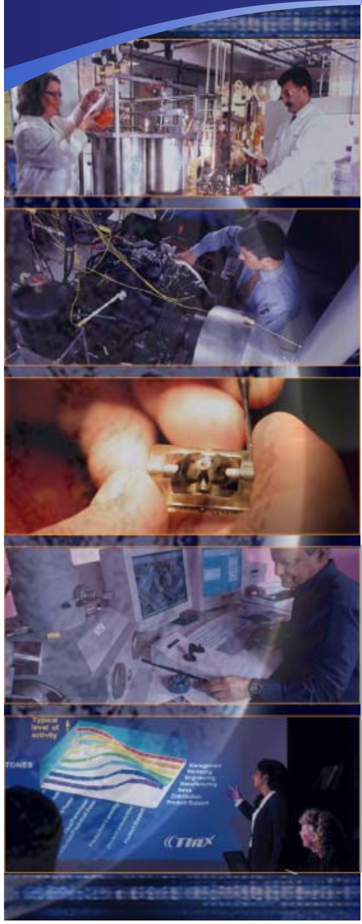
The Energy and Greenhouse Gas Emissions Impact of Telecommuting and e-Commerce



Final Report by TIAX LLC to the

Consumer Electronics Association (CEA)

July 2007

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Reference No.: D5525

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Executive Summary

Study Objectives and Scope

Telecommuting

e-Commerce

- Introduction
- Tangible Goods
- Electronic Goods
- e-Materialization

The Consumer Electronics Association (CEA) contracted TIAX LLC to investigate the impact of telecommuting and e-commerce on U.S. energy consumption, greenhouse gas emissions, and liquid fuel consumption.

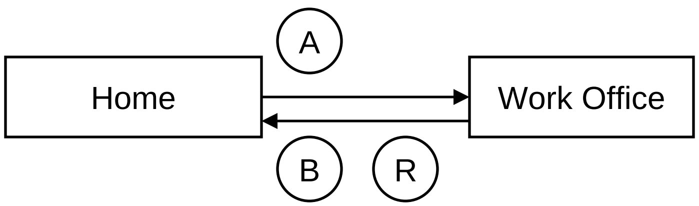
- With projected U.S. factory sales of $155 billion in 2007, consumer electronics is a large and growing industry. (CEA 2007)
- The information and communication technologies (ICT) developed by this industry are used by consumers to communicate, conduct business, and entertain.
- In many cases, these technologies have created new ways for consumers to interact (e.g., cell phones and email) and new methods for conduct business transactions (e.g., working from home, on-line purchasing, ICT information exchange, etc.).
- The emergence of ICT-based systems – in place of traditional brick-and mortar systems – has raised questions about the relative costs and benefits of these new systems to the environment, specifically energy consumption and greenhouse gas emissions.
- While information about the energy consumed while using ICT is available, information about energy consumption and CO_2 generation associated with the full life-cycle of the equipment – and the activities that the equipment support – has been more limited.
- This study was commissioned to provide a clear understanding of the net impact of using ICT-based approaches (i.e., telecommuting and e-commerce) by considering the life-cycle energy consumption and CO_2 generation associated with those activities.

Our first area of focus was telecommuting – when workers spend one or more days working from home each week.

- Telecommuting reduces energy consumption associated with transportation to and from the office and, in some cases, a portion of the energy associated with commercial office space.

Traditional Mode

100% Commuting



Key:

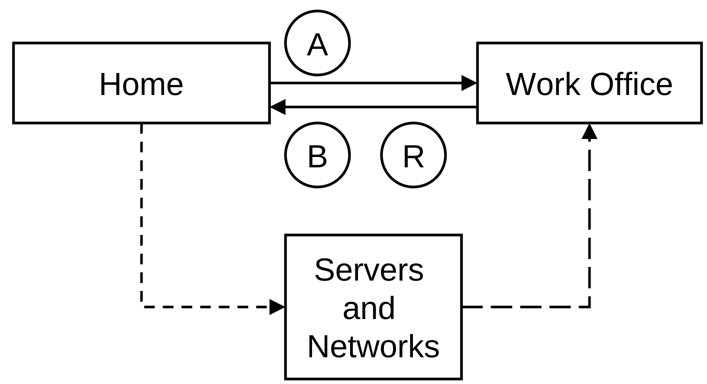
A = Automobile
B = Bus
R = Rail

—— Physical Goods Movement

- - - Electronic Information/Order

E-Commerce Mode

<100% Commuting



>0% Working From Home

The second area of focus was e-Commerce – the purchase of goods and transmission of information through the Internet.

- We considered three categories of e-Commerce:

E-Commerce Category	Description	Examples	Traditional Mode	E-Commerce Mode
Tangible Goods	• Business-to-Consumer (B2C) purchase of physical goods	• Consumer electronics • Housewares • Clothing • Books	Trip to Store	Courier Shipment
Electronic Goods	• B2C purchase/transfer of information-based goods that were previously purchased at traditional stores.	• Music • On-demand videos • Applications/forms (bank, taxes, insurance, DMV, etc.)	Trip to Store/ Location	Electronic Download
e - Materialization	• Replacing physical goods/information previously shipped to the home with electronic versions of the goods	• Personal letters • On-line billing/ payments • Bank statements • Magazines	Mail	e-mail or Website

Throughout this report, we calculate energy consumption using "joules", the International System (SI) unit of energy.

- Technically, a joule (J) is the force of one Newton applied over one meter [$1J = 1kg \times (m^2/s^2)$], or the amount of energy needed to power a 1 Watt light bulb for one second.
- Since a joule is a relatively small amount of energy, the prefixes kilo-, mega-, giga-, etc. are used to denote larger quantities of energy.
- A megajoule (MJ) is a common term used to describe quantities of energy. A MJ is equivalent to:
  - The total energy of 0.07 kWh* of delivered electricity (CMU 2007) – enough electricity to power one desktop PC and one 17-inch CRT Monitor in active mode for half an hour (TIAX 2007).
  - The total energy in about 17 sheets of paper (Nordman 1998, CMU 2007). Therefore, one ream (500 sheets) of paper contains about 30 MJ of embodied energy.
- Each year, an average Light Duty Vehicle (LDV) consumes about 70,000 MJ. If the energy to produce the gasoline and manufacture the car is also included, the value would be about 90,000 MJ (Hu and Reuscher 2004, Willams and Tagami 2003).
- Total U.S. energy consumption in 2006 was 107 EJ of primary energy (EIA 2006).

SI Prefixes		
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1×10^3	kilo-	k
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1×10^{15}	peta-	P
1×10^{18}	exa-	E

* This value different than the ratio for primary energy used by DOE's Energy Information Administration. The CMU values have been used for energy throughout this report.

Overall, the use of information technology equipment and the Internet provides opportunities to reduce energy consumption and the generation of greenhouse gases.

Savings per Activity:

Activity	Description	Energy Savings	Fuel Reduction	CO_2 Reduction
Telecommuting (TC)	Average savings from one day of telecommuting at current average TC trip length	220 – 320 MJ	1.4 gallons	17 – 23 kilograms
e-Commerce: Tangible Goods	The purchase of a product (e.g., book, computer) online instead of from a retail store	Generally Comparable*		
e-Commerce: Electronic Goods	Renting a movie using video-on-demand instead of renting from a video store (6 mile drive)	26 MJ	0.14 gallons	1.9 kilograms
e-Commerce: e-materialization	Substituting emailed/website information for information mailed to your home/office	0.05 MJ	Not assessed	0 kilograms

* The energy consumption and CO_2 generation associated with the traditional and e-commerce methods of purchasing tangible goods are generally comparable - differences are driven by the specific circumstances of the purchase.

These results do not account for the impact of potential “rebound effects”; e.g., increased consumption of goods as a result of lower e-Commerce prices or higher levels of other energy-consuming activities as a result of increased free time.

These energy savings can be converted to more accessible units, namely equivalent number of kWh and hours of average household electricity consumption.

Savings per Activity:

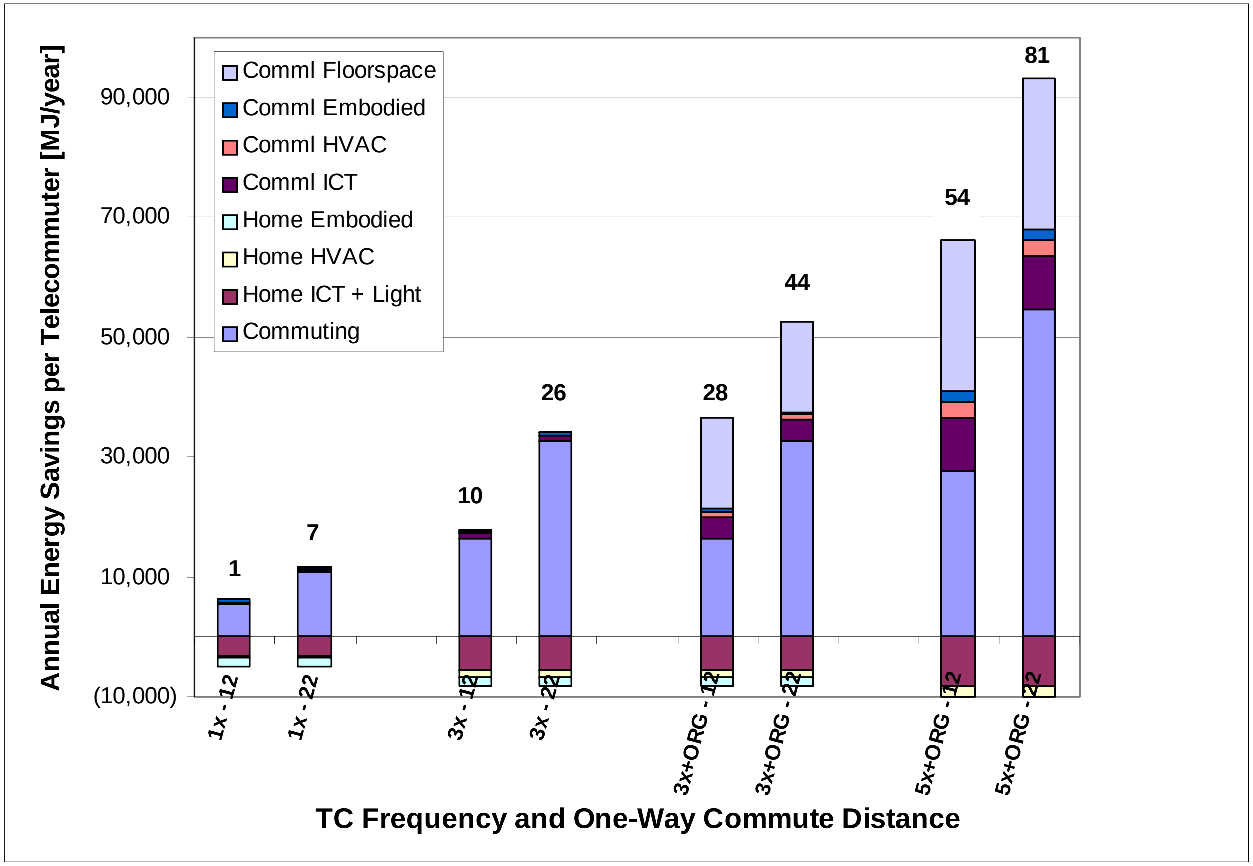
Activity	Description	Energy Savings	Energy Savings – Equivalencies	
			kWh of Electricity*	**Hours of Average Household Electricity Consumption***
Telecommuting (TC)	Average savings from one day of telecommuting at current average TC trip length	220 – 320 MJ	16 -23	12 - 17
e-Commerce: Tangible Goods	The purchase of a product (e.g., book, computer) online instead of from a retail store	Generally Comparable*		
e-Commerce: Electronic Goods	Renting a movie using video-on-demand instead of renting from a video store (6 mile round trip)	26 MJ	1.9	1.4
e-Commerce: e-materialization	Substituting emailed/website information for information mailed to your home/office	0.05 MJ	Small	Small

* Taking into account the energy used to: generate the electricity; transmit and distribute the electricity; extract resources used to generate electricity; and create the infrastructure to extract resources, generate electricity, and transmit and distribute electricity.

Sources: EIA (2006), CMU (2007)

Annually, a worker with a one-way commute of 22 miles can save up to 81,000 MJ of energy by telecommuting fives days a week. 81,000 MJ is equivalent to about 50% of the annual electricity consumption of an average household*.

Annual Energy Savings Per Telecommuter (MJ/year)



Key:

1x, 3x, 5x: The number of telecommutes per week
ORG: Assumes the employer reduces building floorspace
12, 22: One-way commuting distance

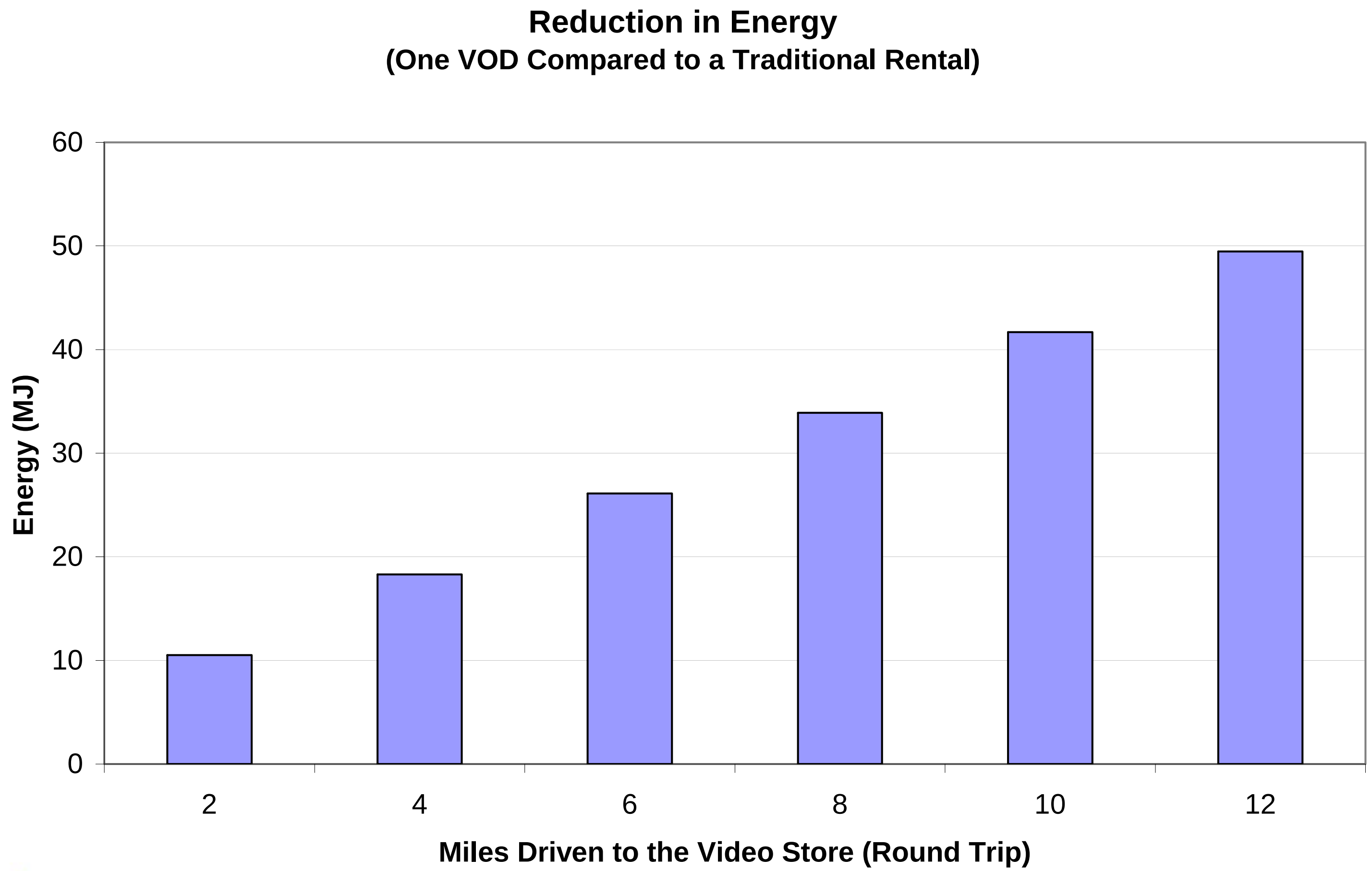
* Taking into account the energy used to: generate the electricity; transmit and distribute the electricity; extract resources used to generate electricity; and to create the infrastructure to extract resources, generate electricity, and transmit and distribute electricity.

Energy use associated with the purchase of tangible goods via e-commerce is, in general, comparable to the traditional retail method – the energy costs/benefits depend on the specific circumstances of the purchase

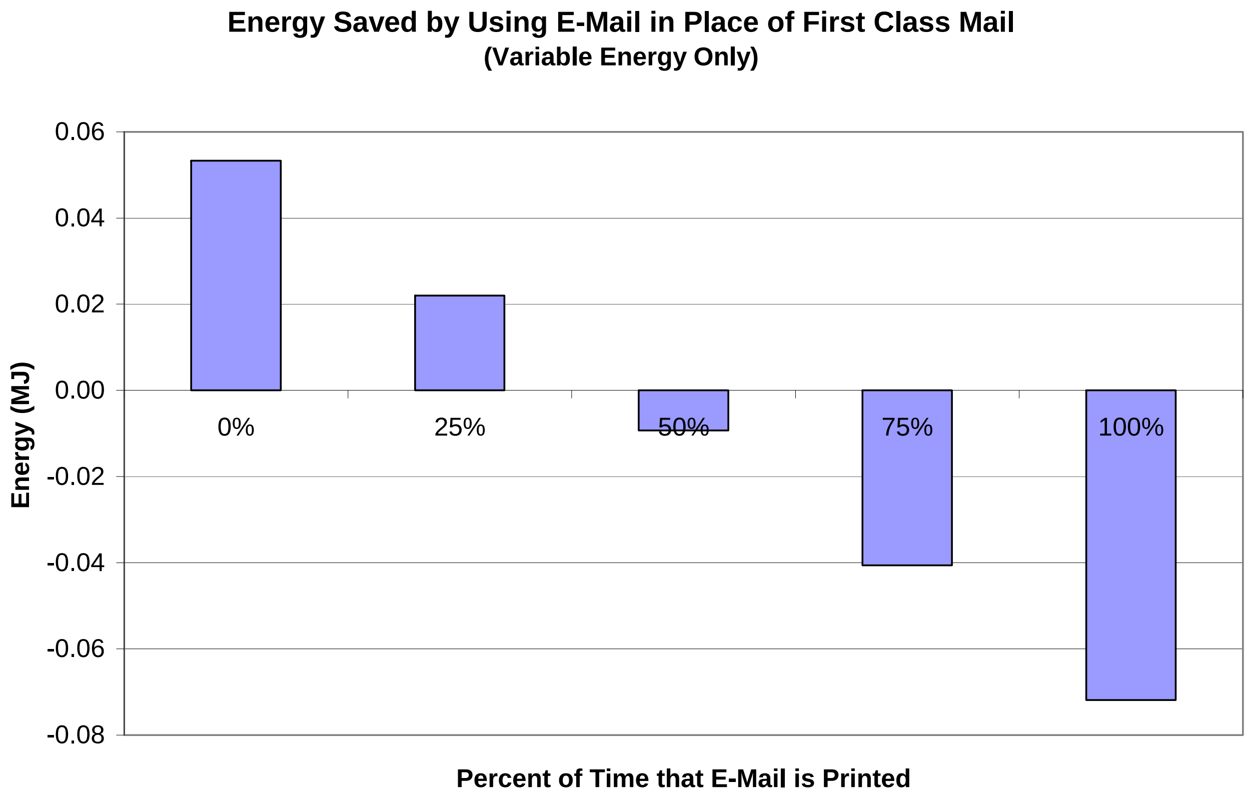
Factors that Affect Energy Consumption			
Factor	**Description**	**e-Commerce**	**Traditional**
Regional Factors (Population Density)	• In high density areas, the distance to stores is low and consumers use of mass transportation is high. • In low density areas, relatively efficient courier services take the place of long drives to a store.	• Favorable in low density areas	• Favorable in high density areas
Product Distribution Mode	• Energy is reduced when air transportation is avoided and loading factors (i.e., the percent of the vehicle capacity filled) are high.	• Air transport is energy intensive	• Rarely uses air transport
Packaging	• The less packaging lower the lower the energy consumption. Packaging used to move product from the manufacturer to the distributor is similar for the two methods, while packaging for consumer delivery is quite different.	• Consumer packaging tends to be greater than Traditional	• Consumer packaging tends to be less than e-Commerce
Supply Chain Management	• Inventory in regional distribution centers and retail stores requires floor space that must be built, maintained, lit, and heated/cooled. • For products like books, reducing the amount of unused product in the supply chain reduces the amount of product produced, the transportation required for product returns, and product disposal.	• Centralized distribution supports greater efficiency	• Decentralized distribution can lead to inefficiency

Downloading electronic goods instead of purchasing physical media in a retail store can provide measurable energy savings.

