# The Love You Save: Improving Energy Efficiency

## Here Today, Gone Tomorrow: Nothing Lasts Forever and a Day

As promised in the introduction, this chapter deals with the question of whether infrastructure improvements will work in existing buildings and equipments. After all it is one thing to document that we can build radically new types of homes and cars. But, what about all the homes that already exist? What of the cars people already drive? Are we going to just throw them away and build new ones? Even if efficiency improvements were free, that kind of premature depreciation and discarding capital goods would be expensive indeed. How are we to increase efficiency with this rock solid infrastructure in place?

Of course, that is a trick question, whose answer is implied by the chapter title. The infrastructure of modern industrial society is not rock solid at all.

"I've been thinking" says a farmer, in conversation with a city bumpkin, looking proudly at his acres of ripening wheat, "I might put in a new variety next year – one that should get my yield way up."

"Hang on" says the city bumpkin. "You already planted your fields. Are you going to pull them all up, and replant?"

And of course the farmer explains that he does that every year anyway. He is going to harvest every blade of wheat he planted; planting something new only costs the differences between varieties.

The same thing is true of almost our entire infrastructure - on a time scale of thirty years or less.

Let's start with residential buildings – which can easily last over 100 years[3]. But, look at major components, not only the whole building, and your home is anything but static. According to Freddie Mac[4] the average life of most types of roof is 12-20 years depending upon materials. Dishwashers and disposals last 5-12 years, clothes washers, dryers, water heaters, warm air furnaces, heat pumps, and air conditioner compressors from 8-12 years, refrigerators and stoves from 15-20 years. Modern residential windows typically have 25 year life spans[5]. Wood, vinyl, fiberglass, and most metal siding last between twenty and thirty years[6]. As homes age, bits and pieces break down or suffer damage.

Similarly, most commercial buildings need a major rehab after 25 years[7]. Individual components such as roof, exterior, HVAC, and plumbing tend to wear out in thirty years or less[8] .

According to the OECD, Deutsche Bundesbank, and U.S. economists, industrial and manufacturing equipment wears out within an average of twenty years at most[9]. This covers a huge variety of lifespans. The most energy intensive equipment often tends to last longest and dying industries will sometimes continue to use equipment long after its normal effective lifespan has passed. For example, PCs, which cost little compared to most capital equipment, and use very little energy in operations (though they require a lot to manufacture), have an estimated average lifespan of around two years[10]. On the other hand, the effective lifespan of coke ovens (which are very energy intensive pieces of equipment) is normally taken to be about 25-30 years[11].

There are exceptions of course. Infrastructure such as bridges, dams, sewage plants, pipelines, and water purification plants tend to last a great deal longer – forty, fifty even 100 years. But maintenance for such infrastructure has been neglected for decades in the name of "cutting fat". The American Society of Civil Engineers says America's infrastructure is deteriorating rapidly - report card style they give it an average grade of D+ [12].

Transportation changes ceaselessly too. The single largest component of U.S. transportation consumption, the automobile, has an average lifespan of about 20 years[13]; but most are driven very lightly after their first thirteen years of life. Many are used so lightly as not to constitute a significant emissions source; those which do produce significant emissions could be bought out cheaply, in programs similar to those used to retire the worst junk cars in many European nations. Freightliner gives the lifespan of a bus chassis as about ten years[14], though I suspect many bus companies manage to go longer between major overhauls. Under optimistic assumptions average heavy truck engines last about 21 years between major overhauls[15]. Airplane bodies last fifty thousand cycles or more (which can translate into fifty+ years); but engines seldom last more than thirty years[16], and usually need major service of some type every ten years or so[17]. On average, freight train locomotive engines need overhauls every six years[18] during their 40 year lifespan[19]. Large scale freight ships (container, bulk cargo, and tanker ships) need to overhaul their engines every ten years or so[20]. The upper limit for the latest generation of ship engines appears to be 25-30 years[21].

So, with minor exceptions, we will replace virtually our entire energy consuming infrastructure within the next thirty years. The bulk of this book will show that as parts of our human built world break down, much more efficient replacements will cost around the same as less efficient ones – making up for the higher prices of renewable sources to run them. Thus the U.S. can drop net greenhouse gas emissions to zero over thirty years at essentially no net cost - even without dramatic technical breakthroughs or drastic lowering of renewable energy costs.

