ECONOMIC ANALYSIS OF PROPOSED AMENDMENT TO CANADA'S ENERGY EFFICIENCY REGULATIONS – ELECTRIC MOTORS

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Under the auspices of the *Energy Efficiency Act*[1], the Government of Canada is proposing an amendment to the *Energy Efficiency Regulations*[2,3] for integral horsepower electric motors. The amendment specifies revisions to: the definition of electric motor, the reporting requirements of dealers, and the minimum energy-efficiency standards for 1 to 200 horsepower electric motors relative to the regulations which came into effect on February 3, 1995. This paper addresses the analysis of the revisions to the minimum energy-efficiency standards proposed in the amendment.

Before discussing the analysis, it is important to provide an overview of Canada's regulatory process. In this regard, Canada is guided by five factors when choosing products and levels for regulation. These factors include:

- harmonization with standards set by other regulating agencies - primarily the provinces, territories, and the United States;
- operational matters such as consensus on testing approaches, availability of laboratory and certification facilities, and national distribution of production;
- the impact on Canadian manufacturers;
- the economic attractiveness of more energy-efficient models of a product; and
- maximum energy savings and reduction in carbon dioxide (CO_2) emissions.

The issue of harmonization with other north american jurisdictions is an important element of the regulatory process. This is certainly true for electric motors, in light of the fact that electric motor manufacturers producing for the Canadian market are currently subject, in the provinces of Ontario, British Columbia, Nova Scotia and New Brunswick, to the same energy efficiency standards as those contained in the amendment. Furthermore, almost all of the motors and associated efficiency levels covered by this amendment will come into effect in the United States in October 1997.

The Canadian regulatory process deals with operational matters and the impact on manufacturers through consultations with dealers. Extensive workshops and meetings have been undertaken with dealers of electric motors.

In terms of economic, energy savings and environmental analysis, Canada follows a similar approach to that of the United States. Analysis is undertaken to assess:

- the economic attractiveness of more energy efficient levels;
- the aggregate energy savings associated with the implementation of minimum energy efficiency standards; and
- the aggregate reduction in CO_2 emissions resulting from energy savings associated with the implementation of minimum energy efficiency standards.

The analysis undertaken in support of the *Energy Efficiency Regulations* requires extensive data collection. As such, Natural Resources Canada engages technical consultants to obtain the required data inputs to the analysis. Examples of these data inputs include:

- benchmark information: including data pertaining to the costs, unit energy use or efficiency rating, size or capacity, expected life, design features and technologies relevant to products characterized by the least efficient product available for sale in Canada;

- technology information: including the incremental costs and energy savings associated with energy efficiency improvements to benchmark products;
- comprehensive descriptions of technologies which can be compared to technologies contained in the benchmark, including the nature or application of the technologies, ease with which they could be implemented, advantages and disadvantages (i.e., technological, economic and environmental) associated with implementation and use, manufacturers' concerns, and impacts on the consumer; and
- market information including: distribution of annual sales by energy use or efficiency rating, penetration rates, and latitude for improvements in energy efficiency.

ECONOMIC ANALYSIS

This section discusses the analysis that was undertaken to determine the economic attractiveness to society of improving the minimum energy efficiency of 1 to 200 horsepower electric motors to levels proposed for federal regulation in Canada. Table 1 presents the minimum levels of efficiency proposed for regulation of electric motors. The levels presented in Table 1 coincide with those currently regulated in the provinces of Ontario, British Columbia, Nova Scotia and New Brunswick, as well as those to be regulated in the United States in October 1997.

Scope of Analysis

The proposed amendment to the *Energy Efficiency Regulations* covers common motor types as well as nine specific types of motors. The analysis of the most common types of electric motors was undertaken in a comprehensive manner in that it addressed nineteen sizes, ranging from 1 to 200 horsepower, and 3 speeds (1200 (6 pole), 1800 (4 pole) and 3600 (2 pole) revolutions per minute (RPM)), for two motor enclosure types: totally enclosed fan cooled (TEFC) motors; and open drip proof (ODP) motors. A total of 112 configurations were analyzed.