- For example, viewing a movie through video-on-demand (VOD) instead of driving to the rental store reduces energy consumption, especially if renting requires a long drive.



The use of e-mail in place of First Class Mail provides energy savings (even when the embodied energy of the Postal Service is excluded); however, printing emails can reduce or eliminate those savings.



- Including the embodied energy associated with the Postal Service into the analysis increases the savings, but these savings would be unlikely to be fully realized because many of the activities are fixed, i.e., they are performed even if First Class Mail declines.

In summary, ICT allows workers and consumers to participate in many daily activities, often with lower overall energy and fuel consumption and lower CO_2 generation - on an annual basis, significant national energy savings accrue.

Annual, National Savings:

Activity	Description	Energy Savings	Fuel Reduction	CO_2 Reduction
Telecommuting (TC)	Savings associated with current estimate of 3.9 million telecommuters	130,000 to 190,000 TJ	840 million gallons	10 to 14 million MT
e-Commerce: Electronic Goods	Potential savings if half of all current video/DVD rentals transitioned to Video on Demand (VOD)	33,000 TJ	180 million gallons	1.3 million MT
e-Commerce: e-materialization	Savings associated with the 3.5 billion unit decline in First Class Mail from 2000 to 2006, with no printing (variable activities only)	200 TJ	Not assessed*	(170) MT

MT = Metric Tons
* Postal Service fuel consumption was considered to be fixed in this scenario.

Note: National annual savings for the "e-Commerce: Tangible Goods" case were not assessed because potential savings depend on the specific circumstances of a particular purchase – the range of scenarios is too great to make a generalization.

The national energy savings can be expressed in terms of the annual electricity consumed by equivalent number of average household (HH) and the average annual energy associated with an equivalent number of light-duty vehicles.

Activity	Description	Annual National Energy Savings	Energy Savings – Equivalencies	
			Annual Electricity Consumed*	Annual Number of Light-Duty Vehicles**
Telecommuting (TC)	Savings associated with current estimate of 3.9 million telecommuters	130,000 to 190,000 TJ	0.8 to 1.2 million Households	1.5 – 2.1 million LDVs
e-Commerce: Electronic Goods	Potential savings if 1.25 billion video/DVD rentals, i.e., half of all rentals, transitioned to Video on Demand (VOD)	33,000 TJ	0.2 million Households	0.36 million LDVs
e-Commerce: e-materialization	Savings associated with the 3.5 billion unit decline in First Class Mail from 2000 to 2006, with no printing (variable activities only)	200 TJ	Small	Small

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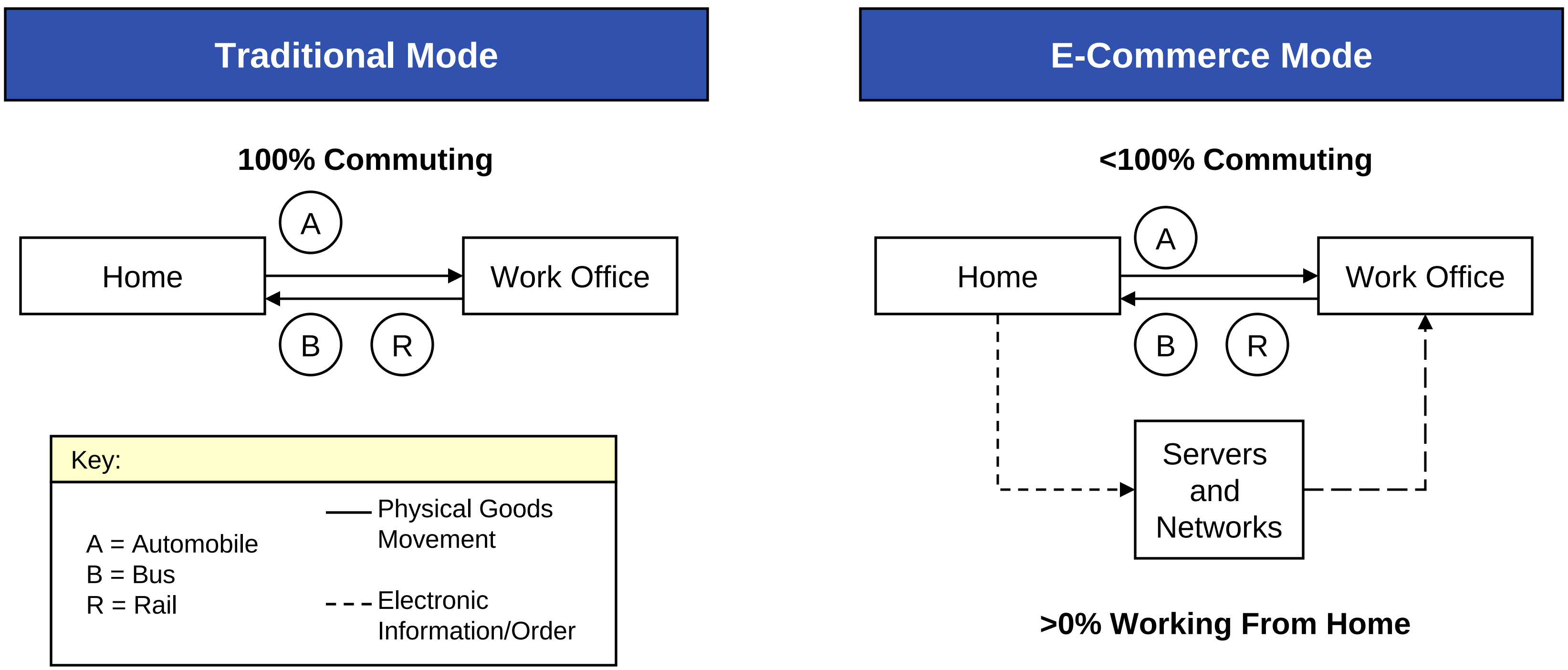

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Our study considered the life-cycle energy consumed as a result of telecommuting and conducting e-commerce, compared to traditional methods.

- Life Cycle Analysis (LCA) methodologies are structured to capture the energy consumption (both fixed and variable) associated with a product or process:
  - **Embodied Energy:** Embodied energy refers to the energy required to produce a product or piece of equipment, including the energy used to produce the production infrastructure (tracked back to the basic resource level). As part of the LCA calculation, that fixed amount of energy must be allocated over the uses of that product or equipment.
    - *For example:* The manufacture of a desktop computer and monitor requires about 7,320 MJ of energy. LCA methodology requires that this energy be accounted for during the use of the computer. Given that a computer is typically used for 3,000 hours each year and has a life of 4 years, about 0.6 MJ of energy is allocated to each hour of the computer's use.
  - **Variable Energy:** Variable (or usage) energy is the energy consumed while the product or equipment is operated.
    - *For example:* A desktop computer and monitor consume about 1.7 MJ of embodied electric energy during an hour in active mode.
  - **Total Energy:** Therefore, considering both the embodied and variable energy, one hour of desk top computer operation consumes about 2.3 MJ of energy.

Most CO_2 production typically results from the consumption of energy (with the amount of CO_2 varying by fuel type) and is accounted for in a similar manner.

The results of a Life Cycle Analysis (LCA) are largely dependent on the "boundaries" that are defined for the study.

- Study boundaries refer to the range of activities considered in a LCA. The boundaries can be limited to "direct energy" or could include all upstream activities.

Example of Study Boundaries: Light Duty Vehicles (LDVs) and Desktop Computers			
Activity	**Description**	**Vehicle (21 miles)**	**Computer + Monitor (1 hour)**
Direct (Site) Energy	The energy consumed at the point of use.	132 MJ	0.4 MJ
Energy Production and Transport/ Transmission	The energy consumed while producing the energy (e.g., crude oil extraction, coal mining, electricity generation) and transporting it (e.g., tanker truck, transmission lines, etc.) to the point of use.	20 MJ	1.2 MJ
Embodied Energy	The energy required to produce the device (i.e., the vehicle or computer) being used. This embodied energy must be allocated over the lifetime of the device.	19 MJ	0.7 MJ
Total Embodied Energy	**Sum of all life-cycle stages**	**170 MJ**	**2.3 MJ**

Note: Values do not sum due to rounding.

This study considers the *total embodied energy*, unless otherwise identified.

The results in this study do not account for the impact of potential “rebound effects” associated with the use of e-Commerce.

- The “rebound effect” refers to the potential for increased consumption of goods as a result of lower prices, or higher levels of other energy-consuming activities as a result of increased free time.
  - *For example*, by downloading a single song from the Internet instead of purchasing a complete CD from a retail store, a consumer may save $10 to $12. To address the “rebound effect”, one must consider the range of alternatives that are available to that consumer. He/she may save the money, download additional songs, spend the money at a traditional retail store, or participate in any number of alternative activities that have their own, additional, energy impacts.
  - Similarly, if a worker saves two hours of commuting time as a result of telecommuting, the work may work an additional two hours, go shopping at retail stores, or any number of alternative activities that, to varying degrees, impact energy consumption.
- The Internet also provides consumers with the opportunity to purchase items that they otherwise would have done without, potentially increase the demand for physical goods and the shipment of those goods to their home.
- That said, the Internet also enables consumers to purchase used items, supporting the reuse of products in place of buying new, potentially reducing for the production of new, energy consuming goods.

The consideration of these types of effects was beyond the scope of this study.

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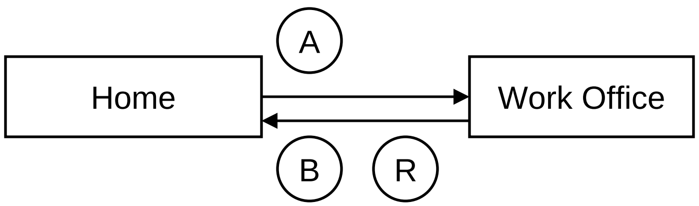
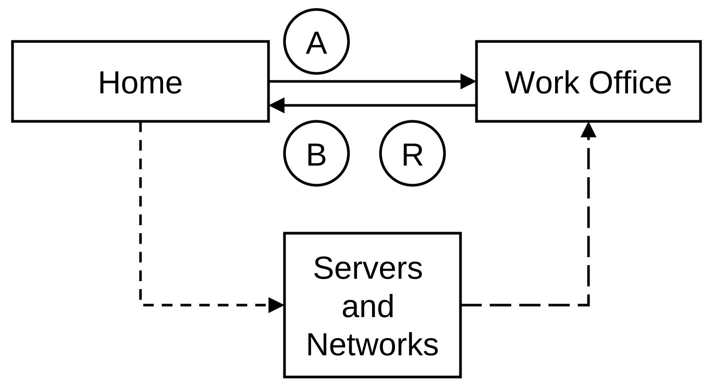


E-Commerce Mode

X% Commuting



Y% Working From Home

Key:

A = Automobile
B = Bus
R = Rail

—— Physical Goods Movement

- - - Electronic Information/Order

Telecommuting impacts energy consumption in several ways. We focused on telecommuters averaging at least one day per week at home because they have the most substantial energy impact.

Energy Impacts of Telecommuting

- **Ground Transport**: Work travel to and from work, including side trips; total energy includes embodied energy of fuel and light-duty vehicles (LDVs)
- **Home and Office ICT:** Operation of PCs, printers, network equipment
- **Office Building Embodied Energy:** Energy consumed to construct the building and to make building materials and construction equipment (including the infrastructure to manufacture materials and equipment)
- **Commercial Floorspace Reduction:** Change in incremental per-person commercial floorspace from organization-level telecommuting (e.g., due to hoteling*)
- **Home Energy Consumption:** Differences in lighting and HVAC energy consumption between telecommuting and non-telecommuting days.
- **PC and Peripheral Embodied Energy –** Included to the extent of marginal impact, i.e., increased or decreased use relative to traditional commuters

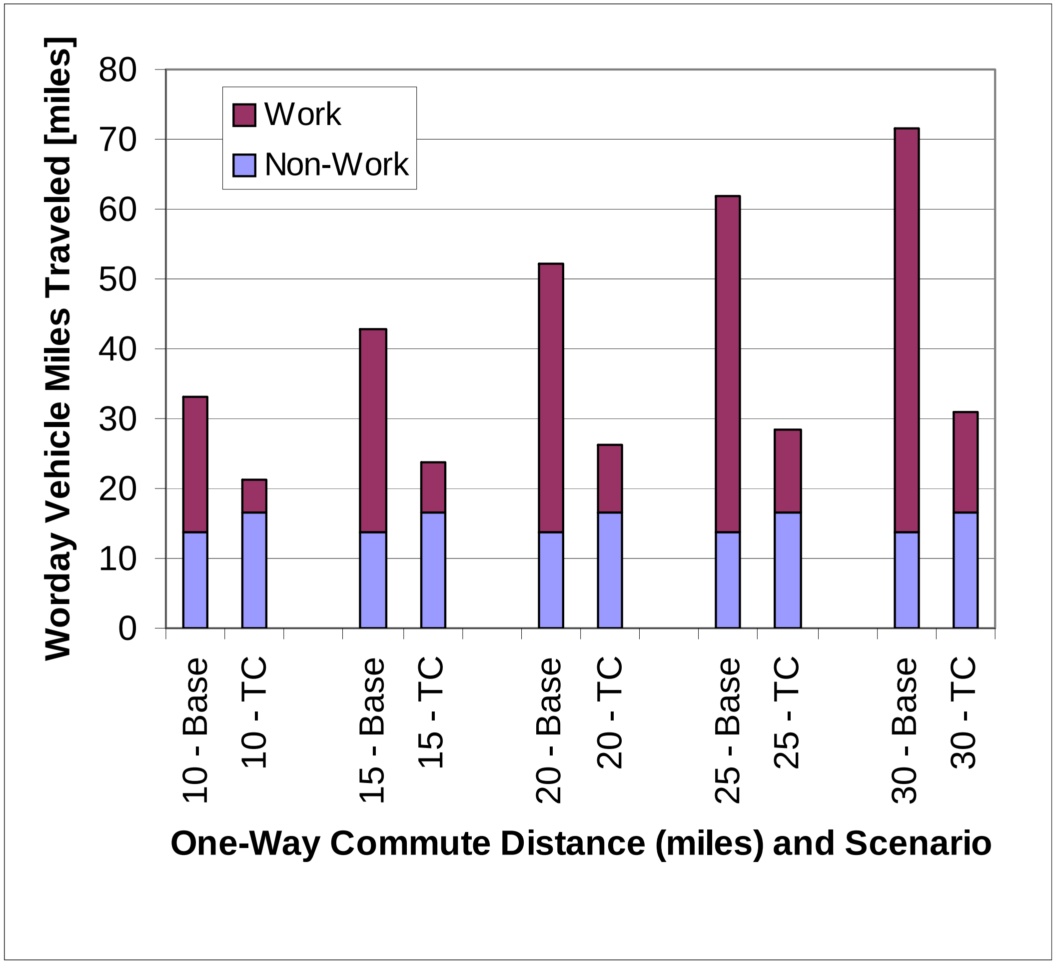
- *Excluded* **–**
  Paper Consumption – Assumed same quantity of paper consumption at home and work (printing, copying and facsimile energy consumption included)
  Home Embodied Energy – Telecommuters and traditional commuters both own homes primarily for non-working reasons, assumed to be the same size

***Hoteling: When an organization reduces the number of workstations in a building by assigning available, shared workstations to telecommuters and travelers on days they are in the office.**

Data from a limited number of prior telecommuting studies indicate that telecommuting (TC) decreases *total* vehicle miles traveled (VMT) by the telecommuter by more than 50 percent on telecommuting days.

- On average, current telecommuters have commutes to work that are almost twice as long as those of typical automobile-based commuters
  - *Telecommuters*: 18 to 22 miles one way (Walls and Nelson 2004, ITAC 1999, Walls and Safirova 2004)
  - *Automobile, Non-Telecommuters*: 12 miles one way (U.S. Census Bureau 2006, Hu and Reuscher 2004)
- A travel diary-based study (Henderson et al. 1996) of telecommuting found that, for telecommuters:
  - On TC days, work-related mileage decreases by about 75%
    - Average one-way commuting distance on TC days was 22 miles
    - About ¼ of telecommuters still made a trip to work
  - On TC days, the number of other trips increased by about 20 percent
    - Average distance per non-work trip of about 6 miles
      - 7 miles average distance for shopping trips in 2001 (Hu and Reuscher 2004)
  - Average *non*-telecommuter made about 2.4 non-work trips per day

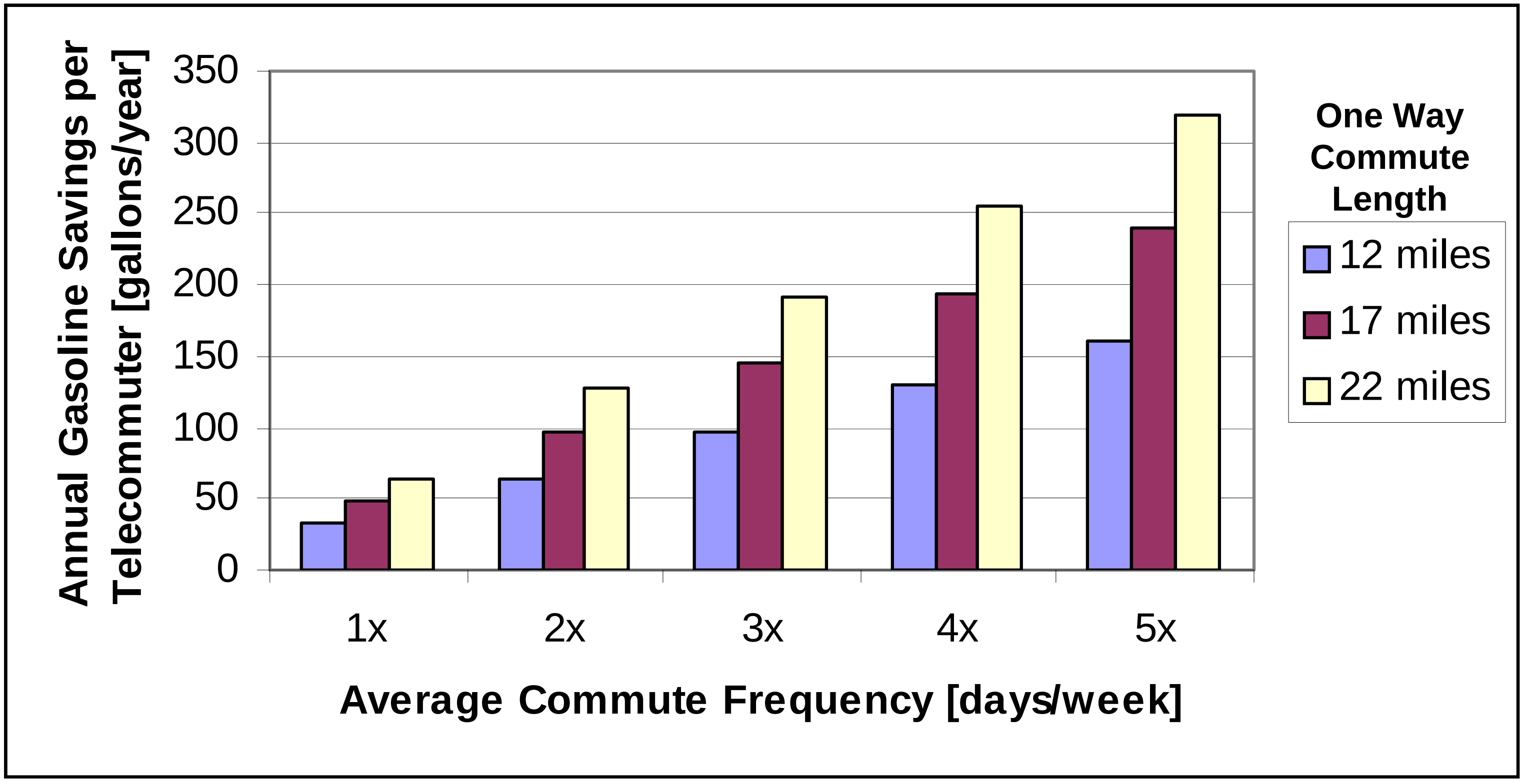
Telecommuting reduces vehicle miles traveled – and, hence, commuting energy consumption – by about 40% for an average commuter (i.e., 12 miles one way). The absolute (miles) and relative (percentage) savings of telecommuting (TC) increase as commute length increases.