# End Notes

[3]Jennifer O'Connor, *Survey on Actual Service Lives for North American Buildings*, Oct 2004). Sep 2004. *Presented at Woodframe Housing Durability and Disaster Issues Conference*, 16/Jun/2006 <http://www.northernrockies.org/Departments/Fire/Wood_Buildings/Wood%2520Buildings%2520Service_Life_E.pdf>.

A good indicator is that the Australian govemment thinks that most Australian homes (which have to meet tougher standards than U.S. ones do) have a lifespan of around 50 years.

Chris Reardon, *Your Home Technical Manual - Design for Lifestyle and the Future - 3.0 Materials Use Introduction*. 1/Mar/2004, Commonwealth of Australia/Joint Initiative of the Australian Government and the Design and Construction Industries, 9/Jan/2005 <http://www.greenhouse.gov.au/yourhome/technical/fs30.htm>.

[4] The Old House Web, *Schedule of Normal Life.* 1995, 1/Jan/2005 <http://www.oldhouseweb.net/stories/Detailed/267.shtml>.

[5]Hawkins, Dominique M., *Saving Wood Windows.* 24/Sep 2004, *State of New Jersey Department of Environmental Protection Division of Parks & Forestry Natural & Historic Resources Historic Preservation Office*, 2/Jan/2005 <http://www.state.nj.us/dep/hpo/4sustain/windowsave.pdf>.

[6]The Minnesota Green Affordable Housing Guide, published by University of Minnesota College of Architecture and Landscape Architecture cites a 25 year lifespan
Regents of the University of Minnesota, *The Minnesota Green Affordable Housing Guide - Components: Cladding (Siding)*, 30/June 2004, 2004 Regents of the University of Minnesota, 09/Jan/2005 <http://www.greenhousing.umn.edu/comp_cladding.html>.

So does the Commonwealth of Massachusetts Historical Commission
Carol DiNinno and Ann Lattinville, "Technical Assistance Tips: Vinyl Siding,". *Preservation Advocate*, no. Spring 2003 (2003), Commonwealth of Massachusetts Historical Commission, 06/Jul/2005 <http://www.sec.state.ma.us/mhc/mhcpdf/pasp03.pdf>. P5.

Jim Cory, "Siding Replacement", *Remodeling Magazine*, no. November 2002 November 2002: 2002 Cost vs. Value Report, Hanley Wood, 10/Mar/2004 <http://www.remodeling.hw.net/pages/remodelingonline/Story.nsp?story_id=1000027503&ID=newsreal&scategory=Computers&type=break>.

Note that many "authoritative" sources give longer, life spans, based upon exaggerated manufacturers claims, rather than real life experience. For instance, one of the sources most commonly cited for lifespans is the September 2002, **Baseline Measures for Improving Housing Durability**, published by the U.S. Department of Housing and Urban Development

Robert E. Chapman and Christine A. Izzo, *Baseline Measures for Improving Housing Durability*, NISTIR 6870. September 2002. *US. Department of Commerce National Institute of Standards and Technology Building and Fire Research Laboratory/U.S. Department of Housing and Urban Development Office of Policy Development and Research*, 06/Jul/2005 <http://fire.nist.gov/bfrlpubs/build02/PDF/b02159.pdf>.

If you look at footnote 26 at the bottom of page 38 of that article, it turns out that average (as opposed to minimum) lifetimes are based on "Life Expectancy of Housing Components" published by Ahluwalia, Gopal, and Angela Shackford. in the August 1993 Housing Economics pp. 5-9 – based on surveys of manufacturers, trade industry associations and researchers. Given that at least two thirds of the sources would tend to be biased towards optimism, I would expect lifespans from such a source to be wildly exaggerated. Let's test this by focusing in on one example – vinyl siding.

The 50 year average estimated lifespan for vinyl siding is widely cited. The Housing Economics is not the sole source of course. The Vinyl Institute promotes this figure as much as possible. But does it make sense compared to environmental and remodeling sources?

Most vinyl siding offers a 50+ year warranty. That appears devastating until you look at what kind of warranty is offered. Many of the warranties are prorated. Those that are not usually have a kicker: they are invalidated or become prorated when the home is sold. Because most people do not stay in the same house for 25 year, the vast majority of these warranties will expose the seller to no significant liability past after a couple of decade. (I know there are exceptions. But, looking at it from the point of view of how much money a warranty will cost the issuer, the exceptions are not significant.

