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THE ROLE OF THE FEDERAL RELIGHTING INITIATIVE IN EMISSION CONTROLS

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INTRODUCTION

The Department of Energy's (DOE) Federal Relighting Initiative (FRI), under the Federal Energy Management Program (FEMP), has developed a comprehensive process to assist federal agencies in meeting the nation's energy mandate. This mandate states that federal facilities must use 20% less energy by the year 2000, based on 1985 consumption levels. Because lighting accounts for about 40% of total federal electricity consumption, the FRI was conceived to help reduce energy use in this important area while improving lighting quality and increasing productivity through relighting. Selected federal rules and regulations provide guidance on the types of energy efficiency techniques required, life-cycle costing methods and lighting levels that should be employed to achieve the federal mandate.[2]

A "DUAL BENEFIT" APPROACH

Although the central focus of this paper is on the environment, this paper takes the perspective that the energy efficiency gains achieved through the FRI would produce both environmental and economic benefits for the United States. For example, improvements in energy efficiency would reduce electricity demand, and would consequently reduce the emissions associated with fossil fuel combustion for power production. These reduced emissions include carbon dioxide, which is associated with the potential for global climate change, and heavy metals, which pose a potential health threat to humans and aquatic ecosystems. Economic benefits of the FRI would include reduced federal expenditures on energy or, possibly, avoiding new power plant construction.

This paper begins with a brief overview of the FRI process. Next, current lighting energy use in federal buildings is evaluated and the potential future energy savings achievable through full implementation of the FRI are estimated. The paper then translates these energy savings into avoided emissions of carbon dioxide and heavy metals and into avoided fuel expenditures.

OVERVIEW OF THE FRI PROCESS

The FRI process for relighting and assisting federal agencies involves a multi-stage approach to the acquisition of life-cycle cost-effective, high-quality lighting systems. The federal relighting process is comprised of the following five stages:

- Screening - review buildings for potential relighting projects
- Selection - identify buildings to be relighted
- Design - design relighting for specific buildings
- Implementation - implement relighting design
- Evaluation - assess system performance.

This process has been developed to assist agencies during each phase of relighting. In addition, a "toolkit" has been designed to support relighting and retrofit activities and the decisions required of the federal facility manager. It assumes that there is strong engineering expertise within each agency's facilities department, but also includes both suggested qualifications to consider when it is necessary to obtain additional design and engineering services and selected educational guidance for in-house professional staff. Together, the process and the toolkit provide the integrated guidance needed to assist the federal sector in relighting buildings.

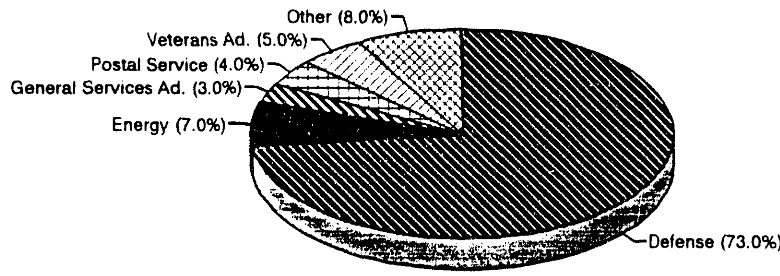
FRI ACTIVITIES

The results from several FRI projects indicate that the energy savings objectives of the Initiative are quite attainable. For example, a recent project to relight a 1.7 million square-foot federal building in Washington, D.C. involved replacing over 40,000 fixtures. The initial measured lighting energy savings exceeded 50% using energy-efficient lighting systems. In another project involving a 200,000-square-foot building, the FRI process is expected to produce energy savings of over 60%. Both sets of results are within the range of savings predictions in a recent report for a full lighting redesign (Energy Information Administration 1992).

CURRENT FEDERAL LIGHTING CONSUMPTION

The federal government consumed nearly 1.5 quadrillion British thermal units (quads) of *delivered* energy in fiscal year 1990 (DOE 1991).[3] Of this total, nearly 1 quad was devoted to "general operations," largely in the form of jet fuel for military transport and defense. Federal buildings and facilities, the focus of this paper, consumed 0.45 quads, but the bulk of this still went to the Department of Defense (DoD). Figure 1 presents energy use in the federal sector, by agency, for fiscal year 1990. As the figure reveals, DoD accounted for nearly 75% of the total, largely to provide energy services to military bases.