Work: Travel to and from work

Non-Work: Additional non-work travel during the commute

On an annual basis, telecommuting can achieve substantial reductions in gasoline energy consumption.



We use several values consistently in our analysis of how telecommuting impacts transportation energy consumption.

Basic Parameters

- 231 workdays per year per employee (3 weeks vacation, 2 weeks holidays, 5 sick days)
- 115 million households in the U.S. in 2006 (EIA 2006)
- Average mileage of light-duty vehicles (LDVs) = 21 mpg (EPA 2006)
- Average gasoline energy = 132 MJ/gallon (ORNL 2007)
- Mileage embodied energy multiplier = 1.29 (Williams and Tagami 2003)
  - Accounts for embodied energy in fuel and light-duty vehicle
- Average CO_2 emissions of LDVs = 0.42 kg / mile (EPA 2006, EIA 2007b)
- LDV embodies CO_2 multiplier = 1.5 (Hendrickson et al. 2006)

Distances

- Average commute = 12 miles, one way (Hu and Reuscher 2004, U.S. Census Bureau 2006)
- Average telecommuter commute = 22 miles, one way (Safirova and Walls 2004)
- Average non-work trip = 6 miles, one way

Number of Trips

- Non-Telecommuting Day =1.92 trips to work, 2.41 non-work trips
- Telecommuting Day = 0.48 trips to work (75% decrease), 2.86 non-work trips (19% increase)

Telecommuting also affects commercial and residential building energy consumption, depending on the extent to which an organization embraces telecommuting. We created two cases to asses this: “Non-ORG” and “ORG.”

Base Case: “Non-ORG”

- Telecommuting is relatively uncommon in the organization where the telecommuter works.
- The organization does not reduce commercial building floorspace or building equipment (e.g., number of printers or copiers) in response to telecommuting.

“ORG” Case

- Telecommuting is embraced by the organization.
  - Hoteling – Employees share workspaces
- The organization realizes additional benefits from telecommuting:
  - For frequent (3+ days/week, average) telecommuters
    - Incremental commercial building floorspace per employee decreases in proportion to TC frequency, e.g., 3 day/week TC = 60% reduction in *incremental* floorspace / employee
      - Building energy consumption savings
      - Building embodied energy savings
    - Commercial printer, copier, and facsimile energy consumption per employee decreases in proportion to TC frequency
      - Ready mode, not printing, accounts for most energy consumption (ADL 2002)

We used several consistent assumptions for our buildings analysis.

General

- 1 kWh = 13.8 MJ of embodied energy (CMU 2007, Hendrickson et al. 2006, EIA)
- 231 workdays per year per employee (3 weeks vacation, 2 weeks holidays, 5 sick days)
- 50% of telecommuters have desktop PCs (one at home and at work) and 50% a notebook PC shared between work and home
  - Estimated split for entire population: 70% desktop, 30% notebook (TIAX 2007)
  - Actual split not known for telecommuters as a function of telecommuting (TC) frequency
- Assumed same paper usage on TC and non-TC days
- Embodied Energy Values:
  - PC (desktop + CRT monitor) = 7,300 MJ (Williams 2004)
    - Averaged over annual average residential usage estimates from TIAX (2006), four-year average product lifetime (Appliance 2006)
      - Desktop = 2,954 hours/year, Notebook = 2,368 hours/year
  - Neglected other products, overall embodied energy appreciably smaller
    - Multi-Function Device ~1,350 MJ/unit, shared with home (TIAX Estimate based on CMU 2007)

Residences

- The size of telecommuters' homes is the same as non-telecommuters

Commercial Buildings

- Most telecommuters would work in an office, i.e., TC displaces office space

Telecommuting (TC) impacts commercial information and communications technology (ICT) energy consumption.

Commercial – ICT Energy

- Usage based on 9-hour workday and daytime usage profiles (percentages) from Kawamoto et al. (2001), with night-status profiles (used also for weekends and vacation) from Roberson et al. (2004)
- PC and Monitor power draw by mode values from TIAX (2007)
- Eliminates copying, printing, and facsimile energy consumption on TC days for organizational TC only
  - Approximately 1.4 kWh / person-day (for office workers; ADL 2002, EIA 1998)
  - Assumes that office building portion of printer, copier, and facsimile energy consumption equal to portion of PCs found in office buildings (based on 1995 CBECS data; EIA 1998)

Telecommuting (TC) also affects residential ICT energy consumption, as well as residential lighting energy.

Residential – IT Energy

- Usage based on 9-hour workday and daytime usage profiles (percentages) from Kawamoto et al. (2001), with night-status and weekend profiles from TIAX (2006)
- All people who TC one or more days per week were assumed to have a shared use (i.e., for work and home use) multi-function device at home that was in "ready" mode 9 hours each TC day
  - All other MFD energy consumption assigned to non-TC home energy consumption
- All telecommuters assumed to have broadband connectivity versus ~36% of the rest of the population (based on estimate that 3.4% of households have at least one person who telecommutes 1+ day/week; EIA 2001)
  - 64% (=100%-36%) of all cable/DSL modem energy assigned to telecommuting
- Device power draw by mode values from TIAX (2007)

Residential – Lighting Energy

Assume additional operation of two 75W lamps for duration of work day (9 hours)

- *This activity is not well understood* (note: current estimate about twice that of Kitou and Horvath 2003)

The "ORG" Case assumes reductions in commercial building floorspace, eliminating the energy that would be directly consumed in that space and the embodied energy of the space.

- **Actual Floorspace Reductions Are Not Well Understood**
  - One person requires about 100ft^2 of incremental floorspace (Kitou and Horvath 2003, TIAX Estimate; average floorspace per person in office buildings ~200ft^2 [Chapman 2003])
  - Floorspace reductions are assumed only to accrue in the "ORG" case for frequent (3+ times/week) telecommuters (similar to Matthews and Williams 2005)
  - The reduction in incremental floorspace is assumed to be proportional to TC frequency
- **Energy Savings – Building Energy Usage**
  - Average office building in 2006 consumed about 240MJ/ft^2/year of energy (embodied), excluding IT energy consumption (EIA 2007a)
  - Energy consumption of ICT equipment was described earlier
- **Energy Savings – Building Embodied Energy: About 10 Times Less than Building Energy Usage Savings**
  - Estimate potential savings based on ~770 MJ/ft^2/ based on:
    - Embodied energy = 7.7TJ/$MM for Commercial & Institutional Bldg. Construction (CMU 2007)
    - $150/ft2 for early 2007, deflated to $1997 using Turner Construction Cost Index (2007)
    - Divided by estimated 50-year building lifetime

Changes in residential and office ICT and lighting energy consumption alter indoor thermal loads and, thus, HVAC energy consumption. Telecommuting eliminates temperature set-up and set-back when people work at home.

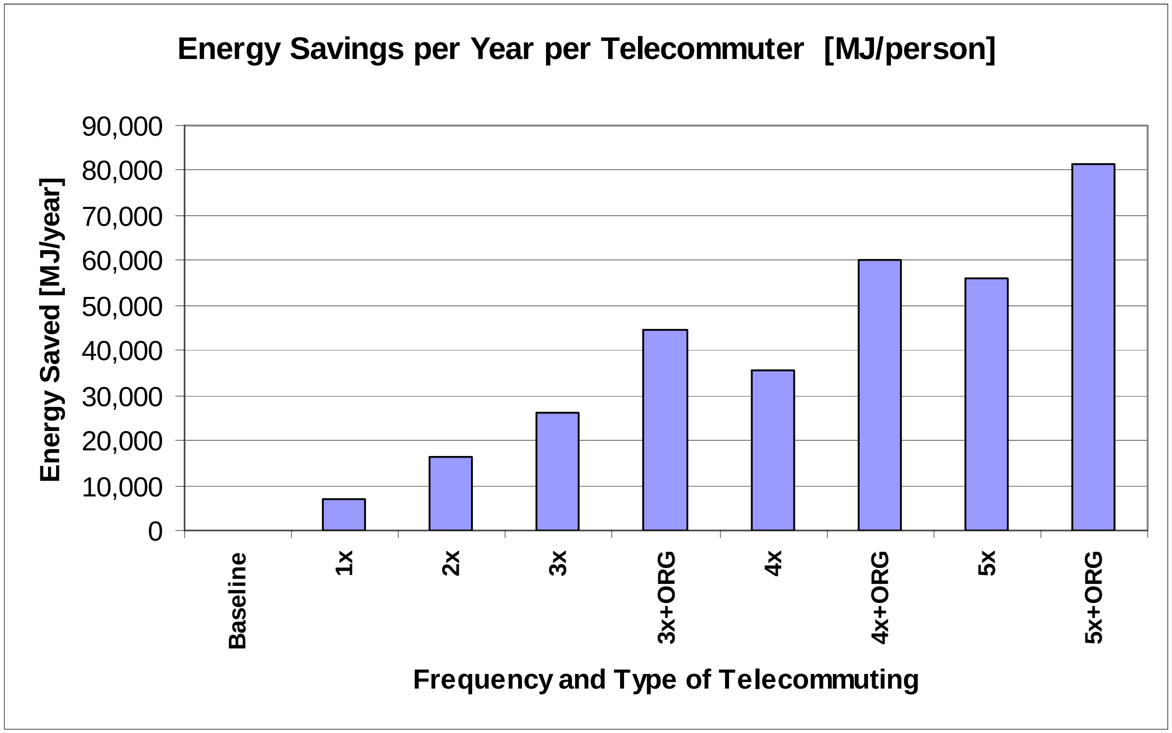
IT and Lighting Energy

- Increase in lighting and ICT energy consumption reduces heating loads while increasing cooling loads
  - *Home*: Net Impact is a decrease in embodied energy equal to approximately 20% of decrease in site energy consumption (TIAX Calculations, EIA 2006, CMU 2007)
    - Assumed average 4-month cooling season and 5-month heating season
  - *Office*: Net Impact is a decrease in embodied energy consumption equal to approximately 30% of decrease in site energy consumption (TIAX Calculations, Sezgen and Koomey 1998, EIA 2006, CMU 2007)

Temperature Set-Up and Set-Back

- Eliminates temperature setback on days when someone works from home
  - ~45% of homes set back temperature during workday when not at home (similar percentage for telecommuters; EIA 2001)
  - Temperature setback and set-up realize average savings of approximately 7.6% and 8.7%, respectively (EnergyStar 2006)
    - Assumed average 4-month cooling season and 5-month heating season
  - Net Impact: Increase of about 9 MJ/TC day per household

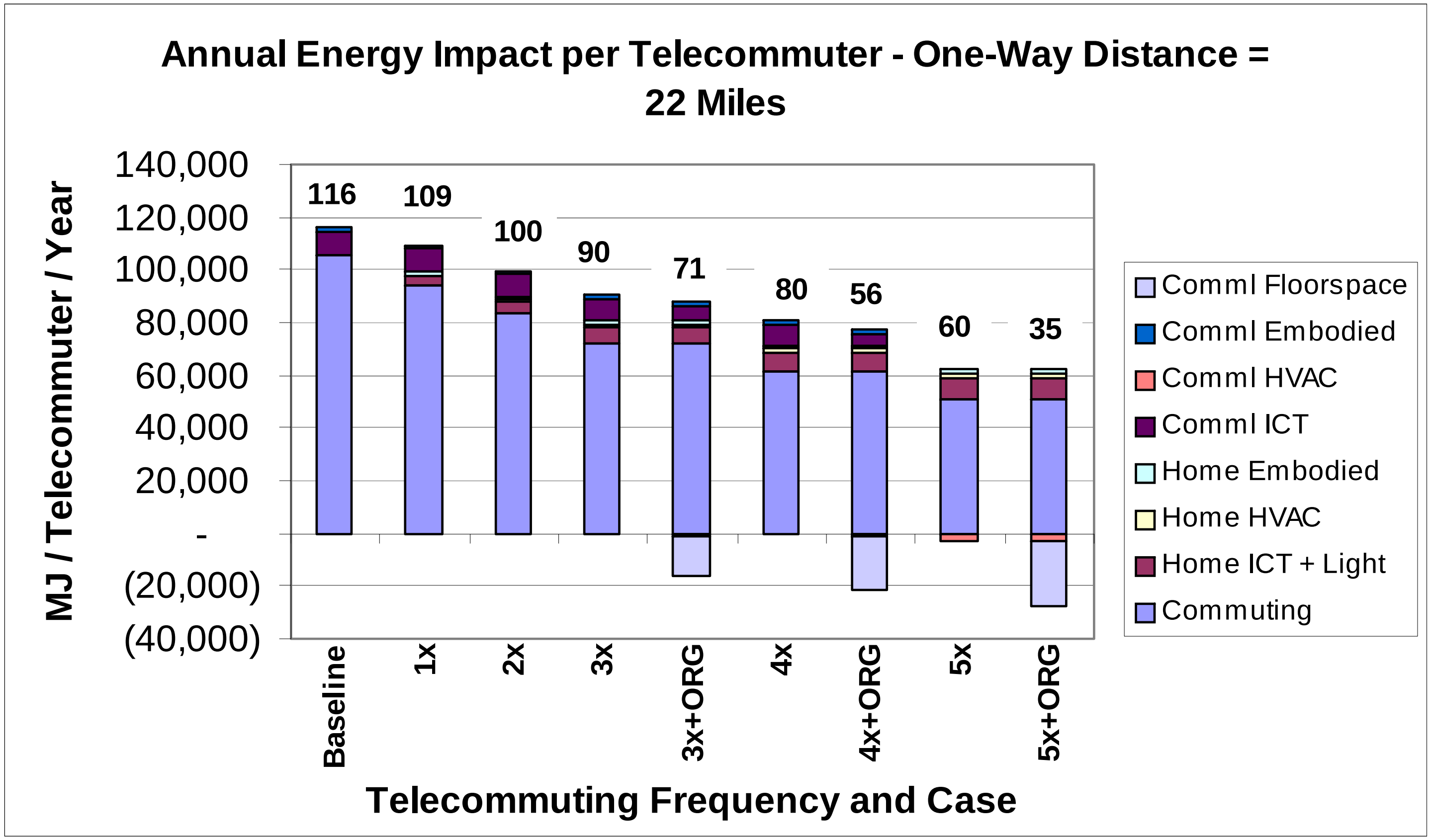
Telecommuting energy savings increase dramatically with telecommuting (TC) frequency and when it reaches a scale sufficient for organizations to reduce office floorspace (the "ORG" case).



1,000MJ is equivalent to the electricity (embodied energy) consumed by an average U.S. household for about 54 hours, while 81,000MJ is equivalent to about 50% of the annual electricity consumption of an average U.S. household*.

* Taking into account the energy used to: generate the electricity; extract resources used to generate electricity; transmit and distribute the electricity; and to create the infrastructure to extract resources, generate electricity, and transmit and distribute electricity.

The net energy impact of telecommuting in all cases is positive and is dominated by transportation impacts. When possible, reductions in commercial floorspace contribute appreciable, additional savings.



***Net values shown.**

Estimates of the number of people that telecommute vary by about an order of magnitude. This reflects different definitions of telecommuting.

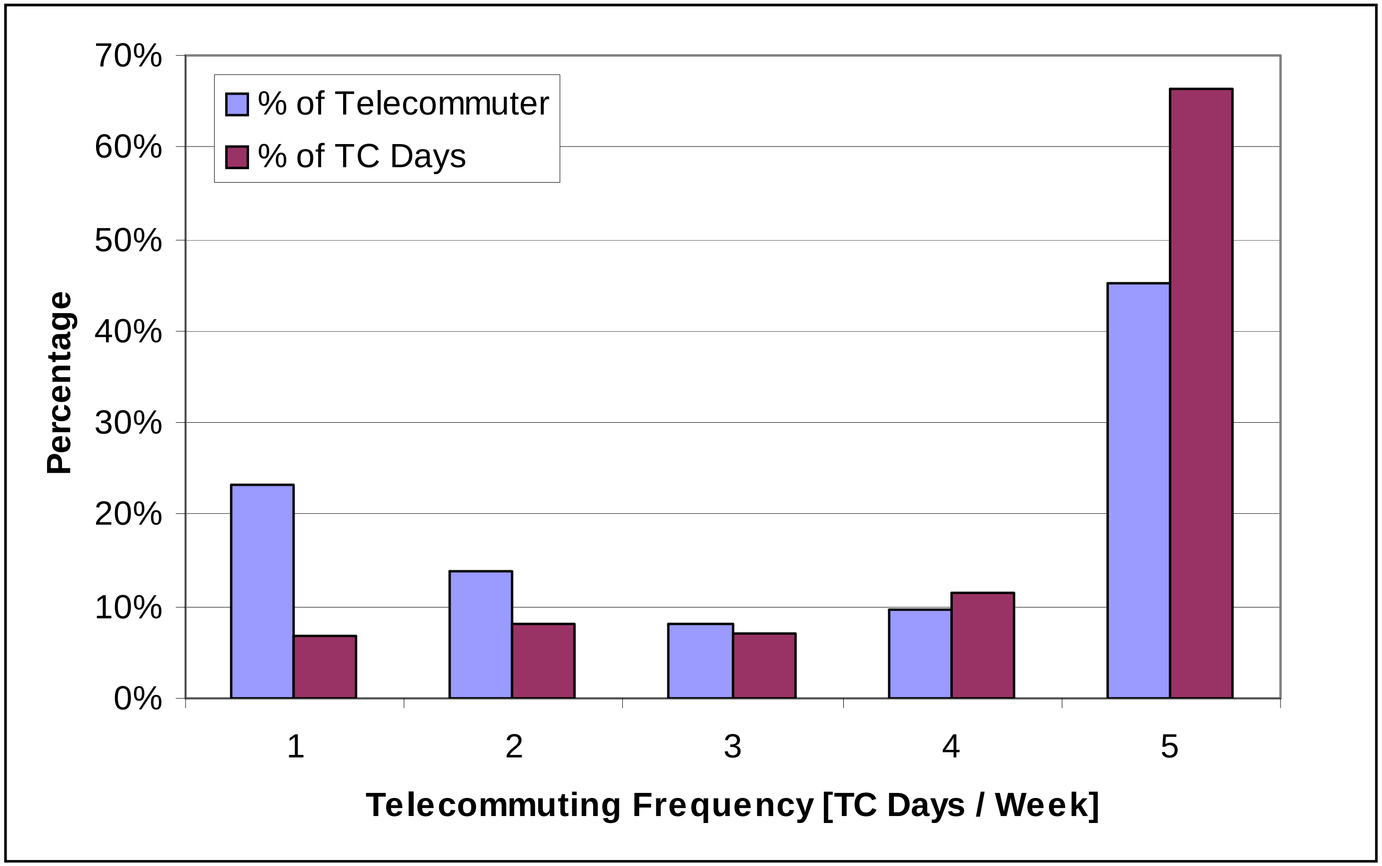
Survey	Year	Millions of Workers	Definition of Telecommuting
U.S. Census	2000	~4	Worked from home most of previous week, includes salaried and self-employed (Mokhtarian et al. 2004)
Current Population Survey	2001	3.4	Wage and salary workers, doing some paid work at home for main job (Mokhtarian et al. 2004)
Cyber Dialogue	2000	16.3	At least once/month; 7.4M full time workers, 4.3M part-time works, 4.0M contract workers (Mokhtarian et al. 2004)
American Community Survey	2005	4.8	Answered “Worked at home” in response to “How did this person usually get to work last week?” (ACS 2006)
RECS (EIA 2001)	2001	3.6	Households responding “Yes” to “Does anyone work on your computer at home instead of traveling to their employer’s place of business?”
American Interactive Consumer Survey	2004	44.4	"employed Americans who performed any kind of work from home, with a frequency range from as little as 1 day a year to full time" (Telework Coalition 2007)
WorldatWork	2006	12.4	"Regular employee who works remotely at least one day per month during normal business hours“ (WorldatWork 2007)
		16.2	"Self-employed individual who works remotely at least one day per month during normal business hours“(WorldatWork 2007)
IDC	2005	9.1	“worked from home three or more days each month during regular business hours,“ 2.2MM exclusively from home (Korzeniowski 2005)

For the purpose of quantifying the national energy impact of telecommuting, we have focused on data about workers who realize significant incremental savings from telecommuting.

