Skip all front matter: Jump to Page 1

This product is part of the RAND Corporation technical report series. Reports may include research findings on a specific topic that is limited in scope; present discussions of the methodology employed in research; provide literature reviews, survey instruments, modeling exercises, guidelines for practitioners and research professionals, and supporting documentation; or deliver preliminary findings. All RAND reports undergo rigorous peer review to ensure that they meet high standards for research quality and objectivity.

REPORT

Energy Services Analysis

An Alternative Approach for Identifying Opportunities to Reduce Emissions of Greenhouse Gases

Keith Crane • Liisa Ecola • Scott Hassell • Shanthi Nataraj

Sponsored by the Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy

RAND

Environment, Energy, and Economic Development

A RAND INFRASTRUCTURE, SAFETY, AND ENVIRONMENT PROGRAM

This report was sponsored by the United States Department of Energy and was conducted in the Environment, Energy, and Economic Development Program within RAND Infrastructure, Safety, and Environment, a division of the RAND Corporation.

Library of Congress Cataloging-in-Publication Data

Energy services analysis : an alternative approach for identifying opportunities to reduce emissions of greenhouse gases / Keith Crane ... [et al.].
p. cm.
Includes bibliographical references.
ISBN 978-0-8330-6036-5 (pbk. : alk. paper)
1. Energy auditing. 2. Energy conservation. 3. Greenhouse gas mitigation. I. Crane, Keith, 1953-

TJ163.245.E54 2012
333.791'6—dc23

2012010449

Published 2012 by the RAND Corporation
1776 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
4570 Fifth Avenue, Suite 600, Pittsburgh, PA 15213-2665
RAND URL: http://www.rand.org
To order RAND documents or to obtain additional information, contact
Distribution Services: Telephone: (310) 451-7002;
Fax: (310) 451-6915; Email: order@rand.org

Summary

The purpose of this technical report is to identify and evaluate new means to reduce energy use and greenhouse gas (GHG) emissions by employing energy services analysis (ESA). Most efforts in this area focus on ways to reduce energy use and GHG emissions by making existing processes more efficient. This report uses ESA to examine possibilities for changing how a service is delivered to reduce energy use and GHG emissions. The report introduces ESA, explains how it differs from conventional approaches and how this type of analysis can be conducted, uses an ESA framework to analyze how changes in the provision of two common services might result in reductions in energy use and GHG emissions, suggests other areas in which ESA could be applied, and ends with some thoughts on using ESA more broadly.

Energy Services Analysis

Energy consumption and GHG emissions in the United States are generally analyzed by end use: residential, commercial, industrial, and transportation. These categories focus on the user, not necessarily the purpose for which the energy is consumed. Stemming from this focus on end use, efforts to identify ways to conserve energy often target improving the efficiency of current technologies. However, in many instances, changing the way in which a service is provided can open up more or better opportunities to reduce energy use than attempting to make the current way of delivering the service more efficient. ESA evaluates opportunities for reducing energy use and GHG emissions by changing how a service is provided.

ESA seeks to rectify two of the main drawbacks of focusing on energy end use rather than the provision of the service desired. First, focusing on the end use does not address the purpose for which the energy is consumed. Second, focusing on the direct use of the energy ignores indirect consumption. For example, the owner of a car purchases gasoline, but energy is also consumed in producing the materials, such as steel, used to manufacture the car, in assembling the car, delivering the vehicle, and the other stages of production.

ESA addresses both of these issues. First, ESA focuses on the service that the energy is used to provide rather than on the consumer of the energy. The goal of ESA is to determine whether the service could be provided in another way that requires less energy. Second, ESA reallocates energy use from the purchaser or consumer to the individual service that is consumed. In so doing, ESA includes all energy used in providing a service, whether directly (by the end user) or indirectly (at any other point in the chain of service provision). In the example above, ESA allocates the energy required to manufacture, distribute, and drive the car to the service of mobility, provided by the vehicle, rather than distribute the energy used by the driver, the automobile manufacturer, and the steel mill into different categories.

Applying Energy Services Analysis

ESA can be conducted using either of two analytical methods. In process analysis, the entire process of creating a product or service, from raw materials to disposal, is laid out. The energy used at each stage of the process is estimated and summed to provide an estimate of total energy consumption, direct and indirect. Process analysis requires highly disaggregated data and is generally conducted at the firm level because it looks only at the manufacturing process. Life-cycle assessment differs from process analysis in that it evaluates energy use and GHG emissions from cradle to grave. Life-cycle assessment measures all the energy consumed, from the equipment and raw materials used to manufacture the product, to production, to final use and disposal.