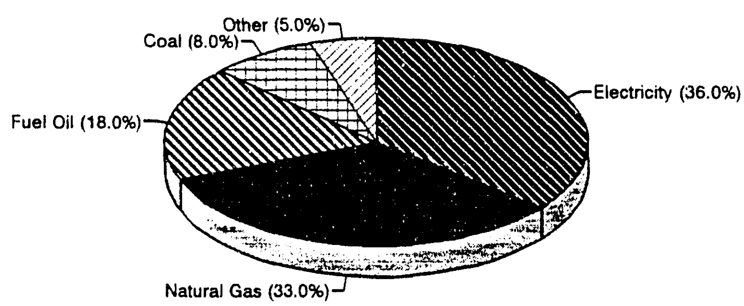
Figure 1. Federal Energy Use in Buildings and Facilities, by Agency (FY90)



Total: 0.45 Quads

Source: U.S. Department of Energy

Figure 2. Federal Energy Use in Buildings and Facilities, by Fuel Form (FY90)



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about 3.4 units of primary energy are required to deliver one unit of electricity to buildings. Lighting therefore used 0.22 quads of electricity in 1990 in primary terms. While this is not, by itself, a large number, it is important to realize that this level of energy consumption is far from trivial. To provide some context, consider that federal electricity consumption for *lighting alone* is equal to or greater than the *total* commercial building electricity consumption of many states, including Louisiana, Maryland, and Colorado (EIA 1992b).

ENERGY SAVINGS FROM THE FRI

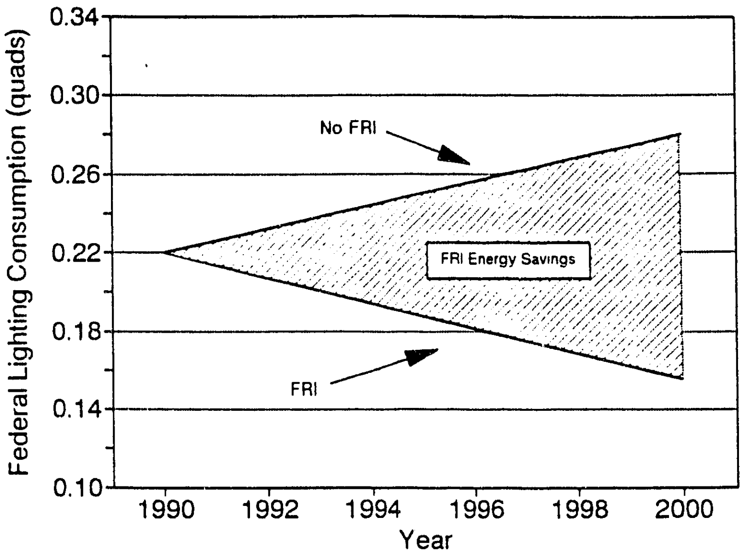
The goal of the FRI is to reduce the energy used for lighting federal buildings and facilities by the year 2000 to at least 20% below the 1985 level. To calculate the potential energy savings from the FRI, it is necessary to project lighting energy consumption in the absence of the Initiative. As energy model-based projections specifically for the federal sector are not available, projections of federal lighting consumption in 2000 in this analysis are based on historical growth rates.

From 1985 to 1990, electricity consumption in federal buildings grew 2.4% per year. Assuming that electricity consumption continues to increase at this rate through the year 2000, total federal electricity use would reach 0.62 quads in 1995 and 0.70 quads in 2000 (primary energy consumption). Assuming that lighting continues to comprise 40% of future electricity demand, the lighting of federal buildings and facilities will consume 0.25 quads in 1995 and 0.28 quads in 2000 in the absence of the FRI. This is depicted in Figure 3 as the "No FRI" scenario, which is a simple linear extrapolation of historical trends.

On the other hand, assuming that the objectives of the FRI are fully satisfied implies that, in the year 2000, federal lighting primary energy consumption will decline to 20% below the 1985 level. In 1985, lighting consumption was about 0.20 quads, so this means that with the FRI, lighting use would decline to 0.16 quad in 2000. This is depicted in Figure 3 in linear fashion as the "FRI" scenario. The cumulative potential savings from 1990 to 2000 from full implementation of the Initiative are shown in Figure 3 as the difference between the "No FRI" and "Full FRI" scenarios.

These cumulative savings would total roughly 0.7 quads, under the simplifying assumption that steady (linear) progress is made towards achieving the FRI objective *beginning in 1990.* A more realistic assumption would be that progress towards meeting the objectives occurs later in decade and is nonlinear. To attempt to capture this more plausible path to the objective, this paper assumes that cumulative savings are less than with the linear approach depicted in Figure 3, and are within the range of 0.3 to 0.5 quads. For purposes of subsequent calculation, this paper assumes that the cumulative savings are 0.4 quads.

Figure 3. Energy Savings from the FRI



Regardless of the path taken to success, the energy savings in the year 2000 would be about 0.12 quads with successful implementation of the FRI.