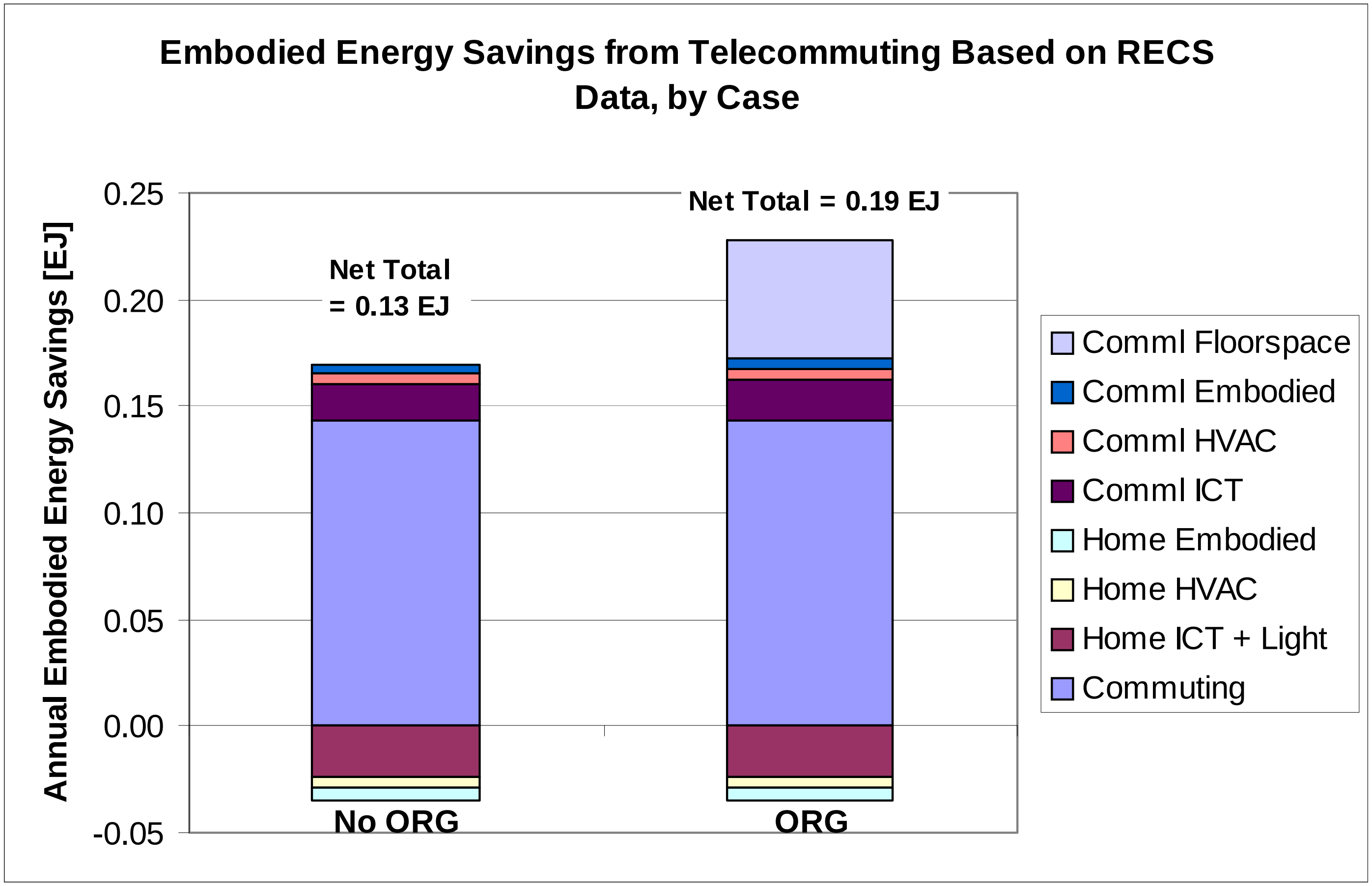
- Excluded home-based businesses because telecommuting likely does not result in appreciable *incremental* savings for them (i.e., they usually work from home)
  - Always been an appreciable population of self-employed work-from-home workers
- Were wary of studies that quantified number of people who do work at home
  - Many people commute to work *and* do some work at home
- Focused on frequent telecommuters, i.e., at least once a week
  - Studies citing number of telecommuters who work from home at least once per month (or year) have limited value.
- *Example*: 2005 American Housing Survey (U.S. Census 2006)
  - 25 million worked at home (during the week prior to the survey); ~47% worked 1-9 hours
  - 13 million worked at home for a wage and salary job; ~45% worked *0* days

Based on RECS, IDC, and the American Housing Survey results, it appears that about 4 to 6 million workers telecommute at least once a week.

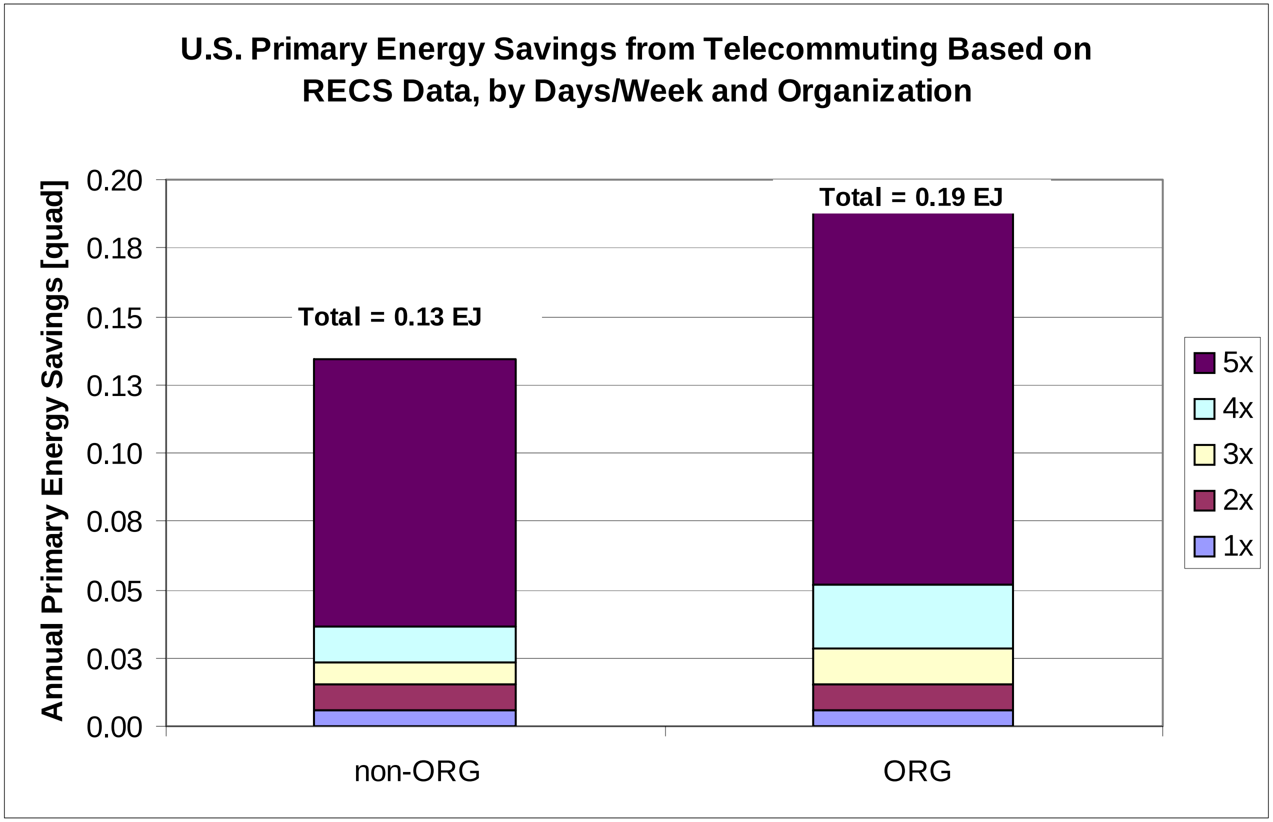
EIA's Residential Energy Consumption Survey (RECS) in 2001 estimated that about 3.4% of households had at least one telecommuter, or about 3.9 million households in 2006. Frequent telecommuters accounted for a majority of telecommuting (TC) days.



Transportation savings accounts for most of the energy saved in the base case, with commercial floorspace reduction making a substantial contribution if most telecommuter work for organizations that have adopted telecommuting (the "ORG" case).



Considering the “No ORG” and “ORG” cases combined with the 2001 RECS telecommuting frequency and prevalence data, telecommuting reduced embodied energy consumption in 2006 by approximately 0.13 to 0.19 Exajoules (10^{18}), or about 0.1 to 0.2% of U.S. primary energy consumption.



People who telecommute five days a week contribute a large majority (around 70%) of the total energy savings.

To put this in perspective, 0.13 and 0.19 Exajoules of embodied energy are approximately equivalent to:

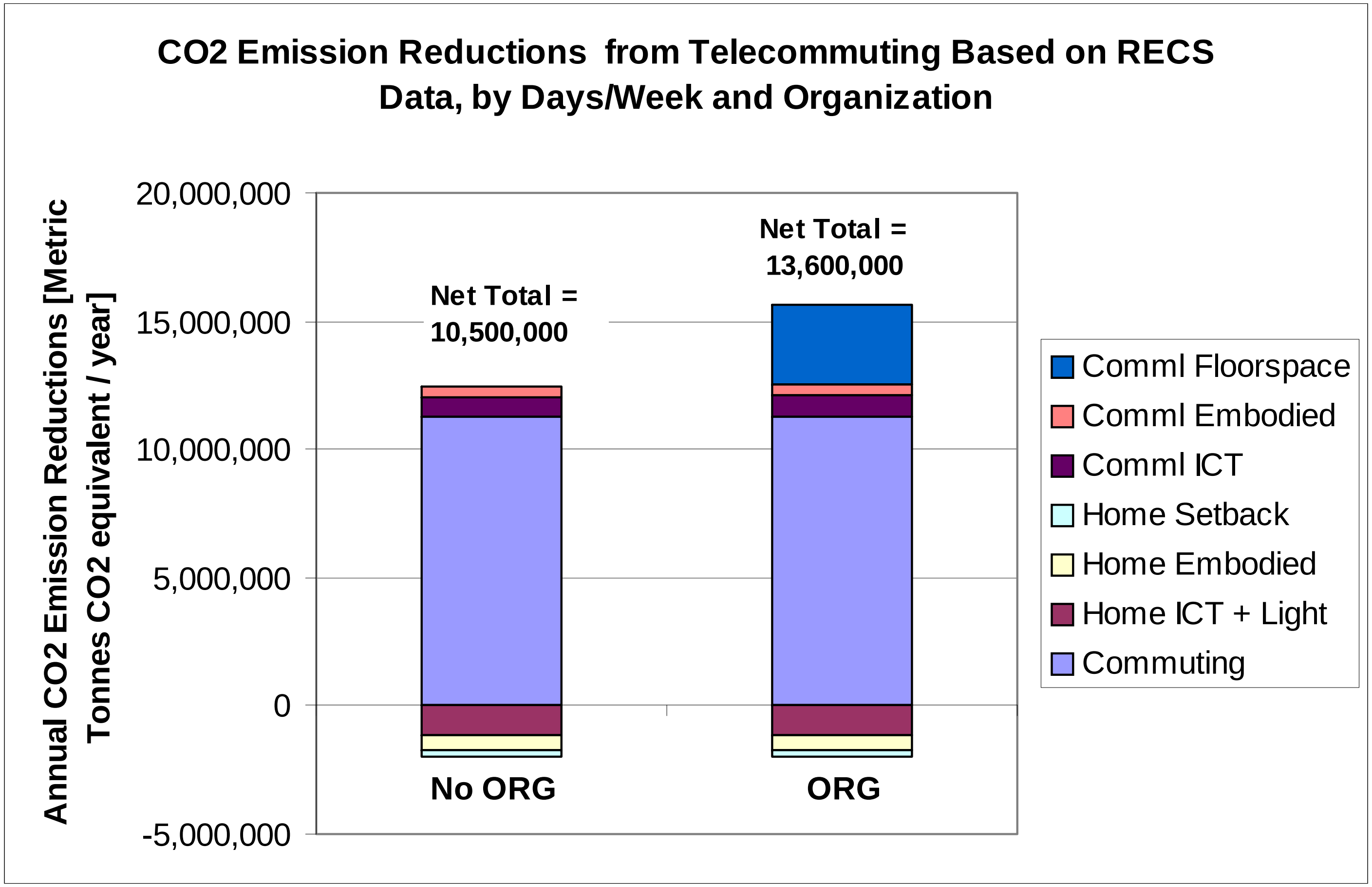
- 0.13 EJ:
  - Annual electricity* consumed by 0.8 million average households
  - Annual energy** associated with 1.5 million light-duty vehicles
- 0.19 EJ:
  - Annual electricity* consumed by 1.2 million average households
  - Annual energy** associated with 2.1 million light-duty vehicles

* Taking into account the energy used to: generate the electricity; transmit and distribute the electricity; extract resources used to generate electricity; and create the infrastructure to extract resources, generate electricity, and transmit and distribute electricity.

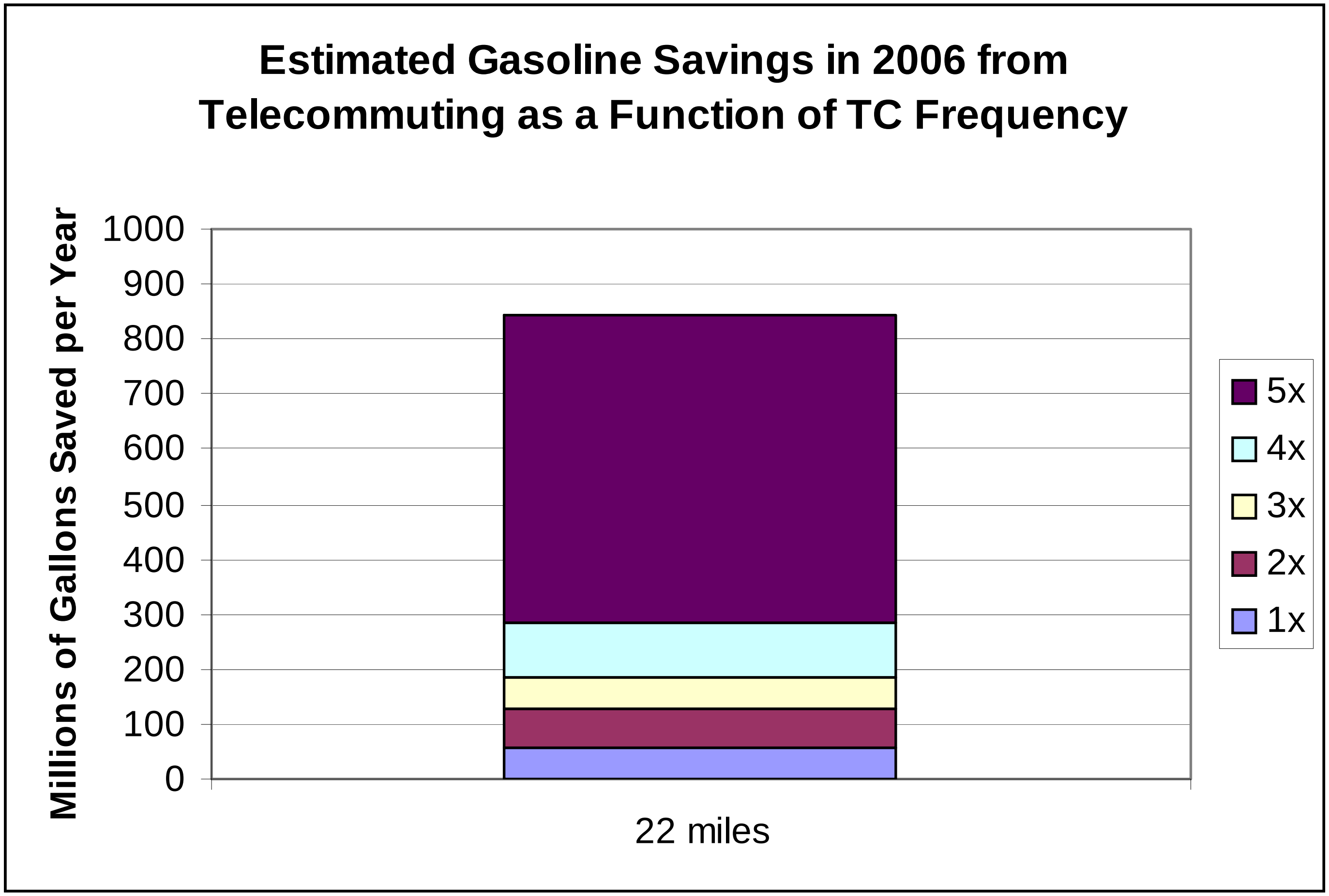
** Taking into account the energy directly consumed by the LDVs and the energy used to: produce the fuel; distribute the fuel; extract the resources used to produce the fuel; and to create the infrastructure to extract the resources, produce the fuel, and to transport the fuel.

Sources: Hu and Reuscher (2004), EIA (2006), CMU (2007). TIAX Estimates

Considering the "No ORG" and "ORG" cases and the 2001 RECS data for telecommuting frequency and prevalence, telecommuting reduced CO_2 emissions by an amount equal to approximately 0.2% to 0.25% of U.S. CO_2 emissions.