ESA involves creating a framework for thinking about alternative means of providing a service. In this report, we use a typology of human wants and needs developed by Costanza et al. (2007) to classify various services so as to evaluate energy consumption by competing means of providing these services. These wants and needs are subsistence, security, affection, understanding, participation, leisure, spirituality, creativity, identity, and freedom. All the energy that people use ultimately fulfills one or more of these wants or needs.

Because energy can be measured with different metrics, our application of ESA focuses on GHG emissions. This makes it easier to compare the effects across various sectors: delivery of written news, vehicle sharing, food, clothing, health care, and waste disposal.

Delivery of Written News

We conducted an ESA for the delivery of written news, a service that fulfills the need for access to information. Electronic dissemination of written news already substitutes for the delivery of some print newspapers. With the advent of electronic readers ("e-readers") and tablet computers, the shift from print to electronic dissemination appears set to accelerate.

Paper manufacturing, printing, and newspaper distribution release substantial amounts of GHGs. The frequency and volume of newspapers makes them particularly energy intensive. We estimate that, in the United States, one newspaper subscription releases 94.7 kg of carbon dioxide annually, for production, printing, and delivery (see Table 3.1 in Chapter Three). Providing written news through alternative means could potentially save substantial amounts of energy and reduce emissions of GHGs. In contrast, the production and operation of a single e-reader or tablet computer generates far fewer GHG emissions, assuming that emissions produced during the manufacture of these devices are spread out over a three-year product life span. Table S.1 shows the differences in GHG emissions from a single newspaper subscription and from using these devices.

We calculated potential reductions by disseminating written news with e-readers rather than newspapers in a "what-if" scenario (that is, what if each current newspaper subscription were replaced today with an e-reader or tablet computer). Adopting e-readers could reduce GHG emissions from publishing and distributing newspapers by 74 percent; using tablet com-

Table S.1
Annual Greenhouse Gas Emissions Associated with Reading a Newspaper and Reading the Same News on a Tablet Computer or E-Reader

Emission Type	Unit	Newspaper	Tablet Computer	E-Reader
GHG emissions per subscription	Kg of CO_2e	94.7	35	24.7
Newspaper subscriptions	Millions	45.9		
GHG emissions	Million metric tons	4.35	1.61	1.13
Reduction compared to newspapers	Million metric tons		2.74	3.21
	Percentage		63	74

NOTE: CO_2e = carbon dioxide (CO_2) equivalent.

puters could result in a 63 percent reduction, assuming that all the GHG emissions associated with producing and operating e-readers or tablet computers are ascribed to reading newspapers. If a more realistic assumption is adopted, that the emissions associated with these devices should be spread across other activities pursued on these devices, the difference would be on the order of 84 to 89 percent less, respectively.

Policy Options

Because of these energy savings and reductions in GHG emissions, the U.S. Department of Energy (DOE) may wish to ensure that consumers are made better aware of the trade-offs in energy use between these two different methods of obtaining written news. Options for increasing this awareness include the following:

- Encourage manufacturers to provide information on the energy efficiency of electronic readers and information and communication technology (ICT) equipment.
- Monitor technological developments in ICT network equipment and usage.
- Provide consumers with the right to retain access to information they have purchased so that consumers do not have to repurchase content if they switch or upgrade devices.

Mobility: Sharing, Rather Than Owning, Vehicles

We also used ESA to evaluate the provision of the service of mobility by shared vehicles rather than by personally owned vehicles. Mobility fulfills a wide variety of human wants and needs, ranging from subsistence to leisure. Vehicle sharing provides personal mobility without owning a vehicle. Participants in vehicle-sharing programs generally give up their personally owned motor vehicles or forgo vehicle purchases, using vehicles owned by the program when needed.

Most transportation in the United States takes place in personally owned light-duty vehicles. The number of miles that the owners of these vehicles drive each year increased steadily until 1999; since then, they have leveled off. Many observers think that one reason for these increases is that vehicle ownership has substantial fixed costs that are incurred regardless of how much the vehicle is driven; the extra costs of taking a trip in the vehicle are small. Vehicle sharing converts these fixed costs into variable costs by charging individuals per trip. Faced with higher out-of-pocket costs per trip, participants take fewer trips by motor vehicle, reducing overall energy use and GHG emissions. Moreover, drivers who do not drive much can save money through vehicle sharing because they do not have to pay the high fixed costs of purchasing and owning a vehicle.