EMISSIONS REDUCTION POTENTIAL OF THE FRI

Electricity is often considered to be a "clean" fuel because of its properties at the point of actual use. In reality, however, electricity is only as clean as the source fuel employed to generate electricity. Electricity generated by wind turbines or hydropower is environmentally benign, at least in terms of the air emissions; coal, on the other hand, releases a host of air pollutants.

Converting primary energy savings from successful implementation of the FRI into emissions reductions is a two-step process. First, primary energy savings must be converted into fuel-specific savings. Second, fuel-specific savings must be translated into the concomitant emissions reductions.

The fuel composition of electricity generation varies widely by region in the United States. Ideally, mapping the location of federal facilities by state or region would yield the most accurate estimate of the impact of the FRI in terms of fossil-fuel-specific energy savings. Since such detail was not available at the time of this analysis, this paper assumes that the fuel-specific savings resulting from the Initiative are in exact proportion to the *national-level* fuel shares for electric generation in the year 2000 as projected by the National Energy Strategy's (NES) Current Policy Base Case (DOE 1991/92). The NES projections for the year 2000 are as follows: coal 51%, natural gas 17%, and oil 5% (nuclear and renewables account for the other 28%). Applying the fossil fuel shares to the total FRI energy savings estimated earlier yields fossil fuel-specific savings, as shown in Table 1.

Table 1. Fossil Fuel-Specific Savings From the Federal Relighting Initiative, Year 2000 and 1990-2000 Cumulative

(Quads primary)

Fuel	Year 2000	Cumulative 1990 to 2000
Coal	0.06	0.20
Natural gas	0.02	0.07
Oil	0.01	0.02

Carbon Emissions Reductions

Anthropogenic emissions of carbon dioxide (CO_2) are associated with the potential for global warming. Carbon dioxide emissions are a by-product of fossil fuel combustion, so the reductions in electricity generation resulting from the FRI would help contribute to the lowering of CO_2 emissions.

To calculate the reductions in carbon dioxide emissions that would result from implementation of the FRI, the fuel use estimates for the year 2000 and the cumulative fuel savings estimates listed in Table 1 were each multiplied by the fuel-specific emission factors for carbon dioxide. These emission factors represent the amount of carbon released per British thermal unit (Btu) of primary energy generated by combustion of a given fossil fuel. Average emission factors used here are 25.1 trillion grams of carbon per quad for coal, 14.4 trillion grams carbon per quad for natural gas, and 20.3 trillion grams carbon per quad for oil (Edmonds et al. 1989).

Applying these emission factors to the fuel-specific savings in Table 1 yields the carbon emissions reductions from the Initiative. For the year 2000, the FRI would reduce carbon emissions by an estimated 2 million metric tons of carbon. In 2000, this would be equivalent to a 0.3% reduction in carbon emissions from fossil-fired plants. Cumulative reduced carbon emissions from 1990 to 2000 are estimated to be 6.4 million metric tons of carbon.

Heavy Metal Emissions Reductions

Fossil fuel-fired electricity generation also results in the emission of a number heavy metals. Once released into the environment, heavy metals from electricity generation can be recovered with existing technology, but it is prohibitively expensive to do so. If fuel combustion and other industrial processes continue at current levels, heavy metal pollution could become a major global environmental problem (Nriagu 1990). Some heavy metals pose a serious threat to aquatic ecosystems because they accumulate in the food chain and, in large quantities, are toxic to humans.

Electric utilities emit heavy metals as a by-product of the combustion of coal and oil -- when these fuels are burned, the metals they contain that are not captured by the boiler control technologies are released as particulates or gases. With the exception of trace amounts of mercury, natural gas does not contain heavy metals. Since there are no available data on average mercury concentrations, the savings in mercury emissions from reduced combustion of natural gas as a result of the FRI are not considered in this paper.

Avoided emissions of selected heavy metals were calculated in much the same way as avoided CO_2 emissions. The coal and oil savings from Table 1 were multiplied by the fuel-specific emission factors for each heavy metal; these factors reflect emissions into the atmosphere *after* removal of the metals by the control technologies. The emission factors used in this study were prepared for the U.S. Environmental Protection Agency (EPA) by the Radian Corporation (Radian 1989).

Estimates of emissions savings were calculated for arsenic, cadmium, chromium, copper, mercury, manganese, nickel, and lead. Table 2 shows the estimates of reduced emissions for these heavy metals for the year 2000 and cumulative over the 1990-2000 period that would result if the FRI objectives are attained. In total, approximately 120 metric tons of toxic heavy metals would be avoided in the year 2000. Cumulative avoided emissions between 1990 and 2000 would total almost 400 metric tons.