Of the nine specific types of motors proposed for inclusion in the amendment, four of these (IEC or metric motors, close coupled motors, vertical pump motors, and explosion proof motors) were subjected to a net benefits analysis — a total of 53 configurations were analyzed. The economics of the remaining five motor categories (flange mounted motors, non-standard voltage motors, washdown duty motors, gear motors, and brake motors) were addressed qualitatively.

The data[4] used in the analysis of the most common types of electric motors were based on the six largest suppliers of electric motors to Canada: General Electric, Westinghouse, Toshiba, WEG (distributed by V.J. Pamensky), Leeson, and U.S. Electric Motors. It is estimated that these six companies collectively account for approximately 70 to 80 percent of new integral horsepower motor sales in Canada.

The data[5] used to conduct the analysis of the specific types of motors relied on a variety of data sources, including existing computer databases as well as "expert judgement".

Methodology and Assumptions

The economic attractiveness of electric motors was analyzed using Natural Resources Canada's Equipment Technology Database and Economic Analysis Program. The Equipment Technology Database contains cost and energy savings data associated with technologies more efficient than the benchmark products. The Economic Analysis Program, designed to interface directly with the Equipment Technology Database, is used to extract the appropriate costs and energy savings data for purposes of calculating economic and financial indicators (*i.e.*, the micro analysis).

The analytical methodology is that of a benefit-cost analysis, in which the net present value (or net benefits) was chosen as the indicator of economic attractiveness. The net present value is calculated by subtracting the present value of incremental costs (referred to below as incremental capital prices) from the present value of incremental benefits over the useful life of the motor. The incremental cost represents the price differential between the least efficient product available for sale in Canada and products with levels of efficiency which would meet the proposed higher standard. The incremental benefits represent the value of energy savings associated with the efficiency improvement.

A net present value that is negative indicates the efficiency improvement is not economically attractive, whereas a net present value that is greater than zero indicates the efficiency improvement is economically attractive. A net present value equal to zero does not provide a definitive indication of economic attractiveness.

Table 1
Proposed Minimum Energy Efficiency Standards for
Integral Horsepower Electric Motors in Canada
(Percent)

Horsepower	1200 rpm	1800 rpm	3600 rpm
1.0	80.0	82.5	75.5
1.5	85.5	84.0	82.5
2.0	86.5	84.0	82.5
3.0	87.5	87.5	85.5
5.0	87.5	87.5	87.5
7.5	89.5	89.5	88.5
10.0	89.5	89.5	89.5
15.0	90.2	91.0	90.2
20.0	90.2	91.0	90.2
25.0	91.7	92.4	91.0
30.0	91.7	92.4	91.0
40.0	93.0	93.0	91.7
50.0	93.0	93.0	92.4
60.0	93.6	93.6	93.0
75.0	93.6	94.1	93.0
100.0	94.1	94.5	93.6
125.0	94.1	94.5	94.5
150.0	95.0	95.0	94.5
200.0	95.0	95.0	95.0

Assumptions for Base Case Analysis

The economic analysis involved both base case and sensitivity analyses. The base case scenario assumed a 7% real discount rate and Canada average industrial electricity prices, based on Natural Resources Canada's official energy supply demand outlook (*Canada's Energy Outlook 1992 - 2020: Update 1994*).

Other key base case assumptions include:

- benefits and costs measured in real $1993;
- incremental motor prices based on a 30% discount of full list price for the commonly stocked motors

and 25% for specific type motors;
- duty cycle: 4,000 hours of operation per year;
- motor load factor: 75%; and
- useful life: 15 years.

Cross-effects (i.e. the partial offset of energy savings associated with the proposed amendment by a net increase in the energy required for space conditioning) were not addressed in the net benefits analysis or the aggregate energy savings analysis, since it was judged that research findings on this issue to date are inconclusive.

