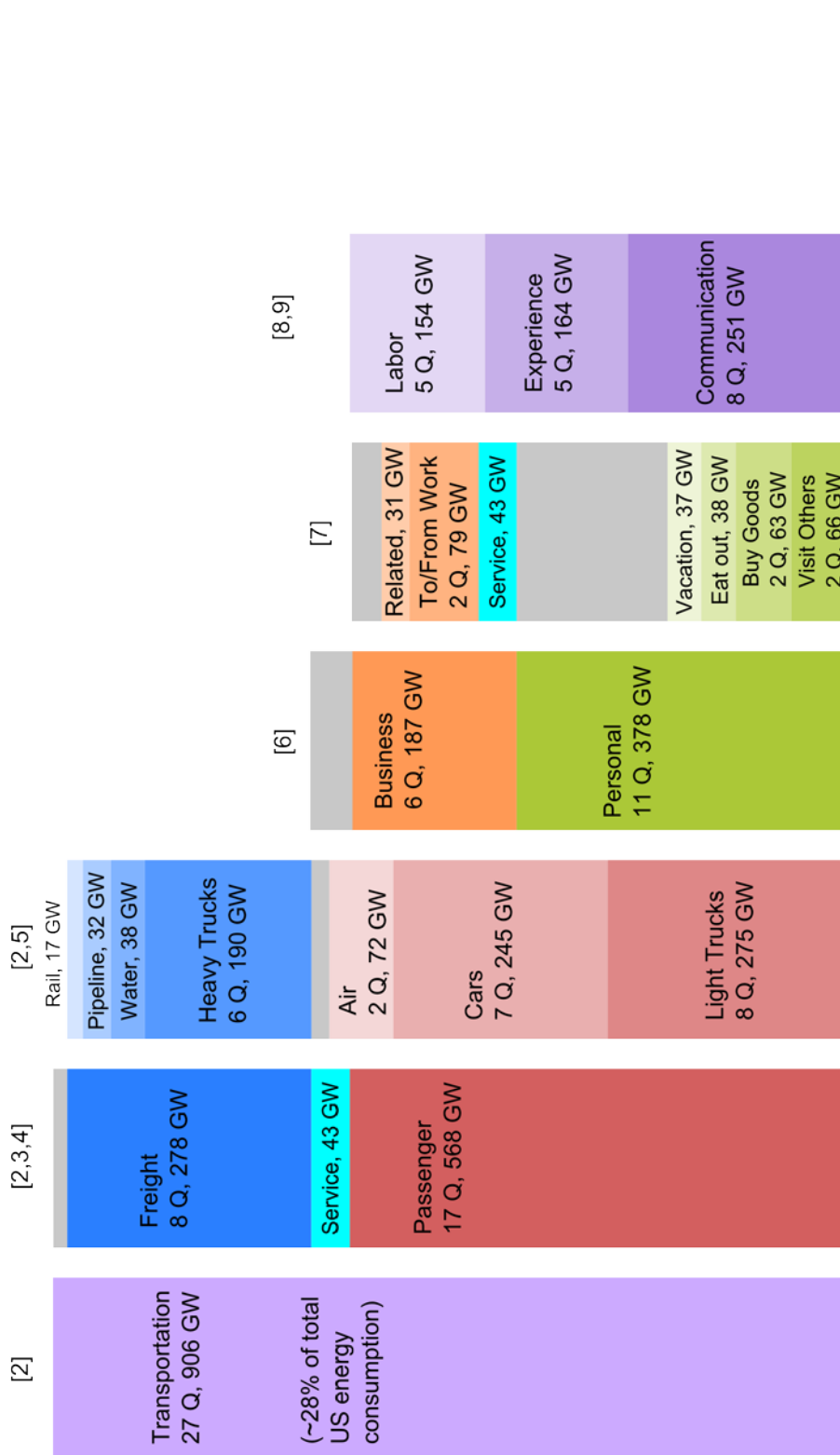
The NHTS is a survey managed by the U.S. Department of Transportation intended to serve as the nation's inventory of daily travel. Data is collected on daily trips taken in a 24-hour period, and includes trip purpose, travel mode, travel time and distance, day and time of the trip, number of passengers, driver characteristics (age, sex, worker status, education level, etc.), vehicle attributes, and many other categories.