Let’s look at one vinyl siding warranty (http://www.mastic.com/warrantyvs.asp) a warranty for Mastic Vinyl Siding from Alcoa, downloaded February 2, 2005 – one that advertises itself as non-pro-rated, transferable. That sounds good – except that as soon as it is transferred it becomes very heavily prorated indeed.

For a second owner, by the time 14 years have passed the warranty covers only 20% of the original cost of the siding. Bear in mind that decently installed, well maintained vinyl siding will last 25-30 years. So imagine every most (non-original owners have problems and try to collect on the warranty 20 years from now. That means the manufacturer will have to pay out 20% of siding sales price in 20 years. But having to pay a dollar twenty years from now does not cost the same as having to pay it now. Using a discount rate of 6.5% that 20% 20 years from now is worth only 3.5% of the current sales dollar. In other words, the manufacturer (knowing that most homes will be occupied by a second (or third or fourth owner)) needs only add 3.5% to the selling price to cover the cost of this 50 year warranty. Actually that is overstating; in practice by the time the home has passed through a number of hands, a lot of people won’t even think of checking to see whether there is a warranty out on siding 20+ years old. What about siding that goes bad sooner? Well remember this particular warranty hits that 20% mark after 14 years. Even badly installed and maintained siding tends to last for 15. But if the siding was improperly installed or poorly maintained that invalidates the warranty in any case. In other words offering a 50 year warranty under those particular terms is a worthwhile investment in marketing terms, even if the siding does not in fact last 50 years. So the existence of such a warranty does not tell you very much.

Also by the time the manufacturers face a significant number of people trying to collect on the warranty, whoever made the recommendation to offer it will be working for a different company or retired.

Fundamentally vinyl (as it is normally installed) just is not sturdy enough to last more than 30 years in the conditions house siding normally faces. It becomes brittle with age, and also brittle in extremely cold (and sometimes in extremely hot) weather. You can harmlessly bounce a hammer off newly installed vinyl siding; try it ten years later and you will shatter your vinyl. The same thing is true in really cold weather. Hit vinyl siding with a snow-blower or lawnmower and it won’t hold up very well. As it grows older, you can damage vinyl siding by leaning a ladder against it to repair a roof or a window. Top quality vinyl siding, perfectly installed and maintained might well last fifty years or longer. But that is not the average case – especially the perfect installation and maintenance.

[7]Robin Suttell, "Intelligent and Integrated Buildings: Technologies and Current Market Conditions Break Down Conventional Barriers,". *Buildings Magazine* November 2002, Statmats Business Media, 5/Jan/2005 <http://www.buildings.com/Articles/detail.asp?ArticleID=1095>.

[8]OUS Capital Construction, *The Oregon University System Sustainable Renewal Program for Failing Assets*. 19/Jul 2004, 02/Jan/2005 <<http://www.ous.edu/board/dockets/ddoc040716-DM.pdf>>.

[9]. Engelbert Westkämper, director of the Institute of Manufacturing and Factory Operation at the University of Stuttgart says "... A factory building normally lasts 30 years, but it doesn't stay the same for 30 years. Machines and systems have an average life span of ten years; in some cases only five years..."

"Prof. Engelbert Westkämper, 56, is a leading expert in the field of manufacturing engineering. Since 1995 he has served as Director of the Fraunhofer Institute for Production Engineering and Automation in Stuttgart, Germany and as Director of the Institute of Manufacturing and Factory Operation at the University of Stuttgart. A mechanical engineer, Westkämper also has a hands-on industrial background, including positions as Manager of Manufacturing Engineering and Technology at MBB in Munich and as Manager of Production Engineering at AEG in Frankfurt. He was also responsible for manufacturing technology at Airbus in Hamburg and Bremen.

"Visualizing Tomorrow's Industrial Environments: Interview with Engelbert Westkämper,". *Siemens Webzine*, no. Pictures of the Future - Fall 2002 (2002), Siemen, 02/Jan/2005 <http://w4.siemens.de/FuI/en/archiv/pof/heft2_02/artikel08/>.

The OECD gives the average service life for capital equipment (weighted by value) as 15 years - not the same as in the U.S., but indicative.