On an annual basis, telecommuting reduced national gasoline consumption by approximately 840 million gallons, or about 0.8% of U.S. LDV gasoline consumption.



Source: TIAX Calculations, Hu and Reuscher (2004), EPA (2006)

Some sources suggest that information and communication technologies (ICT) have supported a long-term growth in telecommuting since the 1980s. Drivers for further growth in telecommuting (TC) include:

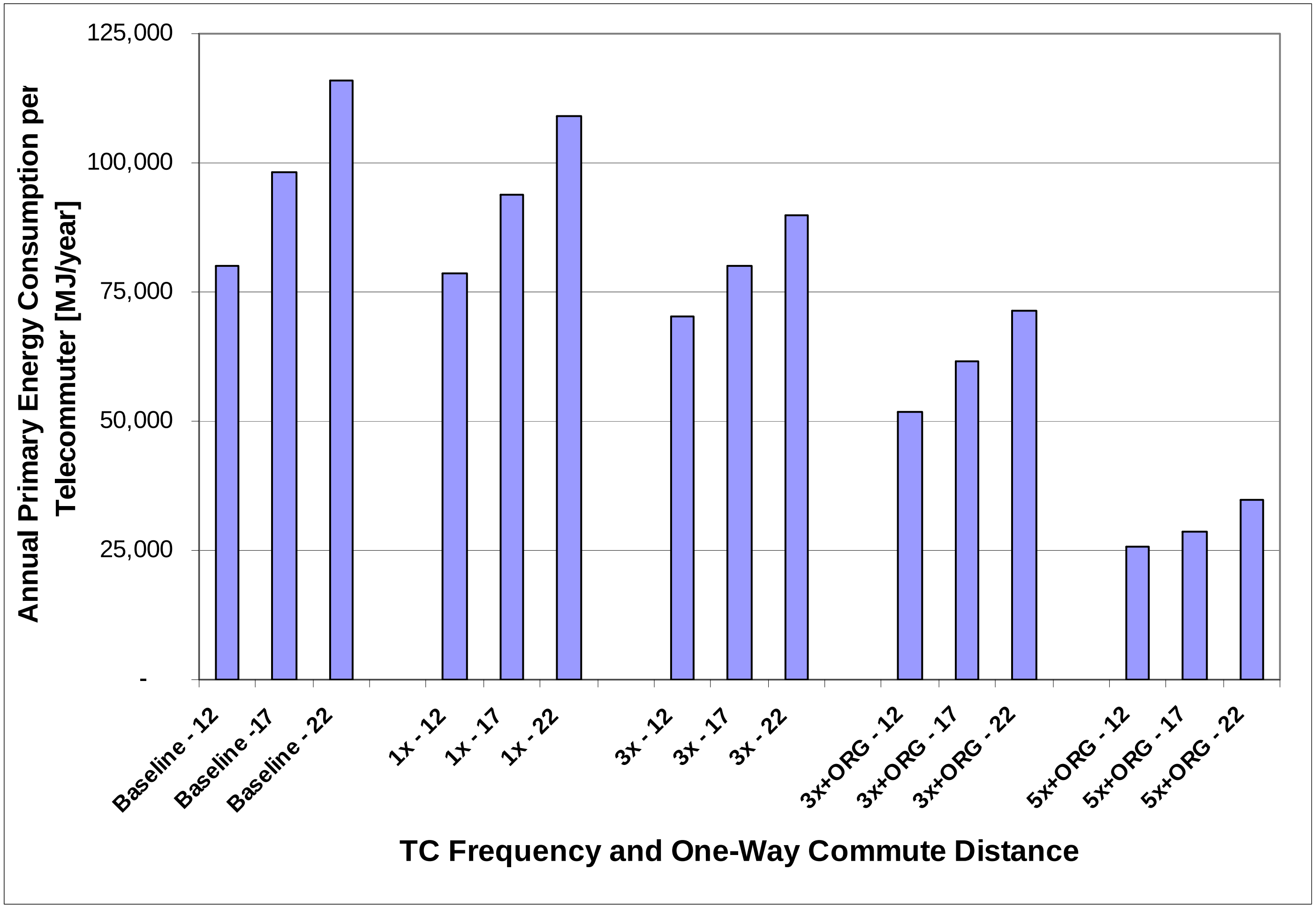
- Increased power, availability, and ease of use of ICT
  - More than 70% of U.S. households have a PC with internet access in 2006
  - Broadband penetration ~40% of U.S. households in 2006
- Benefits of TC for Workers
  - Time savings
  - Workday flexibility
  - Reduced travel stress
  - Geographic flexibility
- Benefits for Companies
  - Help retain and recruit employees
  - Potential reductions in real estate and building operating costs
- Relevant Demographic Trends
  - Dual-career households
  - Aging population
  - Globalization

Source: Mokhtarian et al. (2004), TIAX (2007)

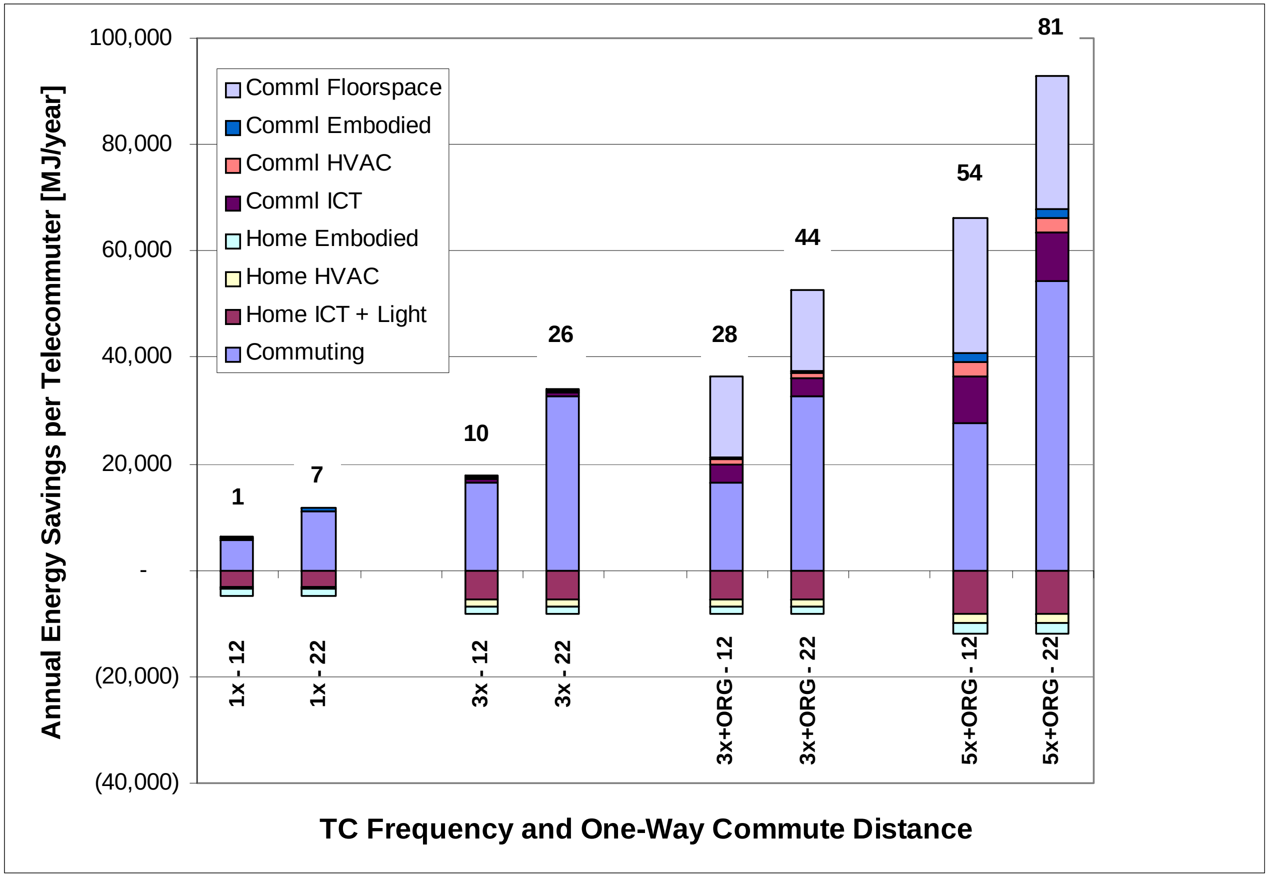
Telecommuting could become much more pervasive and lead to further energy savings.

- Matthews and Williams (2005) estimated that information workers that could have the potential to telecommute represent approximately 40 percent of the U.S. Workforce, i.e., about 53 million workers circa 2002.
  - Focused on jobs with the following characteristics
    - Primarily individual work
    - Clear parameters for evaluation (of performance)
    - Do not require ongoing personal contact with customers
    - Does not require on-site physical work
  - Included the following job categories
    - Professional Specialties
    - Technical Support
    - Administrative Support
    - Some sales positions
  - Matthews and Williams (2005) cite an estimate from Mokhtarian (2004) that approximately 50 percent of information workers could telecommute
    - Suggests around 20 percent of U.S. workforce could telecommute

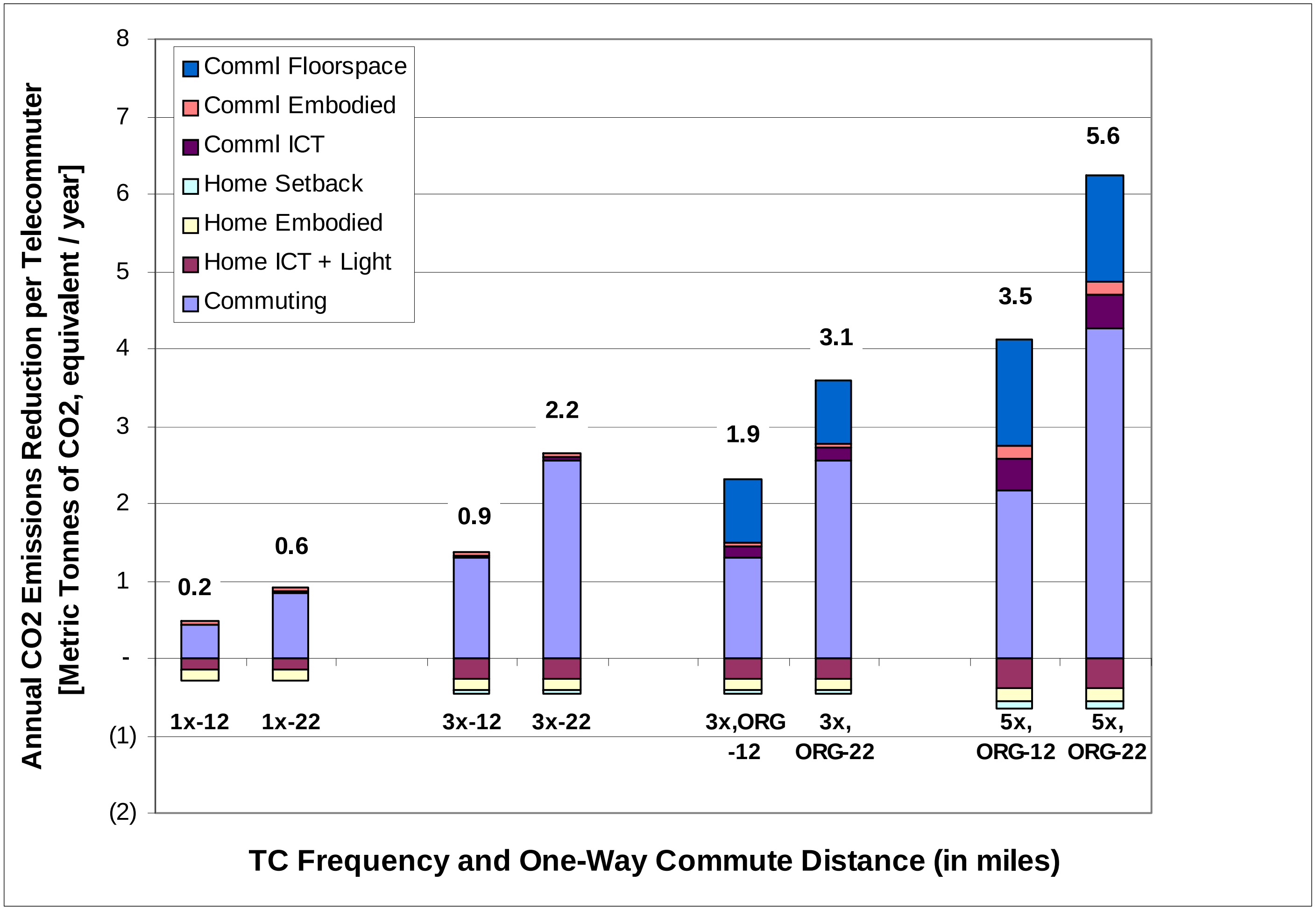
Because current telecommuters drive longer distance than the average commuter, future widespread adoption of telecommuting (TC) would have a smaller incremental impact on energy savings.



The elimination of commercial building floorspace becomes a larger portion of energy savings as the average commuting distance decreases.



Similarly, elimination of commercial floorspace (the "ORG" case) accounts for an increasingly larger portion of potential CO_2 reductions as commute distance decreases.



Telecommuting may have additional energy and environmental benefits that are not accounted for in our models.

- Reduced fuel consumption by reducing traffic congestion (from removing cars from road)
  - Increases efficiency of trips and, likely, gasoline consumption
    - This could be partially offset by rebound from reduced traffic, i.e., decrease in traffic induces more people to drive
- Reduced number of cold starts per day also reduces emissions sensitive to cold starts (Henderson et al. 1998)
  - Total Organic Gases (TOG)
  - CO
  - NO_x

Our study does not consider several other potential factors that could alter the energy impact of telecommuting (1 of 2).

- **Changes in Non-Commuting Travel on Weekends**
  - Home-based workers – which includes a substantial population of people who are NOT telecommuters – spend more time shopping out of the home than traditional workers (Mokhtarian 2004, from Gould and Golob 1997)
    - May be due to desire for social interaction: "it is likely that a number of shopping trips are 'invented' in order to 'justify' (often subconsciously) an urge simply to get out and go *somewhere*." (Mokhtarian 2004)
  - Telecommuters appear to make somewhat more (~20%) non-commuting trips on workdays than commuters (considered in the analysis)
    - This might decrease non-commuting trips on non-workdays

Our study does not consider several other potential factors that could alter the energy impact of telecommuting (2 of 2).

- **Availability of Telecommuting Inducing Longer Commutes**
  - A study of State of California Employees who telecommuted led Ory and Mokhtarian (2005) to conclude that the evidence did not indicate that the availability of telecommuting induced workers to live further from work (which would increase VMT)
- **Home Size**
  - We assumed that telecommuting did not impact home size. If telecommuters purchase larger homes, e.g., to accommodate a home office or because they could afford a larger house further from their workplace, this would increase residential energy consumption
- **Rebound Effects**
  - Energy cost savings used to purchase additional travel or goods
- **Internet Infrastructure Energy Consumption**
  - Assumed to be equal for traditional and telecommuters

Executive Summary

Study Objectives and Scope

Telecommuting

e-Commerce

Introduction

Tangible Goods

Electronic Goods

e-Materialization

Retail e-Commerce includes a variety of product purchases that we have categorized into three groups based on their distribution mode.

E-Commerce Category	Description	Examples	Traditional Mode	E-Commerce Mode
Tangible Goods	• Business to Consumer (B2C) purchase of physical goods • Order placed on-line • Goods shipped by air and/or ground transportation	• Consumer electronics • Housewares • Clothing • Books • Videos (purchase or rent [e.g., Netflix])	Trip to Store	Courier Shipment
Electronic Goods	• B2C purchase/transfer of information-based goods that were previously purchased at traditional stores. • Order on-line • Download goods to computer or similar device	• Music • On-demand videos • On-line educational courses • Applications/forms (bank, taxes, insurance, DMV, etc.)	Trip to Store/ Location	Electronic Download
e - Materialization	• Replacing physical goods/ information, previously shipped to the home, with electronic versions of the goods • Provider produces goods and either emails them to the customer or makes them available on their website.	• On-line billing/ payments • Bank statements • Newspapers/ magazines • Home buying information	Mail	e-mail or Website