We prioritized the data by trip-miles (TRPMILE), and analyzed the 36 trip purpose categories (WHERE TO and AWAY FROM fields) that were broken out in the NHTS. For each category, e.g. "travel to work", "travel to get gas", "travel to friends or family to visit", we estimated what portion of that travel purpose was for communication, labor, or experience.

⁷ National Household Transportation Survey. U.S. Department of Transportation. 2009 dataset. The "AWAYFROM", "WHERE TO", "TRPTRANS", and "TRPMILES" data from the DAYV2PUB datasheet was used in this calculation.



Figure 1: Transportation Energy Consumption, United States 2011¹



1. Data for 2011 were not always available, in which case assumptions or interpolations were made from available data. Q is Quadrillion BTU per year. Gray means "other".
2. Transportation Energy Data Book: Edition 33-2014, Oak Ridge National Laboratory; Freight Facts and Figures 2013. U.S. Department of Transportation (2011 data).
3. "other" includes military and all other possible uses of fuel for transportation (e.g. snowmobiles). "Service" includes plumbers, taxis, police officers, firefighters, cleaning, etc.
4. Accounting for Commercial Vehicles in Urban Transportation Models, Sec. 3. Federal Highway Administration, Office of Planning, Environment, & Realty (HEP).
5. Passenger "other" includes: Water 8 GW, Buses 7 GW, Rail 3 GW, and Motorcycles 2 GW.
6. National Household Transportation Survey. U.S. Department of Transportation, 2009. "Business" refers to business travel-related categories. "Personal" is everything else.
7. Personal "other" includes 26 categories over 0.4 GW, and 12 over 10 GW, e.g. drop someone off, medical/dental services, entertainment, buy gas, etc.
8. Labor Force Statistics from the Current Population Survey, Table 9. Employed persons by occupation, sex, and age. U.S. Bureau of Labor Statistics. 2014 data.
9. Travel "objectives": Communication: to convey/receive information; Labor: to interact physically with the environment; Experience: to intangibly "experience" something.



For example, for “travel to work”, we used a report from the Bureau of Labor Statistics⁸ that outlined how many people are occupied in each profession. We assigned varying weights to each profession based on our subjective understanding of what is required in that line of work.

“Management occupations” were considered 100% communication, whereas “Food preparation and serving related occupations” were considered 100% labor. “Healthcare practitioner and technical occupations” were considered half communications and half labor.

For non-work travel purposes, we similarly assigned varying weights to each category. For example, “Visit friends/relatives” was considered 50% communication and 50% experience; “Rest or relaxation/vacation” was considered 100% experience; and “Use personal services: grooming/haircut/nails” was considered 100% labor.

Though these determinations are largely subjective, we believe that the rough numbers we have computed carry significance. Combining all of the data previously mentioned (energy use by passenger/freight, energy use by travel mode, trip miles by travel purpose and travel mode, and %communication/labor/experience vs travel purpose) yields a distribution of energy use vs communication, labor, and experience.

Our results indicate that, of United States *total* energy consumption, roughly:

8% is associated with passenger transportation for *communication* (7.5 Q, 251 GW)
5% is associated with passenger transportation to *experience* (4.9 Q, 164 GW), and
5% is for *labor* objectives (4.6 Q, 154 GW).

It is important to note that there is substantial overlap in many cases between two or even all three objectives. Figure 2 shows the relative contribution of these objectives and the overlap between them.

For ARPA-E to be interested in running a focused program in any technology area, the investment must be able to have a substantial effect on United States energy.

Accordingly, any technology conceived should be able to displace around one-fifth of travel for communication, labor, or experience, or some equivalent combination across multiple categories.

The proposed impact does not have to be immediate, however we do wish to develop a clear understanding of the priorities for technical investment that could yield the optimum benefits in energy use reduction, and the pathways and timescales on which such benefits may be realized. In this context, we are interested in learning more about the entire technology space relating to providing the benefits of being present in another place without actually physically moving your body.