Estimation of avoided emissions necessitated making several assumptions regarding the parameters that influence heavy metal emissions. One factor influencing emissions is boiler design. This paper assumes that all coal-fired units use pulverized dry bottom boilers. The use of these units is expected to increase in the future, since wet bottom and cyclone boilers are no longer sold, due to their inability to meet nitrous oxide (NO_x) standards. Stoker boilers are also being phased out because they are obsolete. Since there is little variability among oil-fired units, it is assumed that all use tangential boilers.

Another factor influencing heavy metal emissions is the type of control technologies used. It is assumed that all coal-fired utility boilers use electrostatic precipitators (ESP). Based on Radian data from 1983, 979 out of 1195 utility boilers used ESP. This represents more than 92% of the total generating capacity in the United States. Although some oil-fired boilers are equipped with control devices, most are not. It is assumed that oil-fired utility boilers are uncontrolled.

Emissions are also determined by the concentrations of the heavy metals in the fuel. There is wide variability in heavy metal concentrations in coal and oil. Not only do different types of coal and oil have different concentrations of heavy metals, but concentrations can vary widely from region to region and even within regions. Since approximately 95% of the coal burned in the United States is

Table 2. **Avoided Heavy Metal Emissions From the Federal Relighting Initiative**

(In metric tons)

Heavy Metal	2000 Savings	Cumulative 1990-2000 Savings
Arsenic	1.2	3.9
Cadmium	0.2	0.6
Chromium	11.0	37.4
Copper	6.9	21.5
Lead	1.5	4.8
Mercury	0.3	1.1
Manganese	17.4	59.0
Nickel	81.4	269.0
Total	120.0	397.0

Source: Radian Corporation 1989; Pacific Northwest Laboratory 1992.

bituminous, it is assumed that all coal burned is bituminous. Since 93% of the oil burned is residual, it is assumed that all oil burned is residual.

ECONOMIC SAVINGS

It is also possible to monetize the potential energy savings from the FRI. One approach is to estimate the reduction in electricity expenditures by federal customers due to implementation of the Initiative. Another approach is to estimate the deferred construction of power plants due to the FRI-induced reduction in federal electricity demand. The approaches are not additive, however, because the costs of power plant construction are capitalized in the price of electricity.

Cumulative delivered electricity savings from the FRI are 0.12 quads. According to the best source of data on federal energy use (DOE 1991), federal customers paid $16.81 per million Btu of electricity. Under the assumption that the real price of electricity remains constant through 2000, the cumulative cost savings to federal customers would total about $2 billion (undiscounted). Cost savings in 2000 would be $0.7 billion (undiscounted); if discounted at 5%, the savings in 2000 would still total $0.4 billion. To provide some perspective, the year 2000 cost savings would represent about a 20% decrease in electricity expenditures for federal buildings.

Alternatively, the impact of the Initiative could be estimated as deferring the need to construct new electric power plants. To estimate the potential avoided capacity from the FRI, the following equation applies (Secrest and Nicholls 1990):

$$\text{kilowatts of Capacity} = (\text{Trillion Btu Savings})/(3412\ \text{Btu/kWh})/(8760\ \text{hours/year})/(\text{Capacity Factor})$$

Capacity factors for coal run in the range of 0.55 (Secrest and Nicholls 1990). Using this factor in the above equation with the cumulative delivered savings yields 7.3 MW of deferred capacity over the 1990-2000 time frame. This is equivalent to seven 1000 Megawatt plants.

The economic value of this capacity can be estimated from the recent cost of installed capacity for new fossil-fueled steam electric plants larger than 300 MW in capacity. According to EIA, the installed capacity cost for new fossil-fueled plants was $960/kW in 1988 (EIA 1990). The value of the deferred capacity due to the FRI would therefore be in the neighborhood of $7 billion (undiscounted), assuming this cost remains constant for the 1990s.

CONCLUSIONS

The Federal Relighting Initiative -- indeed, the entire Federal Energy Management Program -- can have significant positive effects on this nation's economy and environment. Reduced federal demand for electricity would lower the federal energy bill by $700 million and could avoid the need to construct about seven 1000 MW fossil-fired electric plants. And reduced electricity demand could reduce the emissions and other environmental effects of fossil-fired electricity generation. This paper discussed CO_2 and heavy metals, but other pollutants (SO_2 and NO_x) as well as environmental impacts of coal mining and transportation would also be reduced.

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NOTES

1. Pacific Northwest Laboratory is operated for the U.S. Department of Energy by the Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

2. The regulations include Executive Order 12759, 10 CFR 436, Public Law 101-615, and the Federal Property Management Regulations (10 CFR 101).

3. In primary terms, the federal sector consumed 1.9 quads, or about 2.5% of national energy consumption in 1990.

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