Vehicle sharing is available in many U.S. cities. Current membership figures are about 560,000, which represents 0.27 percent of U.S. drivers. Vehicle-sharing services have been most successful in neighborhoods with good access to public transit and higher-than-average density. Former vehicle owners living in these neighborhoods can easily shift some of their trips to public transit or nonmotorized modes. Vehicle sharing provides efficient alternatives for other niche users, such as businesses and governments that operate vehicle fleets and students on college campuses.

Vehicle sharing has the potential to substantially reduce GHG emissions in three ways. First, some studies (see, e.g., Millard-Ball et al., 2005; and Martin and Shaheen, 2010) find substantial average reductions in vehicle miles traveled after a participant joins a vehicle-sharing organization. Second, shared vehicles are generally more fuel efficient than the existing vehicle fleet. Finally, because members drive fewer miles and vehicles are used more intensively, vehicle sharing reduces the number of cars needed, which, in turn, reduces energy used and GHGs emitted in the manufacture of vehicles. Using this analysis, we calculate that a single driver who shifts from personally owning a motor vehicle to participating in a vehicle-sharing program would likely emit 893 kg of CO_2e per year less than if he or she had continued to own and operate a vehicle. Although the average vehicle-sharing participant would reduce his or her GHG emissions by about 37 percent, it is important to note that the average vehicle-sharing participant drives far less than the average American driver.

We estimated potential reductions in GHG emissions under three cases, which reflect current vehicle-sharing programs. In the base case, we use the current penetration rate of 0.27 percent to calculate reductions in GHG emissions from participation in vehicle-sharing programs in that year. In the second case, called *supportive policies* because it assumes that policies that actively support vehicle sharing lead to increased participation, we estimate potential reductions if 4.5 percent of U.S. drivers were to participate in vehicle-sharing programs. Our third case estimates GHG reductions under the assumption that 12.5 percent of U.S. drivers aged 21 and up in major metropolitan areas join such programs, an upper-bound estimate of potential penetration rates from a study by Shaheen, Cohen, and Roberts (2006).

We found that participation in vehicle-sharing programs may currently result in reductions in GHG emissions of 0.5 million metric tons of CO_2e per year. By way of comparison, we find that light-duty vehicles accounted for 1,071 million metric tons of emissions in the United States in 2009, based on U.S. Energy Information Administration estimates of total GHG emissions from light-duty vehicles. In the second and third cases, the absolute amount of reductions in emissions of GHGs would be substantial, all other factors being equal (Table S.2). These assumptions are based on current models of vehicle sharing; however, other models that are not yet in widespread use (such as peer-to-peer vehicle sharing) may make vehicle sharing more attractive.

Policy Options

Encouraging the expansion of vehicle sharing or other alternatives to private ownership of motor vehicles could substantially reduce energy consumption and GHG emissions. However, these alternatives would have to be competitive in terms of convenience as well as cost. Vari-

Table S.2
Potential Reductions in Greenhouse Gas Emissions from Switching from Personally Owned Vehicles to Vehicle Sharing, Under Three Cases

Factor	Base Case	Supportive Policies Case	Maximum Adoption Case
Number of participants	560,000	7,500,000	20,300,000
Assumed percentage adoption by drivers in urban areas	0.27	4.5	12.5
Total reductions in GHG emissions (millions of metric tons)	0.5	6.7	18.1
Percentage reduction from GHG emissions from U.S. light-duty fleet	0.05	0.6	1.7

NOTE: Reductions in GHG emissions per participant are 893 kg. The percentage reduction is based on 1,071 million metric tons of GHG emissions from light-duty vehicles (EIA, 2012, Table 19).

ous policies might help speed the adoption of vehicle sharing as it currently exists, as well as promote new models:

- Adopt parking policies that allow one-way, dynamic vehicle sharing.
- Change insurance regulations to facilitate peer-to-peer vehicle sharing.
- Alleviate the tax burden on shared vehicles.
- Help advance technologies that facilitate vehicle sharing.
- Legalize and provide better operating environments for shared neighborhood vehicles.
- Research material advances to enable greater user of shared neighborhood vehicles.
- Develop better technology for ride-matching services to enable smart paratransit and dynamic ride-sharing.
- Continue research into and regulation of the technology to enable driverless vehicles.
- Change liability laws to enable use of driverless vehicles.