Capital Pricing

Although manufacturers publish full list prices for electric motors, they rarely sell them at such rates. Depending on the size of the purchase, motor prices can vary from full list price to discounts of 25 percent, 30 percent, 50 percent and 70 percent. In general, large industrial customers normally purchase in significant quantities and typically deal directly with the motor manufacturer to obtain discounts in the range of 40 to 55 percent. Smaller industrial customers or commercial accounts would normally expect discounts in the order of 30 percent.

In light of the fact that it is difficult to determine which motors are used in commercial versus industrial applications, we chose the more conservative approach to capital pricing. In this regard, a 30 percent discount of full list price was incorporated in the base case analysis for all common types of motors and 25 percent of full list price for all specific types of motors.

Duty Cycles

The greater the duty cycle, the greater is the potential to save energy. The duty cycle or annual hours of operation for motor use can vary from 2,500 to over 8,000. The annual operation for large industrial plants, which operate on a continuous shift basis, amounts to 8,400 hours. The duty cycle for a 2 shift manufacturing operation is 4,000 hours per year. Furthermore, a B.C. Hydro study[6] found that the average duty cycle for all industrial applications to be 6,250 hours per year. Typical operating periods for commercial applications are generally estimated to be about 4,000 hours per year. Although likely conservative, a duty cycle of 4,000 hours was adopted in the base case analysis.

Motor Load Factor

Average Canadian motor load factors for commercial and industrial applications are in the range of 75 percent to 80 percent. In keeping with relatively conservative assumptions, an average motor load factor of 75 percent was adopted in the base case analysis.

Useful Life

The effective operating life of electric motors is in the range of 15 to 20 years, depending on application. For purposes of this analysis, fifteen years was chosen as the useful life. Although improved quality of design and materials can lead to longer life expectancy and increased resistance to power quality problems in more energy efficient motors, this was not considered in the analysis.

Examples of improvements in design and materials include:
- more copper in stator windings;
- low-loss silicon steel and thinner laminations in the stator core;
- longer rotor core;
- optimized air gap between rotor and stator core;
- improved bearings and seal design;
- higher quality insulation material; and
- optimized fan and air flow design.

Sectoral Electricity Prices

Another important factor which influences the results of the analysis is the choice of energy prices. Although some motor applications are concentrated in the commercial sector, we do not have data which would allow us to disentangle commercial motor types from industrial. In keeping with the above assumptions pertaining to capital pricing, duty cycles, motor load factor and useful life we chose the conservative approach where energy prices are concerned. As mentioned earlier, Canada average industrial electricity prices were assumed in the base case. One should keep in mind that Canada average commercial electricity prices can be one-third to almost 50 percent greater than industrial prices. In this regard, the economic attractiveness of motor technologies would be significantly improved by applying commercial prices to the energy savings.

Assumptions for Sensitivity Analysis

In addition to the base case, sensitivity analyses were carried out on the following: discount rate, energy prices, incremental capital prices, duty cycles and combinations of the above. All sensitivity analyses were calculated from the base case.

Under the discount rate sensitivity analysis, the base case was re-evaluated under five and ten percent real discount rates.

Under the energy price sensitivity, Canada average industrial electricity prices were substituted with the range of industrial electricity prices projected across Canada, according to *Canada's Energy Outlook 1992 - 2020: Update 1994*.

In the combined energy price and discount rate sensitivity analysis, the base case was re-evaluated under two extreme scenarios. The first scenario is extremely optimistic in that it combined high energy prices with the low discount rate (5%), thus enhancing the present value of the energy savings relative to the base case. The second (extremely conservative) scenario, had the opposite effect in that it combined low energy prices with the high discount rate (10%). In the capital pricing sensitivity analysis, the following capital pricing regimes were analyzed: full list price, and discounts of 50 percent and 70 percent.

The sensitivity analysis associated with duty cycles considered 2,500 and 6,250 hours of operation per year.

Results of Economic Analysis

The results of the net benefits analysis are presented in tables 2 through 4. Table 2 presents the base case results, measured in terms of net present values, for TEFC motors. Table 2 indicates that all motor configurations are economically attractive.