Paul Schreyer, *Capital Stocks, Capital Services, and Multi-Factor Prodductivity Measures. Economic Studies*, Draft. 3/Nov 2003, OECD Statistics Directorate, 3/Jan/2005 <http://www.oecd.org/dataoecd/30/46/29877839.pdf>. P10.

According to the Deutsche Bundesbank , U.S. capital equipment generally lasted about 25 years in 1987, and the rate of depreciation has risen drastically every one of the 18 years that followed (meaning lifespan has fallen).

Ulf von Kalckreuth and Jurgen Schröder, *Monetary Transmission in the New Economy: Service Life of Capital, Transmission Channels and the Speed of Adjustment*, Discussion Paper 16/02. 16/June 2002, Economic Research Centre of the Deutsche Bundesbank,p2, 03/Jan/2005 <http://www.bundesbank.de/download/volkswirtschaft/dkp/2002/200216dkp.pdf>.

Some U.S. economists calculate an average 5.9% depreciation rate for U.S. physical capital, which is consistent with a 20 year lifespan:

M. Ishaq Nadiri and Ingmar R. Prucha, "Estimation of the Depreciation Rate of Physical and R&D Capital in the U.S. Total Manufacturing Sector,". *Economic Inquiry* XXXIV January 1996: 43-56, Western Economic Association International, 03/Jan/2005 <http://www.econ.nyu.edu/user/nadiri/pub86.PDF>.

[10]Region 2 United States Environmental Protection Agency, *Life Cycle of Old Computers - Problem Continued*. 15/October 2002, U.S. EPA, 3/July/2005 <http://www.epa.gov/region02/r3/problem.htm>.

[11] "The generally accepted standard for the normal effective lifespan of a coke oven is 25 to 30 years."

Office Technology Assessment, "Technology and Raw Materials Problems - Chapter 7," *Technology and Steel Industry Competitiveness*, June 1980), NTIS Order #PB80-208200. 1996, 223. *Office Technology Assessment*, Princeton University, 02/Jan/2005 <http://www.wws.princeton.edu/cgi-bin/byteserv.prl/~ota/disk3/1980/8019/801909.PDF>.

[12]American Society Civil Engineers, *ASCE Report Card for America's Future: 2003 Progress Report And Update to the 2001 Progress Report*. September 2003, 1, ASCE, 10/Jan/2005 <http://www.asce.org/reportcard/pdf/fullreport03.pdf>.

The EPA sponsored a study that focused on water infrastructure, and concluded the ASCE was too generous.

American Water Works Service Co. Inc. Engineering Department, *Deteriorating Buried Infrastructure Management Challenges and Strategies*. May 2002. *Environmental Protection Agency*, 10/Jan/2005 <http://www.epa.gov/safewater/tcr/pdf/infrastructure.pdf>.

[13]S. Lu, *VEHICLE SURVIVABILITY AND TRAVEL MILEAGE SCHEDULES*, DOT HS 809 952. Jan 2006, : NHTSA's National Center for Statistics and Analysis NCSA, 12/Jan/2007 <http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/Rpts/2006/809952.pdf>.

Florida Department of Highway Safety and Motor Vehicles, *How to Buy a Used Car*. 21/May 2004, 3/July/2005 <http://www.hsmv.state.fl.us/dmv/usedcar.html>.

[14] Freightline Custom Chassis, *Commericial Bus Chassis: Frequently Asked Questions*. 03/Jan/2005 <http://www.freightlinerchassis.com/cb_default.asp?page=cb_faqs&nav=mb>.

2nd source:
Research and Special Programs Administration John A. Volpe National Transportation Systems Center, *Transit Security Design Considerations: Final Report*. November 2004, 7-8. *Federal Transit Authority of the U.S. Department of Transportation*, 05/Jul/2005 <http://transit-safety.volpe.dot.gov/security/SecurityInitiatives/DesignConsiderations/CD/ftasesc.pdf>.

[15] We have to combine two figures here, average number of miles traveled annually by heavy trucks, and engine life in miles. The Department of Transportation suggests that heavy trucks average 47,022 miles annually in the U.S.