Other Opportunities for Employing Energy Services Analysis

Many other services could be evaluated for their potential to be provided in alternative ways. Some of these alternatives are available now, while others are not yet commercially available. Examples of other services that could be assessed with ESA include the following:

- Food: ESA can be used to evaluate the energy used to produce locally grown food as opposed to food produced elsewhere and shipped. Employing ESA to compare the energy and GHGs emitted in producing certain types of food, such as protein sources, could identify foods that entail the lowest amounts of energy. ESA could also be used to evaluate the energy intensity of food preparation, comparing lower-energy cooking techniques or out-of-home food preparation with traditional food preparation.
- Clothing: ESA could be used to evaluate energy savings associated with materials that last longer or need less laundering, or better channels for distributing used clothing to extend its useful life.

- Health care: ESA could be used to evaluate the life-cycle energy consumption associated with particular medical treatments. It could also look at ways to reduce energy consumption in health care settings or reduce the length of stay in such facilities so that more patients can be served.
- Waste disposal: ESA could be used to evaluate the energy consumption of landfills as opposed to recycling or other forms of disposal.

In the residential energy-use category, direct energy use accounts for only one-third of all energy consumed, while indirect energy accounts for two-thirds. ESA thus offers a practical way to look for energy savings by identifying the services that consume the most energy and investigating alternative means of delivering those services.

Conclusions

ESA provides a useful means of looking at energy use differently. Changing the way in which a service is delivered can translate into large reductions in energy use and GHG emissions. Reductions ought to be considered both per user and in aggregate, as alternative ways of providing a service result in aggregate declines stemming from widespread substitution of the new activity for the old. Table S.3 summarizes these differences in per capita and aggregate decreases for both of our examples, as well as our assumptions about the diffusion of the alternative way of providing the service.

For the delivery of written news, the percentage reduction estimated in this summary is as much as 89 percent, both on a per-user basis and in aggregate, assuming that all users switch from newsprint to reading electronically. The absolute reductions could be as high as 84.1 kg

Table S.3
Comparison of Estimated Greenhouse Gas Emission Reductions for News Delivery and Personal Mobility, Per Capita and Total

Factor	Written News	Personal Mobility (maximum adoption case)
Reductions per user		
Current annual GHG emissions (kg CO_2e)	94.7	2,380
Maximum potential annual GHG emissions avoided with alternative service provision (kg CO_2e)	84.3	893
Maximum percentage reduction	89	37
Total reductions		
Current annual GHG emissions for sector (millions of metric tons)	4.35	1,071
Assumed percentage of users who adopt alternative service provision	100	12.5
Maximum potential annual GHG emissions avoided with alternative service provision (kg CO_2e)	3.87	18.1
Maximum percentage reduction	89	1.7

of CO_2e per user, or 3.87 million metric tons overall. Reducing GHG emissions by similar amounts by improving the efficiency of publishing paper newspapers is infeasible. Even in the future, technical improvements in the efficiency of producing paper or printing newspapers could not generate such large reductions in energy use or GHG emissions. Although the total emissions of 4.35 million metric tons of GHG emissions from the newspaper industry are not a large total of U.S. GHG emissions, they represent a substantial reduction for one sector.

Vehicle-sharing programs also generate substantial per-user reductions in GHG emissions, about 37 percent per user. However, only 0.27 percent of U.S. drivers currently participate in vehicle-sharing programs; maximum potential participation has been estimated at 12.5 percent. Participation is constrained by the availability of public transportation, the availability of vehicle-sharing services, and ease of use. Moreover, the profile of those who join vehicle-sharing organizations is quite different from those who do not: Members of vehicle-sharing organizations drive far fewer miles annually than the average U.S. driver. In the unlikely event that maximum potential participation is achieved, the corresponding reduction in total U.S. GHG emissions would be on the order of 18.1 million metric tons. Because potential likely members drive so much less than the national average, this reduction in emissions would be equivalent to only 1.7 percent of total GHG emissions (1,071 million metric tons) from light-duty vehicles. Thus, although the relative size of reductions may be large, overall reductions in the context of total U.S. emissions of GHGs would likely be relatively small.