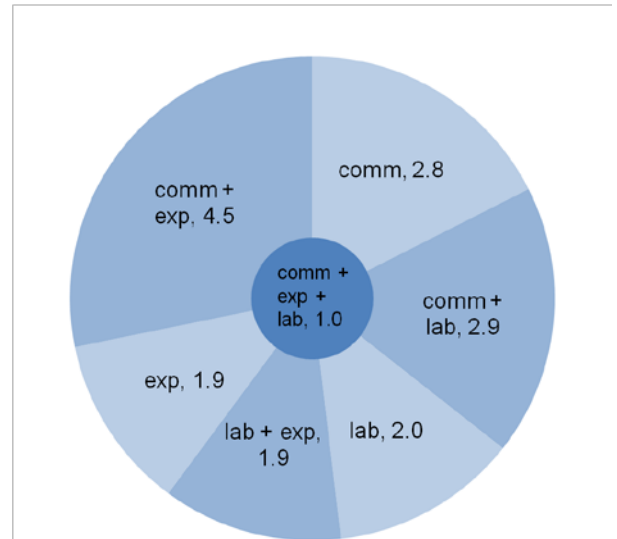


Figure 2. Donut chart breakdown of passenger transportation energy consumption for communication (comm), labor (lab), and experience (exp), and the overlap between objectives. The center hole represents overlap between all three objectives. (units quadrillion BTU/yr)

⁸ “Labor Force Statistics from the Current Population Survey, Table 9. Employed persons by occupation, sex, and age”. U.S. Bureau of Labor Statistics. 2014 data. <http://www.bls.gov/cps/cpsaat09.pdf>



Table 1 builds out a preliminary understanding of the technical space of telepresence, broken into topical areas and the categories of Hardware, Software, and fundamental Knowledge. In some cells, we have provided an example technology for additional clarification.

We are interested in your perspectives on the ability of these various technology categories, and specific technologies that may fit within them, to be able to reduce passenger transportation energy expenditures.

We have drafted the following list of questions that you may use to guide your response. Please feel free to provide perspective outside this technical space or these questions that you feel is important to consider when investigating telepresence for the purposes of reducing energy expenditures.

Table 1: Technical Space for Telepresence, with examples solely for clarification

	<i>Hardware</i>	<i>Software</i>	<i>Knowledge</i>
<i>2D Telepresence</i>	e.g. webcam	e.g. Skype	e.g. gaze importance
<i>3D Telepresence</i>	e.g. head mounted displays		e.g. value of 3D
<i>Virtual Worlds</i>	e.g. limb tracking	e.g. Second Life	e.g. adoptability
<i>Augmented Reality</i>	e.g. retina projection		e.g. collaborative work
<i>Robotic Telepresence</i>	e.g. Da Vinci Robot		e.g. cost vs. adoption
<i>Dermal Interaction</i>	e.g. haptic gloves		
<i>Brain-Computer Interface</i>	e.g. EEG		
<i>All</i>	e.g. bandwidth	e.g. ease of use	e.g. adoption barriers
<i>Other</i>			



Purpose and Need for Information:

The purpose of this RFI is solely to solicit input for ARPA-E consideration to inform the possible formulation of future programs intended to help reduce the total energy used in the transportation sector. Information obtained may be used by ARPA-E on a non-attribution basis. This RFI provides the broad research community with an opportunity to contribute views and opinions regarding novel telepresence solutions. Based on the input provided to this RFI and other considerations, ARPA-E may decide to issue a formal FOA for this area. If a formal FOA is issued, it will be issued under a new FOA number. No FOA exists at this time. ARPA-E reserves the right to never issue a FOA in this area.

REQUEST FOR INFORMATION GUIDELINES:

ARPA-E will not pay for information provided under this RFI, and there is no guarantee that a project will be supported as a result of this RFI. This RFI is not a FOA, and ARPA-E is not accepting applications for financial assistance or financial incentives under this RFI. Response to the RFI will not be viewed as any commitment for the respondent to develop or pursue the project or ideas discussed. ARPA-E may decide at a later date to issue a FOA based on consideration of the input received from this RFI.

Respondents shall not include any information in the response to this RFI that might be considered proprietary or confidential.

Questions and comments can be sent to ARPA-E-RFI@hq.doe.gov for those considering whether to participate, to seek feedback, or exchange ideas prior to a formal submission.