Executive Summary

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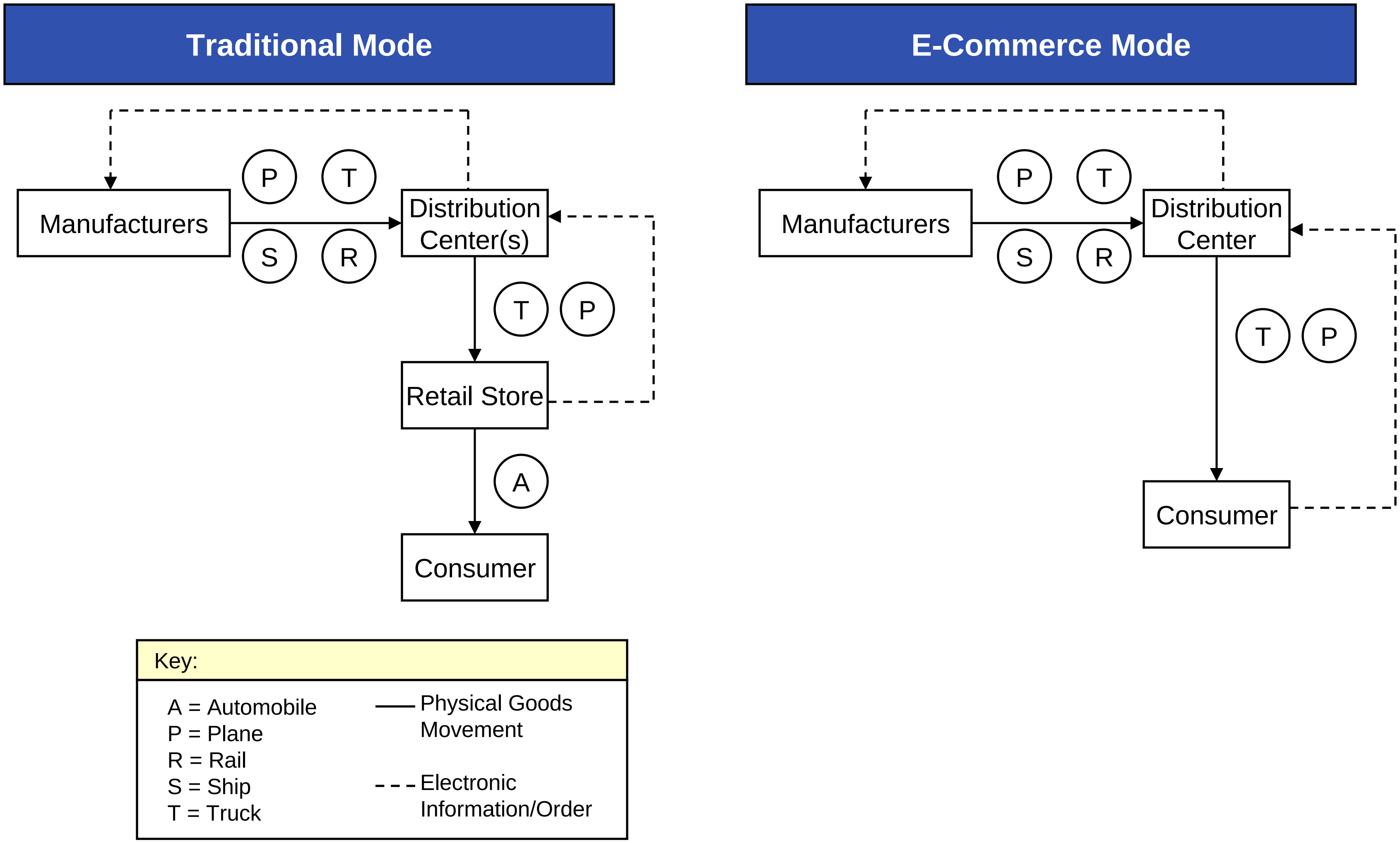
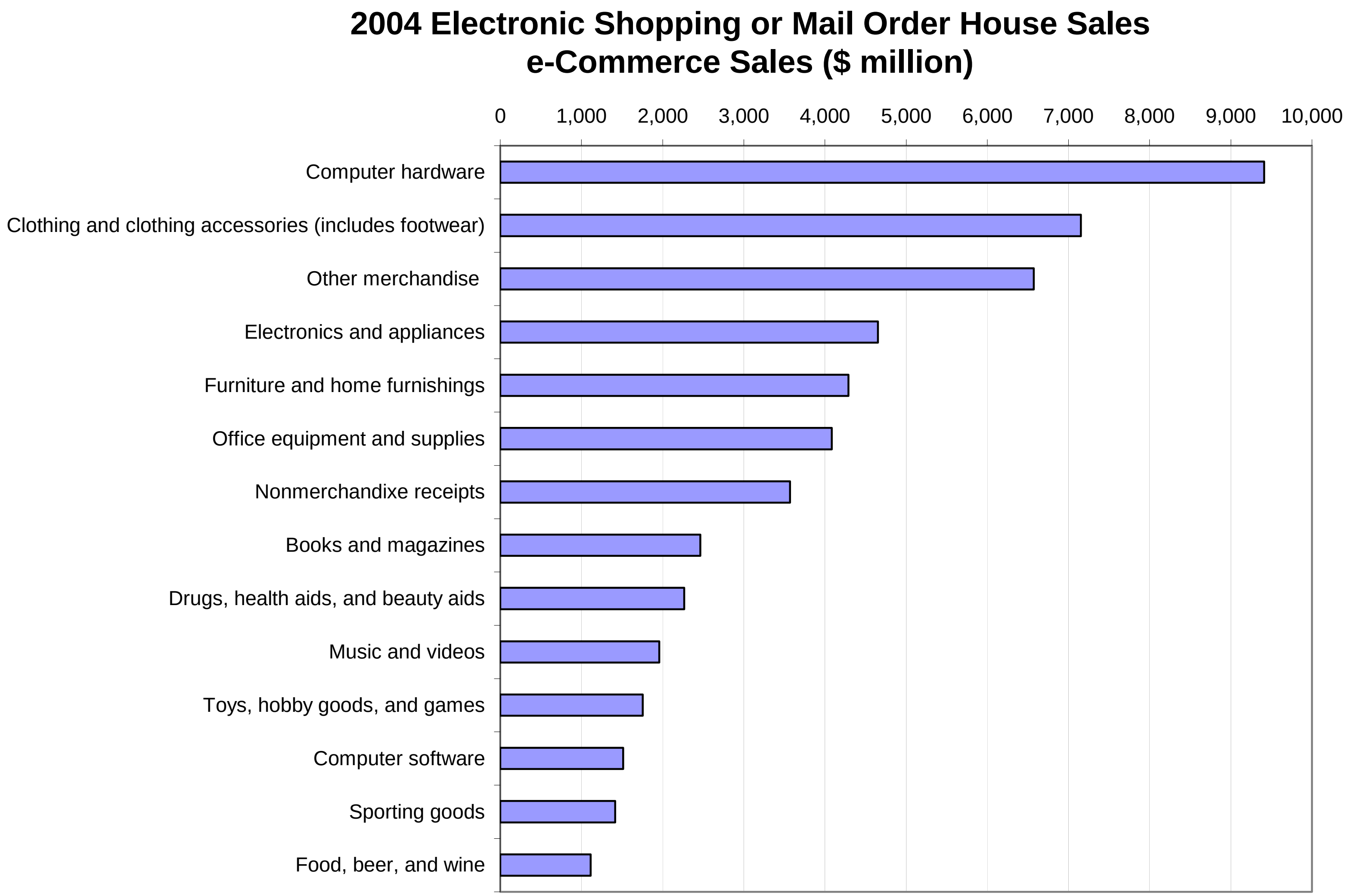
e-Materialization

With "Tangible Goods", trips to the store and retail space are replaced with delivery of goods from the distribution center (DC) to the home.



Of the $52 billion of retail e-commerce sales identified as "electronic shopping or mail order" – the majority were of tangible goods.

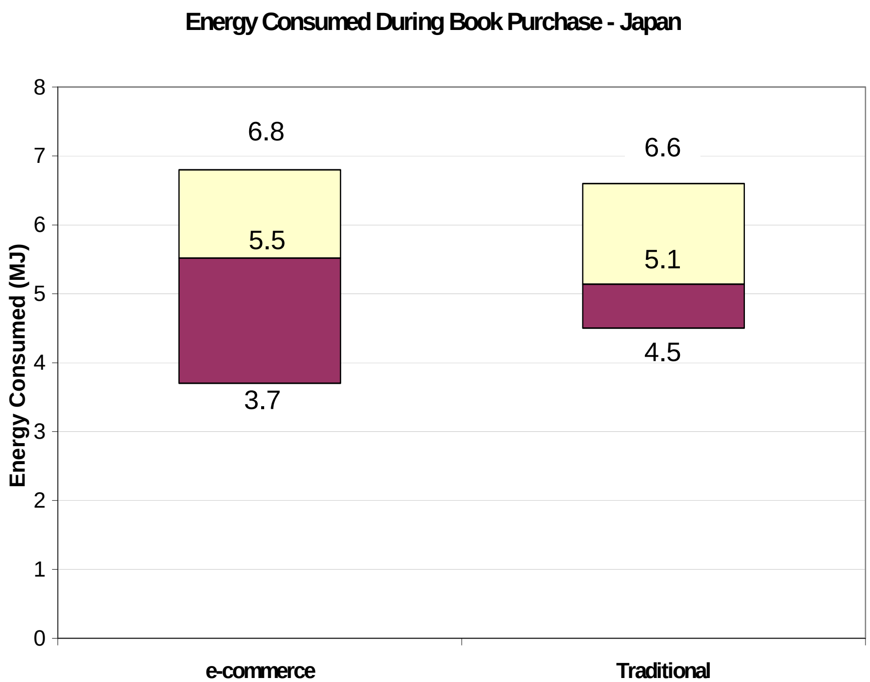


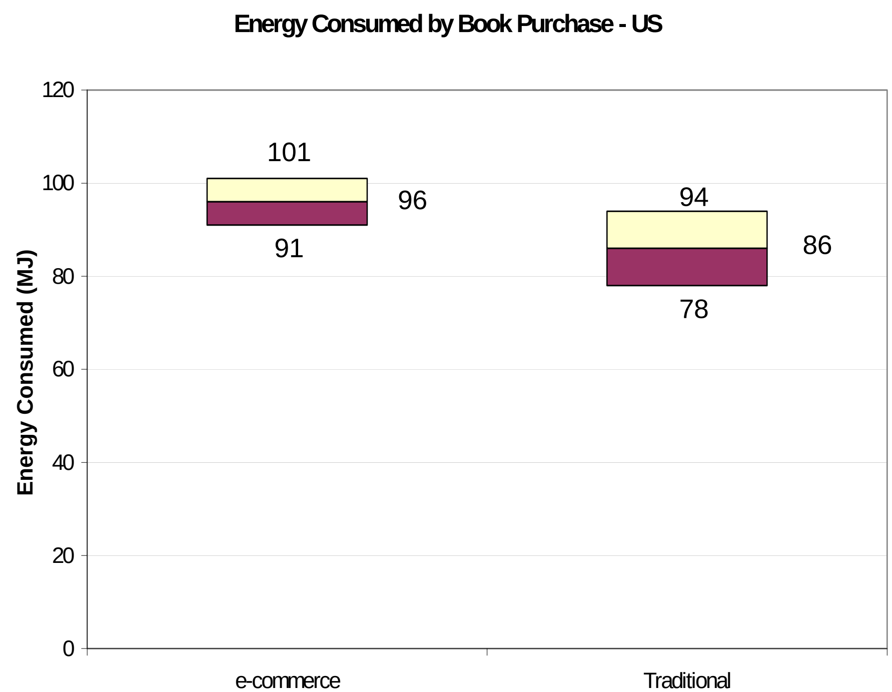
Source: U.S. Census Bureau, E-Stats, May 25, 2006

Energy consumption associated with the sale of Tangible Goods (considering both e-commerce and traditional methods) has been evaluated by several researchers – the focus has been on books.

- ***Why Books?:*** The analysis of e-commerce book purchases provides a valuable, illustrative example of the key issues associated with energy consumption of Tangible Goods:
  - Books are regularly purchased both on-line and at traditional stores.
  - They represent a large number of items purchased through e-commerce.
  - Compared to other types of tangible goods (e.g., clothing, furniture, computer hardware, etc.), the size of a book – and therefore the amount and type of packaging required – is fairly uniform. The uniformity of the product helps to reduce the number of assumptions required in the analysis.
- ***Study Descriptions:*** Two major studies have been conducted to estimate the energy consumption of purchasing books via e-commerce. One study focused on the U.S. (Matthews and Hendrickson 2001) and the second focused on Japan (Williams and Tagami 2003).
  - The U.S. study has a larger "system boundary" (i.e., considers a broader range of energy-consuming activities) and addresses differences in distribution modes (i.e., truck, rail, air) and the impact of reducing book inventories due to the efficiencies associated with on-line purchasing.
  - The Japan study addresses differences in energy consumption due to regional population density, the mode of consumer transport, and changes in residential energy consumption.

While the magnitude of energy consumption estimated by the two book studies is quite different, both studies concluded that the energy consumption associated with Traditional and e-commerce purchasing modes is similar.





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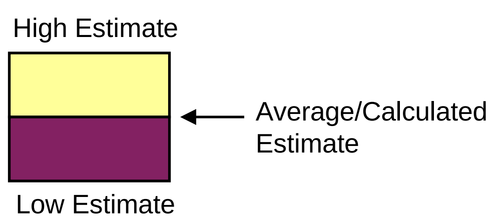


Notes:

- For the Japan study, the High and Low Estimates are based on a sensitivity analysis conducted by the Japan study authors. The "Average/Calculated Estimates" are the calculated values from the study.
- For the US study:
  - E-commerce: High assumes air delivery; Low assumes truck delivery
  - Traditional: High assumes 35% of books sent to retail stores are returned; Low assumes that no books sent to retail stores are returned.
  - The Average/Calculated Estimate is the average or the High and Low estimates.

While these studies suggest that energy consumption is similar for the two purchasing methods, specific factors can influence the results to favor one or the other purchasing method.

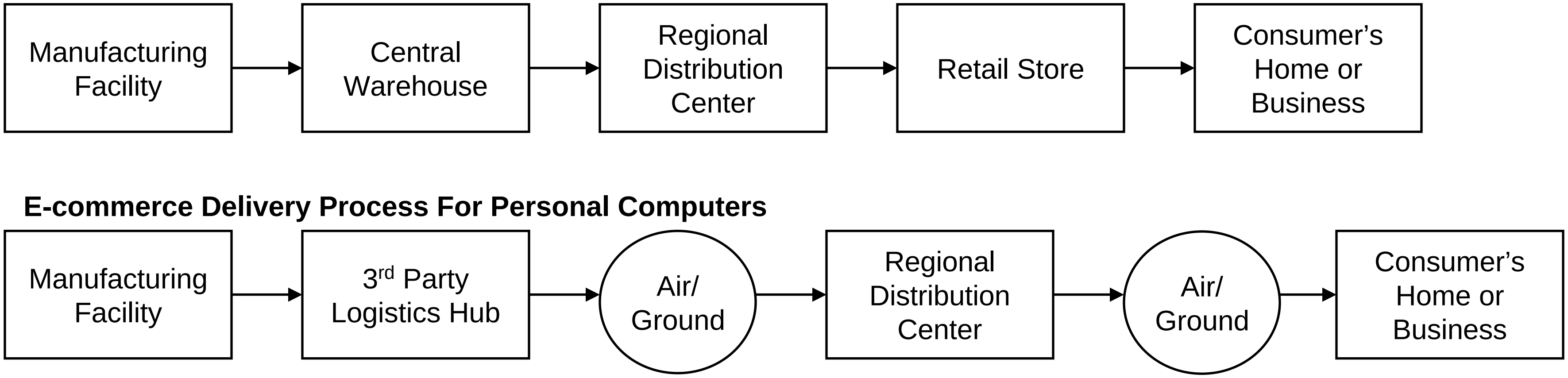
Factors that Affect Energy Consumption			
Factor	**Description**	**e-Commerce**	**Traditional**
Regional Factors (Population Density)	• In high density areas, consumers travel short distances to stores use more mass transportation. • In low density areas, relatively efficient courier services take the place of long drives to a store.	• Relatively favorable in low density areas	• Relatively favorable in high density areas
Product Distribution Mode	• Energy is reduced when air transportation is avoided and loading factors (i.e., the percent of the vehicle capacity filled) are high.	• Use of air transport is energy intensive	• Rarely uses air transport
Packaging	• The less packaging, the smaller the energy impact. Packaging used to move product from the manufacturer to the distributor is similar for the two methods, while packaging for consumer delivery is quite different.	• Consumer packaging tends to be greater than Traditional	• Consumer packaging tends to be less than e-Commerce
Supply Chain Management	• Inventory in regional distribution centers and retail stores requires floor space that must be built, maintained, lit, and heated/cooled. • For products like books, reducing the amount of unused product in the supply chain reduces the amount of product produced, the transportation required for product returns, and product disposal.	• Centralized distribution supports greater efficiency	• Decentralized distribution can lead to inefficiency

A third study, focusing on the sale of personal computers, emphasized the large energy savings that e-Commerce can provide by eliminating retail and distribution floor space.

- The study (Gay et al. 2005) quantifies the energy and air emissions associated with personal computers purchased through traditional retail and e-Commerce.
  - The e-Commerce model was based largely on the operations of Dell Computer, which assembles its computers to order as part of its “no finished goods inventory” strategy.
- The authors identify that the three major differences between the two purchasing methods are the warehousing, transportation, and distribution processes.

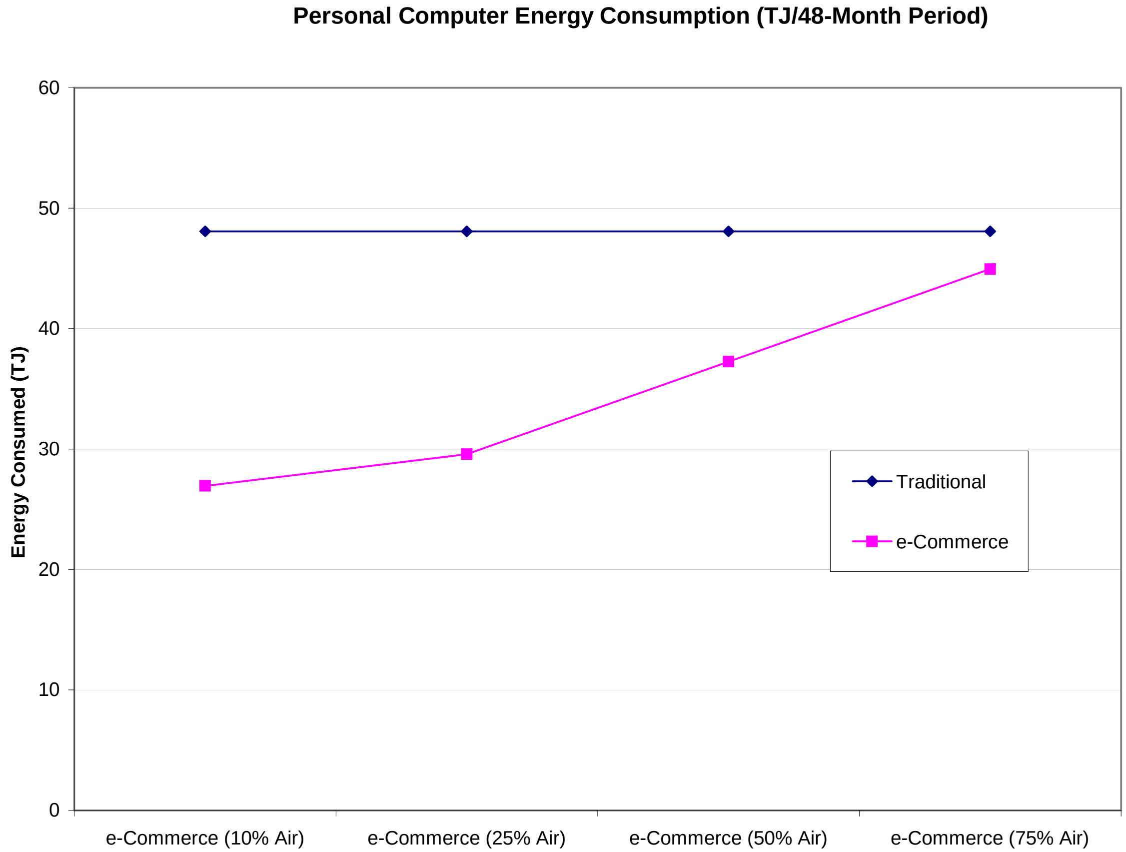
Traditional Delivery Process For Personal Computers

E-commerce Delivery Process For Personal Computers



Source: Gay et. al. (2005)

Gay et al. (2005) identifies that the energy consumption associated with a computer purchase via e-Commerce is up to 44% less than a purchase via the traditional retail system – the percentage of air transportation is a key variable.

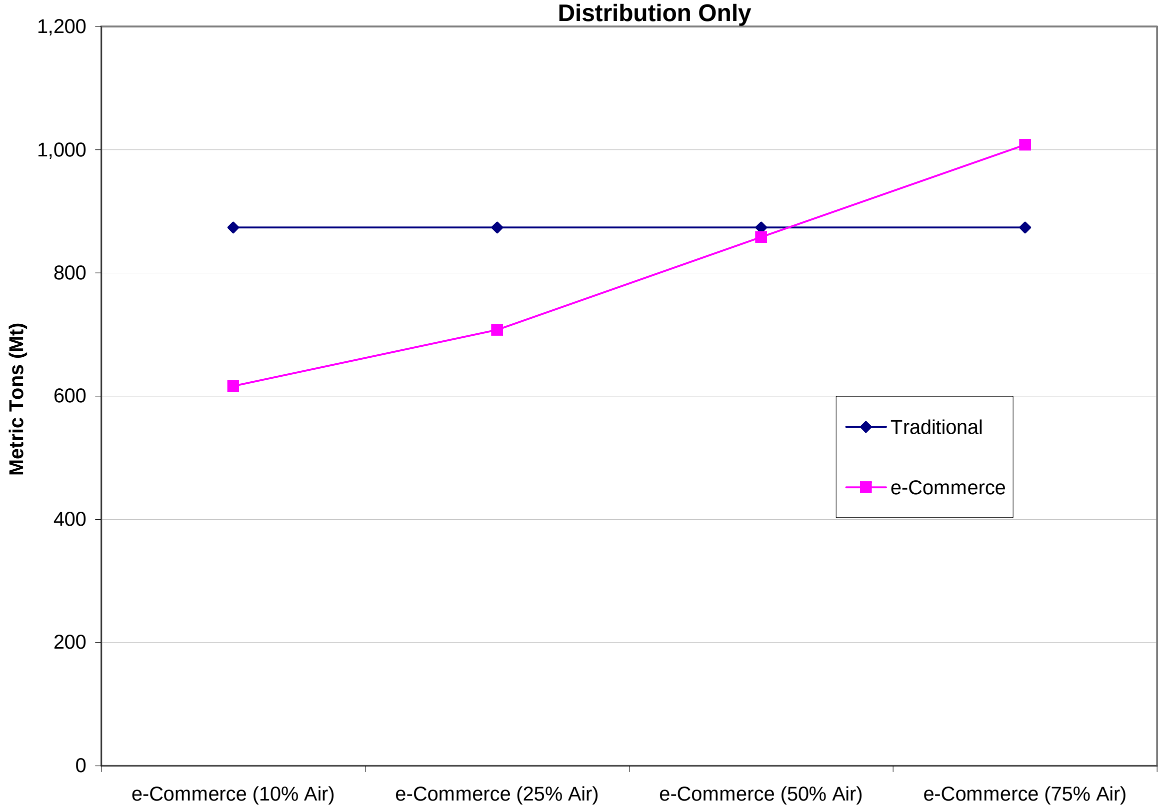


% Air Transportation in e-Commerce	Reduction in Energy Consumed (%)
10%	44%
25%	38%
50%	23%
75%	7%

"It takes approximately six times the fuel to receive products overnight than through normal delivery methods." – Gay et al. (2005)

Note: Energy values shown are for a volume of 200 PCs per week over a period of four years, i.e., a total of 41,600 PCs (Gay et al. 2005).