Stacey C. Davis and Susan W. Diegel, *TRANSPORTATION ENERGY DATA BOOK: - Edition 23*, ORNL-697(Edition 23 of ORNL-5198). October 2003, Chapter 5: Heavy Vehicles and Characteristics, Page 5-7, Table 5-Truck Statistics by Size - 1997. *Oak Ridge National Laboratory for the U.S. Department of Energy Office of Planning, Budget Formulation and Analysis Energy Efficiency and Renewable Energy*, 24/Feb/2003 <http://www-cta.ornl.gov/data/tedb23/Full_Doc_TEDB23.pdf>.

The Pacific Northwest National Laboratory suggest that a heavy truck, on average, needs a major overhaul at between 400,000 and one million miles. (A truck that is used a lot, but run at a low mileage, spending a lot of time idling or in stop and go traffic, or turning around in narrow streets and parking lots will wear out in a lot fewer miles, so the range makes sense.) Therefore if we assume that million miles, divide the 47,022 miles traveled annually into it and calculate a 21 year life span, we are projecting an optimistic length of time between major overhauls for an "average" heavy truck.

PNNL, "Need For Transportation Technologies Heads Into Overdrive,". *PNNL Breakthroughs Magazine: Science, Technology, Innovation* Fall 2002, Pacific Northwest National U.S. Department of Energy Multiprogram National Laboratory - Richland WA, 3/Jan/2005 <http://www.pnl.gov/breakthroughs/fall02/special.stm>.

[16]"When Should Part-Life Engines Be Built?" *Engine Yearbook 2005*. 2005. Aviation Industry Press Ltd., London, 11/Jan/2005 < http://www.aviation-industry.com/atem/newpages/eyb2003pdfs/E2005_TES.pdf>.P30.

[17] "Commercial Aero-Engine MRO Outlook - a New Dawn?" *Engine Yearbook 2005*. 2005. *Aviation Industry Press Ltd*, 11/Jan/2005 <http://www.aviation-industry.com/atem/newpages/eyb2003pdfs/E2005_aerostrat.pdf>.p4.

[18]Charles River Associates for Diesel Technology Forum, *Diesel Technology and the American Economy*, Report D02378-00. October 2000, 12/Jan/2005 <http://www.dieselforum.org/enews/downloads/DTF-Economic-Study.PDF>. p2.

For rail transport in general the same figure seems to be 12 years (ibid 14:Volpe above)

[19] “Locomotive engines are expected to last for at least 40 years, which places greater emphasis on durability. This low turnover rate also limits the penetration rate of new technologies; however, locomotives undergo many overhauls, providing opportunities for modifications throughout their lives.”

Frank Stodolsky, Railroad and Locomotive Technology Roadmap, ANL/ESD/02-6. December 2002. Center for Transportation Research, Energy Systems Division - Argonne National Laboratory, 11/Jan/2005 <http://www.transportation.anl.gov/pdfs/RR/261.pdf>.p13.

[20]Yes, this is a press release – a press release boasting about an extraordinary example of product life – with no claim that it represents typical results. The estimate is likely to be high rather than low; and higher numbers are less favorable to the case we are making.

Torben Klingenberg, *Press Release: Heading for 30 000 Operating Hours with HFO GenSets*. October 2003. *MAN B&W Diesel A/S*, 17/Jan/2005 <http://www.manbw.com/files/news/filesof3003/CP_ships_pr_nov.pdf>.

[21]As previously noted, the following press release is more likely to give a high than a low lifespan estimate.

Vesa Tompuri, "Wärtsilä’s New Medium-Speed Diesel Engine Has the Lowest Emissions on the Market," *WATTSON:Wärtsilä’s Investor Magazine*. 2004. *Sanoma Magazines Custom Publishing Division for Wärtsilä Corporation*, 13/Jan/2005 <http://www.wartsila.com/Wartsila/docs/en/investors/English_lowres.pdf>.p13.

2nd source: a 1999 study was pessimistic about reducing greenhouse gas emissions in ships, because they have lifespans of 20 years or more.

Bronson Consulting Group CPCS Transcom Ltd. for Marine Sub-Group of the Transportation Table on Climate Change, *Marine Summary:Transportation &Climate Change : Assessment of Opportunities to Reduce GHG Emissions in the Marine Transportation Industry*. July 1999, 18/Nov/2003 <http://www.tc.gc.ca/programs/environment/climatechange/subgroups1/marine/Exec_Summary/English/Marine.htm>.