Comments in response to this RFI should be submitted in PDF format to the email address ARPA-E-RFI@hq.doe.gov by 5:00 PM Eastern Time on October 30, 2015. ARPA-E will accept responses to this RFI immediately.

Please insert "Responses for RFI for FOA DE-FOA-0001424" in the subject line of your email, and include your name, organization, email address, and telephone number in the body of your email. Responses to this RFI are limited to no more than 3,000 words in length.

ARPA-E will not provide any debriefings or prepare and publish a synopsis of materials received in response to the RFI.

Thank you very much for your time and effort in helping ARPA-E refine its perspectives about telepresence and its potential impact on reducing transportation energy consumption.

RFI Questions:

Technological Barriers

1. What do you view as the most critical technologies needed to substantially reduce the need for labor- and communications-focused travel?
 - a. What critical capabilities do current technology solutions lack?
 - b. What technical limits represent the greatest challenges to realizing these necessary capabilities?
 - c. From a technology-agnostic point of view, what would the ideal solution look like?



2. What are the critical technologies in telecommunications and telelabor that could help reduce the need for personal transportation but are not getting funded? What impacts could a focused investment in these areas make? What scale of investment would be needed for the impact?
3. How would you distinguish between incremental and transformational technology capabilities in telepresence?
4. What is included in the R&D roadmap of the existing technology providers?
 - a. What new technologies and projects are expected to be fielded in the next 5 years? By whom?
 - b. Which of these technologies could clearly support the goal of reducing the need for personal transportation?
 - c. Which of the technologies under item (b) appear to be furthest on the horizon, yet could be accelerated with successful R&D breakthroughs?
5. Are there advanced telepresence technologies which have failed to be embraced as a telepresence solution? Why did they fail?
6. What research has been done (or could be done) to quantify the relationship between the various technical issues/opportunities in telepresence and customer acceptance of telepresence as an alternative to physical presence?

User Adoption Questions

7. What does a telepresence technology need to achieve such that it is widely adopted outside of the gaming or entertainment sectors? What metrics could you use to describe this?
8. Why do people not use telepresence more today? What are the important aspects of presence that current technology fails to achieve?
9. How would you prioritize the various aspects of presence; reliability, ease of use, gaze direction, body language, microexpressions, texture resolution, 3D visual, 3D aural, and the others?

Utility Questions

10. What specific communities may be unserved by the market, but could represent a significant population where passenger transportation activities could be reduced by telepresence usage?
11. What new transportation-reducing roles could telecommunications and telelabor systems allow users to take on, or what existing roles could be done remotely with equal or greater efficiency than by today's methods?
12. What concepts for conducting business via enhanced telepresence could be enabled beyond today's status quo?

Technology-Specific Questions:

13. For robotic telemanipulation and teleoperation systems (those physically affecting the environment):
 - a. Where does the R&D roadmap put this technology within 3-5 years?
 - i. What will it be able to do?
 - ii. What are its performance targets?
 - iii. What technical challenges are the current foci?
 - b. What roles could this technology enable remotely?
 - c. What exemplar tasks could be a focal point for teleoperation systems research that would greatly reduce transportation costs associated with the tasks? Could the remote robotic interface be low enough in cost for wide deployment without adding new transportation costs?
14. For head-mounted displays and other body-tracking virtual or augmented reality systems:
 - a. Where does the R&D roadmap put this technology within 3-5 years?



- i. What will it be able to do?
 - ii. What are its performance targets?
 - iii. What technical challenges are the current foci?
 - b. What are the white spaces for investment in these technologies?
 - c. Which applications that would reduce the need for physical transportation could benefit the most from this technology?
 - d. What research is or could be done to quantify how these issues impact customer uptake of telepresence in place of physical presence?
15. For 2-D (video, arguably with sound) and 1-D (audio) telepresence capabilities, what technologies could enhance this mature field of communication to enable greater presence and expand the communities using this technology in lieu of travel? What research is or could be done to quantify how these issues impact customer uptake of telepresence in place of physical presence?
16. For reproducing realistic digital representations of humans, how far are we from being able to generate perfectly realistic and comfortable human avatars with real time machine vision capture of the subject and flawless translation of all relevant human features to the avatar? What research is or could be done to quantify how these issues impact customer uptake of telepresence in place of physical presence?