Similarly, CO_2 emissions associated with e-Commerce are lower than traditional retail up to the point where air transportation accounts for about 50% of the distribution.



Note: Energy values shown are for a volume of 200 PCs per week over a period of four years, i.e., a total of 41,600 PCs (Gay et al. 2005).

% Air Transportation in e-Commerce	Reduction in Energy Consumed (%)
10%	29%
25%	19%
50%	1.8%
75%	(15%)

The study focused on CO_2 associated with distribution only – assuming that CO_2 generated from other life cycle activities would be comparable.

The study's authors identify that about 40% of the e-Commerce energy savings is associated with the reduction of inventory in the supply chain.

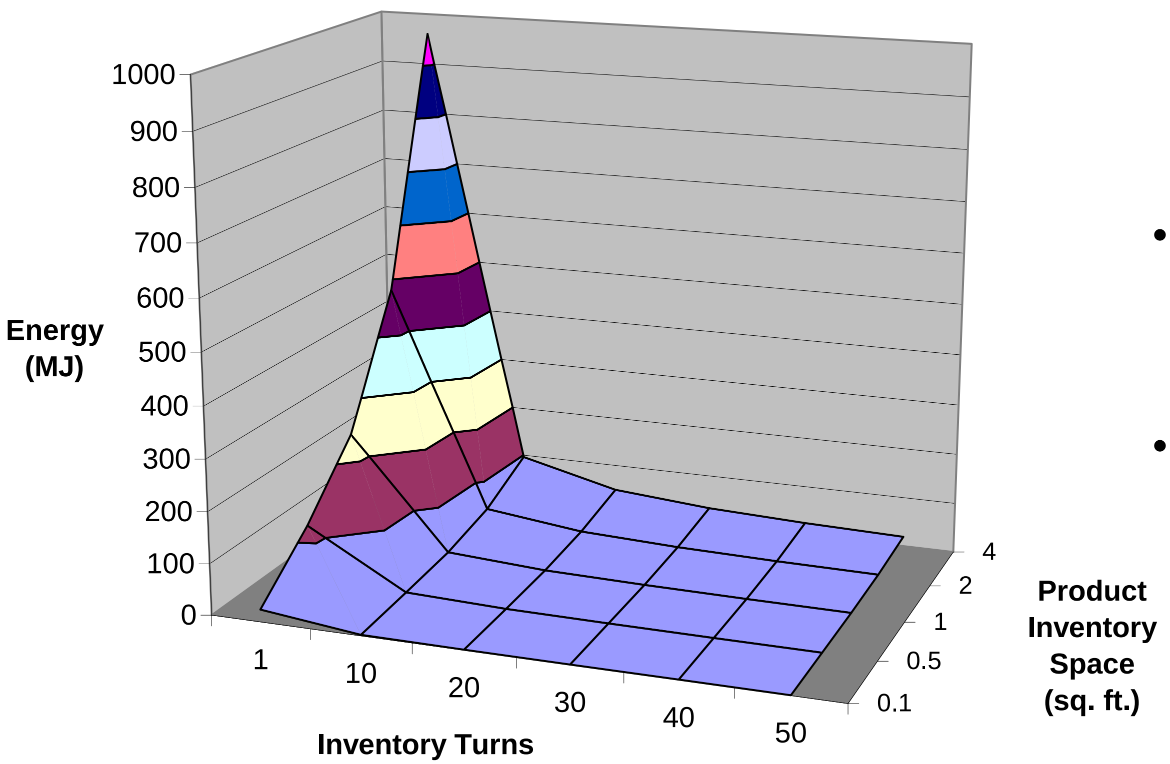
- For e-Commerce sales, computers are built to order and shipped directly to the consumer. Regional distribution and retail floor space are not needed.
- In traditional retail sales, computer inventory is housed in regional warehouses and in retail stores until it is purchased by the consumer.
  - The authors' survey of computer retailers (Best Buy and Circuit City) identified that 2,000 ft^2 are dedicated to the display, service, and inventory storage of personal computers.

Factors that Influence e-Commerce Savings Relative to Traditional Retail		
Influencers	**Energy**	**CO_2 (Distribution Only)**
Cars	7%	23%
Distribution without Cars	29%	77%
Retail and Warehouse	9%	n/a
Inventory	39%	
Packaging	17%	
Total	100%	100%

Source: Gay et. al. (2005)

Retail floorspace can be a significant contributor to a product's LCA energy consumption – key factors are the amount of space required and the number of annual inventory turns.

Impact of Product Size and Inventory Turns on Retail Energy Consumption



- ***Retail Energy Consumption:*** Due to high lighting and HVAC loads, retail space can be fairly energy intensive – about 240 MJ/ft^2/year (i.e., 225 MJ consumption and 15 MJ for the embodied energy in the building)
- ***Product Inventory Space:*** Different products require varying amounts of space for sales displays and product storage.
- ***Inventory Turns:*** A "turn" is the number of times inventory is sold (turned over) each year (e.g., If a computer sits in a store for one year, that is one turn. If a store sells 50 of those computers in a year, that is 50 turns).

Inventory space of less than 0.5 ft^2 and/or turns of 20 or more will typically result in a low allocation of retail energy consumption per unit

These three studies suggest that there is no clear difference between the energy and CO_2 emissions associated with the sale of Tangible Goods via traditional and e-Commerce methods.

- Either method may have a higher or lower energy and CO_2 impact depending on the specific circumstances of the product sale.

Traditional sales consume less energy when . . .

- **Population density is high** - consumers live close to stores
- **Consumer transport is minimal -** mass transportation more often used to shop
- **Distribution:**
  - e-commerce would involve air transportation
  - Traditional distribution to retail store is very efficient (high load factor and energy efficient vehicles)
- **Packaging:** e-commerce would require heavy external and substantial internal packaging
- **Retail inventory is low** - the floor space dedicated to the storage and display of the products is low

E-Commerce sales consume less energy when . . .

- **Population density is low** - consumers live far from stores
- **Consumer transport is significant** – the consumer drives a car to the store
- **Distribution:**
  - e-commerce would involve ground transportation only
  - Traditional distribution to retail store is inefficient (low load factor and standard vehicles)
- **Packaging:** e-commerce requires only light packaging (e.g., light corrugate or Tyvek bag)
- **Retail inventory is high** – significant floor space is dedicated to the storage and display of the products

Executive Summary

Study Objectives and Scope

Telecommuting

e-Commerce

Introduction

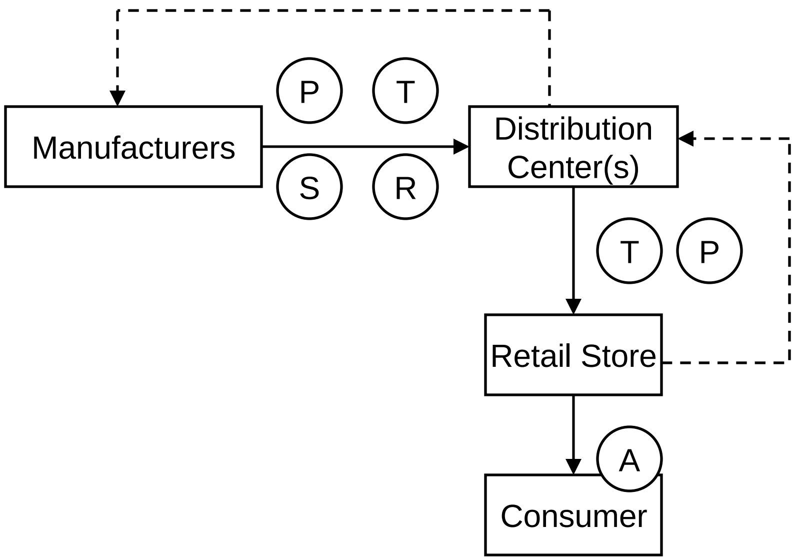
Tangible Goods

Electronic Goods

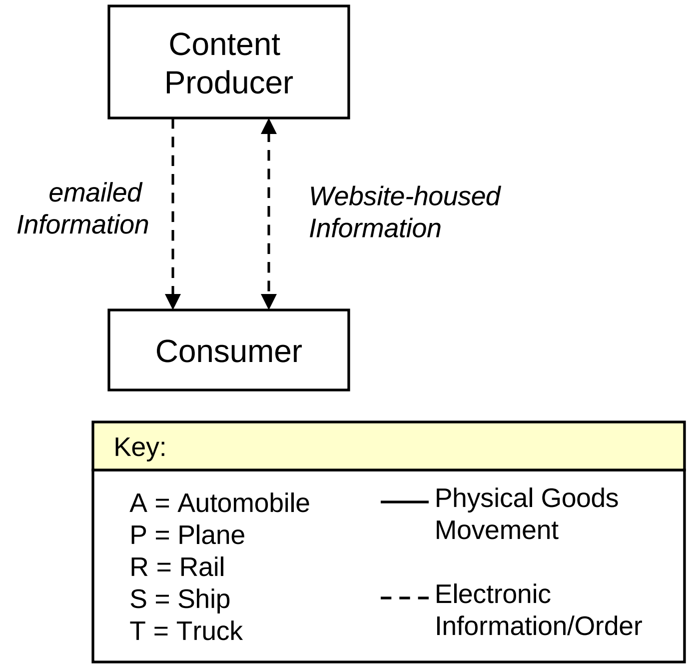
e-Materialization

The second e-Commerce category considered in this study is "Electronic Goods"; i.e., goods that are delivered electronically, in place of a physical product.

Traditional Mode



E-Commerce Mode



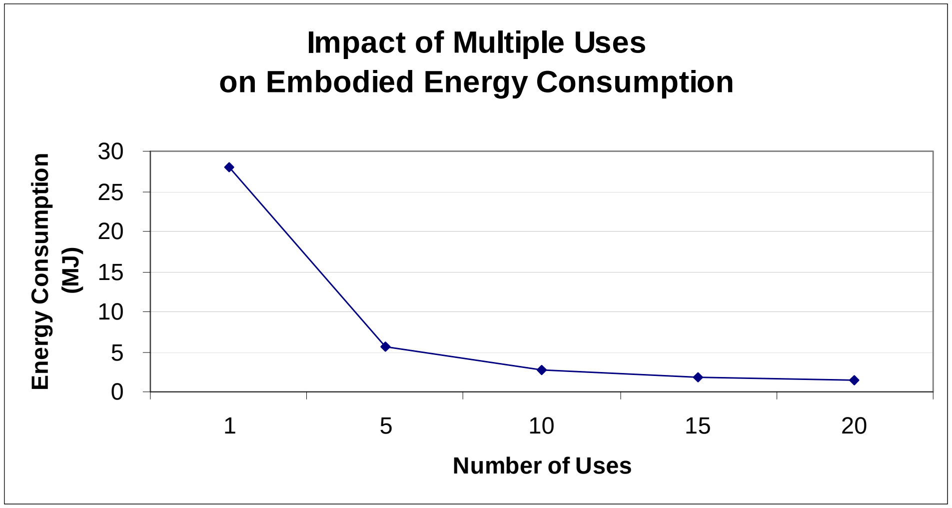
Electronic Goods include video-on-demand (instead of VHS or DVD), music or software downloads (instead of packaged CDs), and similar products.

Our analysis of energy consumption and CO_2 production of Electronic Goods focused on DVD rentals compared to video-on-demand (VOD).

- Video-On-Demand (VOD) is an increasingly popular service provided by television service providers that allow homeowners to “rent” movies and other content through their set-top controller.
- VOD competes directly with the traditional video rental industry, i.e., when the customer picks up the physical media – DVD or VHS tape – at a video rental store.
- By transferring the video content electronically, a variety of energy consuming and CO_2 producing activities are avoided:
  - Producing and packaging the product (DVD or VHS tape)
  - Distributing the product to the rental store
  - Holding product inventory in the rental store
  - Transporting the consumer to the video rental store (round-trip)
- The impact of the upstream activities (i.e., product production through delivery to the video rental store) is reduced by the fact that the product is rented multiple times. Therefore, the upstream activities must be amortized over the number of times that the product is viewed.
- The energy consuming and CO_2 producing activities associated with VOD are primarily associated with the embodied energy of the set-top box and the electricity consumed while viewing the video content.

The upstream activities associated with a DVD consume about 8 MJ of energy; however, after considering the number of viewings this energy consumption becomes insignificant.

- The upstream activities associated with DVDs primarily involve injection molding polycarbonate into disks, saving the content on the disks, packaging the disks, and distributing the products to rental stores.
  - DVD production: 28 MJ*
  - DVD distribution: 7 MJ**
  - Total energy: 35 MJ



- As the number of viewings/uses of the DVD increase, the effective, embodied energy consumption declines (e.g., 2.8 MJ after 10 uses).
- On average, DVDs/videos are rented 5 to 6 times per year. (Entertainment Merchant's Association 2007, TIAX estimates)

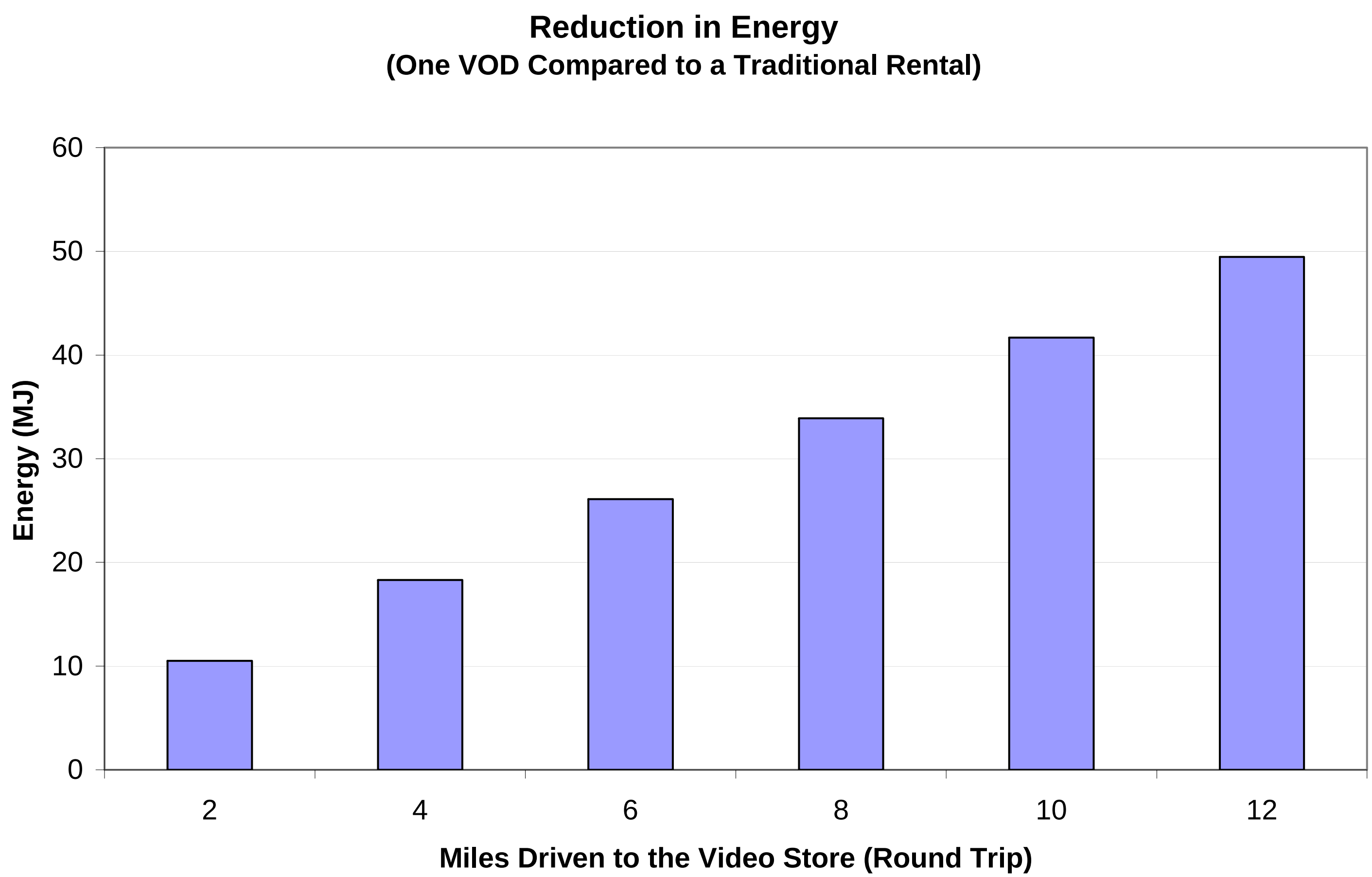
* Sivaraman et al. (2007)
** TIAX estimate based on Matthews et al. (2002)

The difference between the two purchasing modes is primarily the difference between the energy consumed by the set-top box (for VOD) and the consumer's drive to the rental store and use of a DVD player.

- Video Store Rental Assumptions:
  - Fuel economy of a passenger car: 7.8 MJ/mile (total energy)
  - Number of DVDs rented per trip: 2 videos per trip
  - DVD + packaging embodied energy: 2.8 MJ (assuming 10 uses over the life of an average DVD)
  - DVD + packaging embodied CO_2: 0.13 kg (assuming 10 uses)
  - DVD player embodied energy: 0.02 MJ/hour
  - DVD player usage energy: 0.18 MJ/hour
  - Movie length: 2 hours
- VOD Assumptions:
  - Set-top box embodied energy: 0.04 MJ/hour
  - Set-top box usage energy: 0.19 MJ/hour
  - Movie length: 2 hours

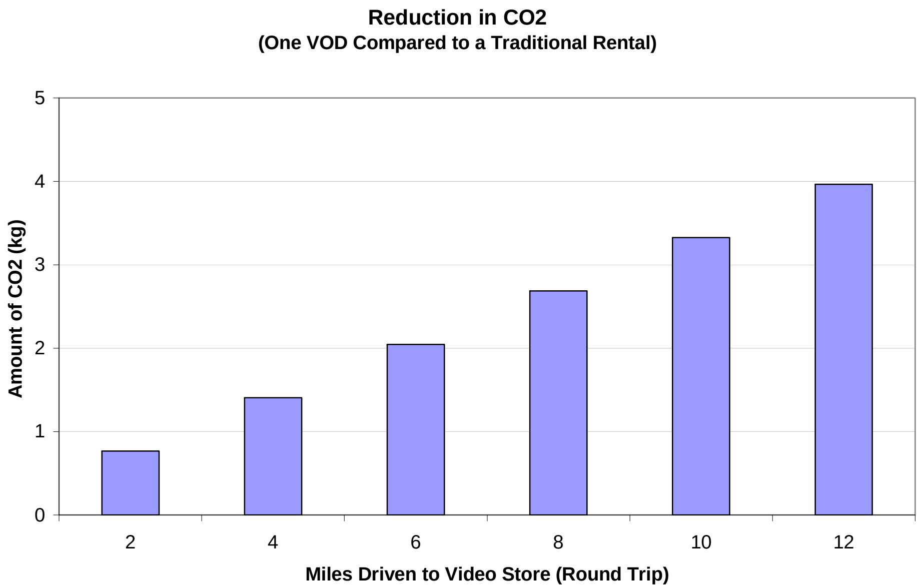
Sources: Hu and Reuscher (2004), CMU (2007), Sivaraman et al. (2007), Sivaraman (2007), TIAX (2007), TIAX Estimates.