Table 3 presents the base case results for ODP motors. As was the case for TEFC motors, all ODP motor configurations were found to be economically attractive under base case assumptions.

Table 4 presents the base case results for four specific types of motors: IEC or metric motors, close coupled motors, vertical pump motors, and explosion proof motors. IEC motors are not offered in a full range of sizes. Furthermore, the analysis addressed the most common motor type (TEFC) and speed (1800 RPM) for the 11 sizes available on the market. The results of the IEC motors analysis are economically attractive for all 11 sizes.

Data availability limited the analysis of close coupled motors to the 1 - 15 horsepower size range. Similar to IEC motors, the analysis focussed on the dominant type (ODP) and speed (1800 RPM). The results of the close coupled motors analysis are economically attractive for the 8 sizes analyzed.

The analysis of vertical pump motors addressed the most common (1800 RPM TEFC) application. The results are economically attractive for the 16 sizes analyzed.

The results of the net benefits analysis for explosion proof motors, which focussed on the most common (1800 RPM TEFC) application, are economically attractive for all sizes.

For reasons discussed below, economic analysis was not undertaken for the remaining four specific motor categories (flange mounted motors, non-standard voltage motors, washdown duty motors, gear motors, and brake motors) proposed for inclusion in the amendment.

Table 2
Summary of Net Benefits Analysis:
TEFC Motors
(Net Percent Value $1993)

Horsepower	1200 rpm	1800 rpm	3600 rpm
1.0	12.14	21.54	139.37
1.5	60.46	50.24	54.29
2.0	74.22	24.99	106.44
3.0	122.94	157.17	108.84
5.0	142.08	155.20	232.60
7.5	124.83	233.87	394.12
10.0	189.12	187.75	237.29
15.0	454.62	440.67	550.60
20.0	661.61	522.54	769.73
25.0	749.42	543.91	727.38
30.0	797.27	614.28	1068.25
40.0	978.50	663.52	1481.51
50.0	1210.87	611.39	1312.13
60.0	1079.91	530.56	1508.84
75.0	489.51	1165.07	1236.56
100.0	681.77	1124.36	1434.51
125.0	1629.34	1094.88	1990.77
150.0	644.26	940.30	1868.93
200.0	4105.97	460.52	616.28

Economic analysis was not undertaken for flange mounted motors because the principal difference between this category of motors and the more common foot mounted motors is in the external mounting hardware, which has little or no effect on motor efficiency.

Non-standard voltage motors were not subjected to economic analysis because the design voltage of a motor can be changed by selection of the wire size and the number of turns in the winding without any significant effect on efficiency.

Except for the use of seals, which may increase windage friction losses, the design of washdown duty motors is virtually identical to the more common types of motors. Lack of data did not permit a net benefits analysis.

As in the case of flange mounted motors, the motor portion of a gear motor is typically a common design. Furthermore, the very wide range of possible combinations of torque-speed reducer types makes it virtually impossible to define appropriate efficiency and price data to conduct a net benefits analysis.

Shaft length is the only difference between brake motors and standard NEMA "T" frame motors. Because the longer shaft associated with brake motors does not impact on energy efficiency, these products were not subjected to a net benefits analysis. The results of the analysis, which applies relatively conservative assumptions concerning capital pricing, duty cycles and sectoral energy prices, show that on average there are positive net economic benefits to Canada from adopting the proposed efficiency standards.

Table 3
Summary of Net Benefits Analysis:
ODP Motors
(Net Present Value $1993)

Horsepower	1200 rpm	1800 rpm	3600 rpm
1.0	n.a.	47.31	n.a.
1.5	68.91	139.53	50.64
2.0	73.42	105.53	131.48
3.0	132.16	173.50	161.52
5.0	167.57	241.61	224.08
7.5	287.69	281.20	208.95
10.0	180.92	446.12	394.49
15.0	235.71	297.50	235.71
20.0	507.71	595.06	771.56
25.0	1011.57	327.91	393.03
30.0	1031.49	541.40	1805.90
40.0	983.17	1293.93	758.18
50.0	1497.99	1359.50	707.57
60.0	1354.61	1722.86	776.54
75.0	1706.04	2712.58	1339.46
100.0	1847.32	2718.15	1245.89
125.0	2102.25	2337.43	2809.51
150.0	1995.37	2804.60	2585.59
200.0	2104.82	2945.67	1808.55

n.a.: data not available to conduct analysis

Table 4
Summary of Net Benefits Analysis:
Specific Motor Types
(Net Present Value $1993)

Horsepower	IEC (Metric) 1800 rpm TEFC	Close Coupled 1800 rpm ODP	Vertical Pump 1800 rpm TEFC	Explosion Proof * 1800 rpm TEFC
1.0	102.76	70.79	n.a.	55.44
1.5	153.00	90.65	n.a.	62.13
2.0	123.01	64.96	n.a.	39.32
3.0	286.44	340.55	237.96	388.50
5.0	160.63	461.31	156.78	345.94
7.5	265.86	606.54	389.72	407.91
10.0	369.95	788.78	560.53	315.00
15.0	424.75	485.08	429.72	1202.53
20.0	521.91	n.a.	634.34	1084.94
25.0	576.46	n.a.	848.98	1147.92
30.0	651.07	n.a.	981.51	595.35
40.0	n.a.	n.a.	1532.51	1704.56
50.0	n.a.	n.a.	1688.65	1534.62
60.0	n.a.	n.a.	1909.73	2116.45
75.0	n.a.	n.a.	1456.54	1370.31
100.0	n.a.	n.a.	1979.67	4107.43
125.0	n.a.	n.a.	2005.56	6274.73
150.0	n.a.	n.a.	3363.50	6413.46
200.0	n.a.	n.a.	840.21	n.a.

n.a.: data not available to conduct analysis
* Based on use in hazardous applications (eg. in petro chemical and mining industries) the duty cycle for explosion proof motors is assumed to be 6,250 hours of operation per year.

ENERGY/CO_2 ANALYSIS

Methodology and Assumptions

The energy savings impacts associated with the amendment were calculated using Natural Resources Canada's energy end-use models. The aggregate energy savings were determined by comparing the 'business as usual' case (*i.e.*, excluding the proposed amendment) and the impact case (*i.e.*, the business as usual scenario including the proposed amendment) for the commercial and industrial sectors.

The reductions in CO_2 emissions were calculated by applying emissions factors, consistent with those published by Environment Canada, to the marginal fuels used to generate the electricity that would be saved through the amendment. This analysis was done on a provincial basis to reflect regional differences in the mix of fuels to produce electricity.

Results

The impact of the amendment, in terms of aggregate annual energy savings, is presented in Table 5. The sectoral results are presented for the years 2000, 2005, 2010 and 2020. As indicated in Table 5, 4.3 petajoules of energy would be saved in the year 2000. Energy savings would continue to increase through 2020 as sales of new motors steadily replace the pre-regulation stock. Furthermore, expansion of the stock (i.e., associated with new construction) would enter the market at the higher efficiencies prescribed through regulation. Approximately 17.7 petajoules of energy would be saved in the year 2020.

The estimated annual reductions in CO_2 emissions, resulting from the aggregate energy savings, are presented in Table 6. As shown in Table 5, the estimated reduction in CO_2 amounts to 0.56 megatonnes in the year 2000 and increases to 2.14 megatonnes in the year 2020.

Table 5
Aggregate Energy Savings
(Petajoules)

	2000	2005	2010	2020
Commercial Sector	2.1	4.6	6.8	6.7
Industrial Sector	2.2	5.9	9.5	11.0
Total Energy Savings	4.3	10.5	16.3	17.7

Table 6
Reduction in Carbon Dioxide Emissions
(Megatonnes)

	2000	2005	2010	2020
Total Reduction in CO_2 Emissions	0.56	1.33	2.03	2.14

REFERENCES

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