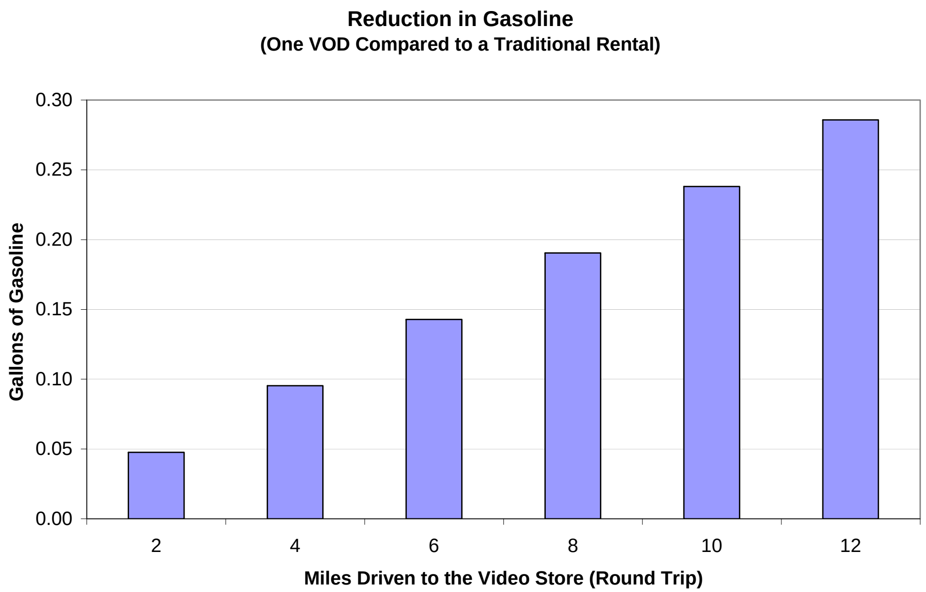
As a result, the distance that a customer must travel to get to a video store has a large impact on the energy impact of VOD.



For reference, 13.8MJ is equivalent to the total energy (including embodied energy) of one kWh of electricity.

The impact of driving distance on CO_2 emissions and gasoline consumption is similar to what is observed with energy.





- In all cases, driving to the video store accounts for more than 75% of the CO_2 generated during a traditional video rental (not including the distribution chain).
  - DVD + packaging embodied energy and DVD player operation (electricity consumption and DVD player embodied energy) account for the balance of the CO_2 impact
- Gasoline consumption is due solely to driving to the video store.

If 50 percent of the 2.5 billion DVDs and VHS tapes rented per year* were delivered via VOD, it would reduce energy consumption by an amount equivalent to the annual electricity consumption of about 200,000 households.

Impact of Replacing Traditional Video Rental (6 mile round trip drive) with VOD					
Percent Transitioned to VOD	Energy Reduction (PJ)	Energy Savings – Equivalencies		CO_2 Reduction (million MT)	Gasoline Reduction (million gallons)
		Annual Electricity Consumed**	Annual Number of Light-Duty Vehicles***		
25%	16	0.1 million households	0.18 million	0.6	90
50%	33	0.2 million households	0.36 million	1.3	180
75%	49	0.3 million households	0.54 million	1.9	270
100%	65	0.4 million households	0.71 million	2.6	360

* EMA (2007)

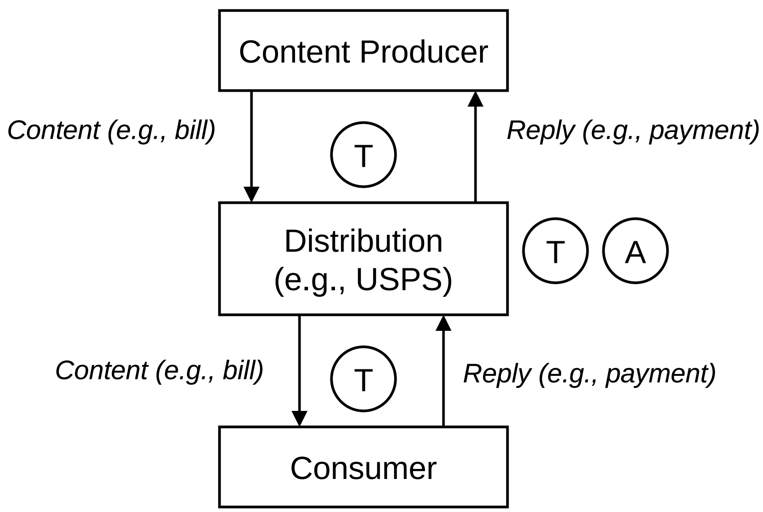
** Taking into account the energy used to: generate the electricity; transmit and distribute electricity; extract resources used to generate electricity; and create the infrastructure to extract resources, generate electricity, and transmit and distribute electricity.

*** Taking into account the energy directly consumed by the light-duty vehicles and the energy used to: produce the fuel; distribute the fuel; extract the resources used to produce the fuel; and to create the infrastructure to extract the resources, produce the fuel, and to transport the fuel.

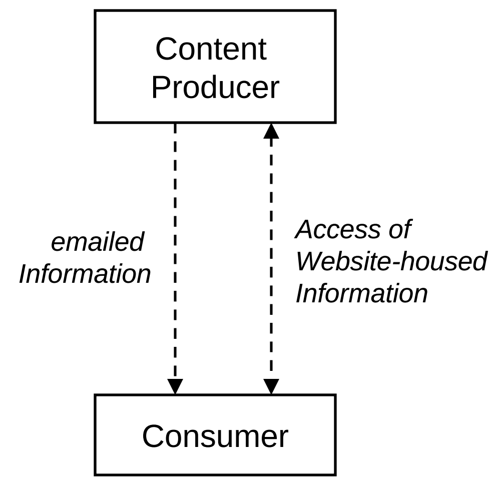
- Executive Summary
- Study Objectives and Scope
- Telecommuting
- **e-Commerce**
  - Introduction
  - Tangible Goods
  - Electronic Goods
  - **e-Materialization**

"e-Materialization" delivers electronically goods that had been mailed to the home.

Traditional Mode



E-Commerce Mode



Key:

A = Automobile
P = Plane
R = Rail
S = Ship
T = Truck

—— Physical Goods Movement

- - - Electronic Information/Order

e-Materialization refers to the substitution of electronic media for a physical product.

- For this study, the specific aspect of e-Materialization evaluated was viewing information in an email or on a website instead of receiving the same information in hardcopy form through the United States Postal Service (USPS).
- By viewing the information electronically, several energy consuming (and, therefore, CO_2-producing) activities are eliminated:
  - Producing the printed material (e.g., paper, envelope, printing)
  - Distributing the printed material by truck and/or air
- Energy consuming activities associated with viewing the electronic information include the embodied energy of the computer and the electricity consumed while viewing.
  - In addition, if the user elects to print out the electronic information, additional information is consumed with respect to the:
    - Embodied energy in the paper
    - Embodied energy in the printer
    - Energy consumed while printing the information

We considered a range of scenarios in our comparison of traditional mail and e-mail energy consumption.

Scenario	Message Delivery Mode	"Fixed" Energy Consuming Activities Considered	"Variable" Energy Consuming Activities Considered
All Activities	Mail	USPS Delivery	Embodied energy in a letter
	e-mail	Embodied energy of a computer and printer	Energy consumed while viewing/composing, and printing (including embodied energy of paper)
No Fixed Activities	Mail	None	Embodied energy in a letter
	e-mail	None*	Energy consumed while viewing/composing, and printing (including embodied energy of paper)
E-mail Worst Case	Mail	None	Embodied energy in a letter
	e-mail	Embodied energy of a computer and printer	Energy consumed while viewing/composing, and printing (including embodied energy of paper)

- The rationale for selecting these three scenarios is:
  - ***All Activities***: Captures all reasonable fixed and variable energy-consuming activities, assuming that the fixed activities would not consume energy if the message is not sent.
  - ***No Fixed Activities:*** Ignores most fixed energy consuming activities, acknowledging that the fixed activities will not go away if one less message is sent, notably that mail trucks will still make their rounds and computers will still sit on desks.
  - ***E-mail Worst Case:*** Ignores only the fixed costs of mail delivery, acknowledging that the consumer choice to purchase a computer is more variable than the scaling down of the postal service.

* Printer embodied energy is included in our calculations, but at 0.003 MJ/minute, the impact appears to be negligible (CMU 2007, TIAX Calculations).

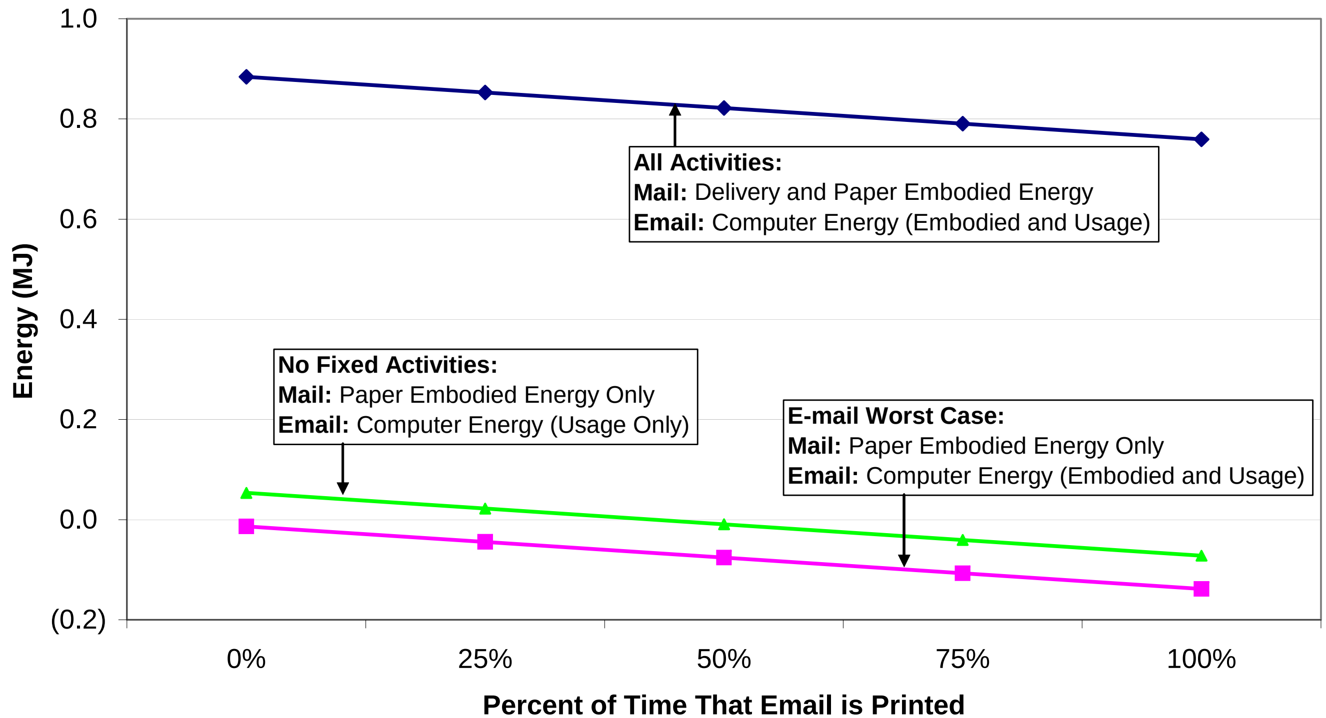
The analysis assumptions address embodied energy, usage energy and computer usage time – energy associated with printing (printer use and paper) was varied to assess the impact of printing e-mails.

Key Assumptions – Fixed Activities		
Topic	**Assumption**	**Source**
Mail: Delivery Energy	0.90 MJ/piece of First Class Mail	CMU (2007), with a First Class Letter costing $0.33
Printer: Embodied Energy	0.003 MJ/minute	CMU (2007), Williams (2004), TIAX estimates
Printer: Usage Energy	0.002 MJ/minute	CMU (2007), Williams (2004), TIAX (2007)
Printer: Printing Time	1 minute	TIAX estimate
Printer: Paper Consumed	2 sheets	TIAX estimate
Computer: Desktop Embodied Energy	0.6 MJ/hour	CMU (2007), Williams (2004), TIAX estimates
Computer: Desktop Energy Consumption	1.7 MJ/hour	CMU (2007), Williams (2004), TIAX (2007)
Computer: Notebook Embodied Energy	0.8 MJ/hour	CMU (2007), Williams (2004), TIAX estimates
Computer: Notebook Energy Consumption	0.35 MJ/hour	CMU (2007), Williams (2004), TIAX (2007)
Computer: Time to Read e-mail	0.1 hour (6 minutes)	TIAX estimate
Internet: Usage Energy per e-mail message	0.02 MJ / 100kB message	Data Flows in 2006: Odlyzko (2007) Infrastructure Energy: Koomey (2007), ADL (2002)

Our analysis suggests that e-mail saves up to about 0.9 MJ of energy per piece of First Class Mail delivered – depending on the scenario considered.

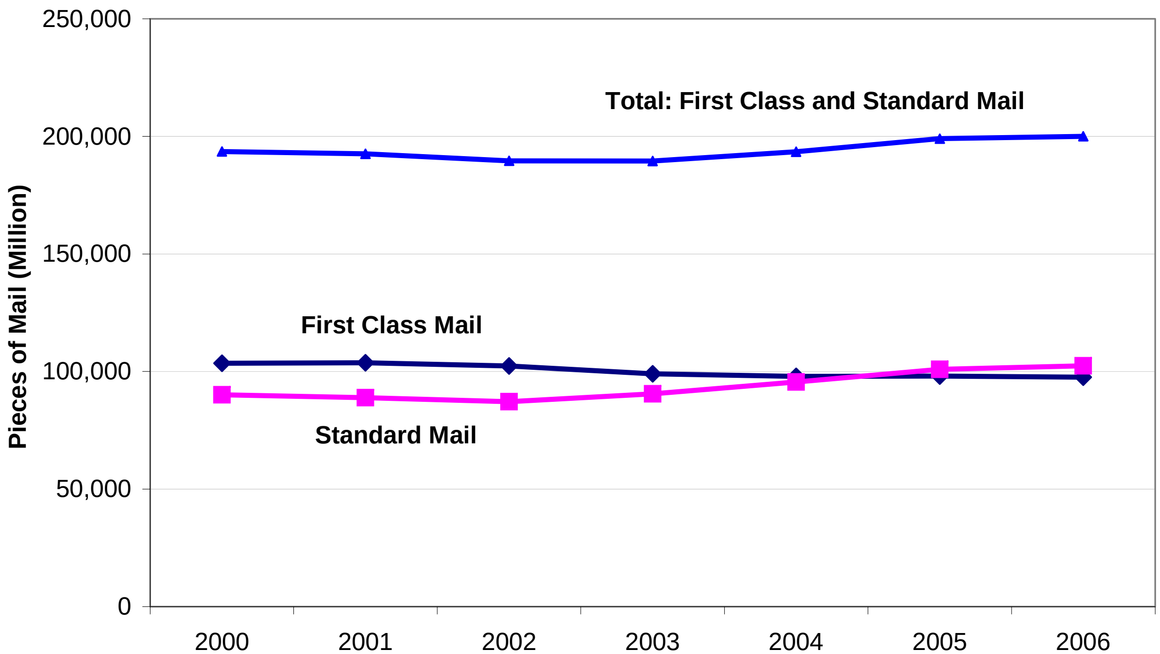
- When all activities are considered, e-mail is beneficial regardless of the amount of printing that takes place.
- In the worst case scenario for e-mail, the two methods are comparable only when e-mails are not printed.

Energy Saved by Using Email in Place of Standard Mail
(Considering Three Scenarios)



While email has helped to cause a decline in First Class mail over the last six years, Standard Mail volume has grown – as a result, the overall volume of mail has remained relatively flat

USPS Mail Volume (2000 to 2006)
First Class and Standard Mail



Source: USPS, 2001, 2003, 2005, 2006

- "eCommerce and electronic messaging are slowly replacing personal paper based correspondence and paper based commercial transactions using First-Class Mail." (USPS 2006)
- Between 2000 and 2006 First Class Mail declined by 1% - a cumulative reduction in mail of about 22 billion pieces.

Given its mandate to provide mail service to the nation and the mix of Standard and First Class Mail, declines in First Class Mail volume are unlikely to cause comparable reductions in USPS energy consumption.

Given an assumption that the annual decline in First Class Mail has been replaced by e-mail, energy savings (without printing) are estimated to range between (50) and 3,300 TJ per year across our three scenarios.

Scenario	Annualized Energy Savings: 2000 to 2006 (TJ)				
	0% Printing	25% Printing	50% Printing	75% Printing	100% Printing
All Activities	3,300	3,200	3,100	3,000	2,800
No Fixed Activities	200	80	(40)	(150)	(220)
E-mail Worst Case	(50)	(170)	(280)	(400)	(520)

- The “All Activities” scenario is largely theoretical since the Postal Service energy consumption is only marginally affected by changes in First Class Mail volume.
- The “No Fixed Activities” and “E-mail Worst Case” scenarios provide more practical estimates for the actual energy tradeoffs between these two activities.

While theoretical fuel savings associated with the switch from First Class Mail to e-mail are significant, on a practical basis real savings are negligible.

- In the comparison of Traditional Mail to e-mail, the consumption of distillate fuel is considered in the *All Activities* scenario.
  - Fuel (distillate) represents 75% of the Postal Service's energy costs (USPS 2006)
  - Assuming that 75% of the Postal Service energy consumption is fuel, each piece of delivered mail requires the consumption of 0.68 MJ fuel, or 0.005 gallons of fuel.
  - Therefore, about 20 million gallons of fuel are needed to deliver 3.7 billion pieces of mail, the annual volume decline in First Class mail between 2000 and 2006.
  - This calculation, however, is theoretical. It assumes that the Postal Service has saved energy as a direct result of the decline in First Class Mail. In practice, the decline in First Class Mail has been replaced by increases in the volume of Standard Mail and the Postal Service infrastructure and delivery practices are largely unchanged. Postal Service energy savings are likely to be more closely linked to programs to improve energy efficiency than to the decline in First Class Mail.
- The consumption of fuel in the other scenarios is negligible.

To assess CO_2 reductions related to the use of email in place of Traditional Mail, we again assumed an annual decline of 3.7 billion pieces of mail.

Scenario	Annualized CO_2 Reductions: 2000 to 2006 (Metric Tons)				
	0% Printing	25% Printing	50% Printing	75% Printing	100% Printing
All Activities	75,000	70,000	65,000	60,000	56,000
No Fixed Activities	(170)	(5,000)	(9,900)	(15,000)	(20,000)
E-mail Worst Case	(12,000)	(17,000)	(22,000)	(27,000)	(32,000)

- The “All Activities” scenario includes the CO_2 emissions associated with transporting mail.
- The “No Fixed Activities” and “E-mail Worst Case” scenarios show relatively higher CO_2 emissions associated with the embodied and usage energy of a computer than with the production of paper for the traditional letter.
- Rebound effects (e.g., changes in the amount of movie viewing or number of car trips due to additional free time or saved money) associated with the transition to VOD were not considered in these analyses.

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