



BNM M04: Electric Motors Government Standards Evidence Base 2009: Best Available Technology Scenario

Version 1.1

This Briefing Note and referenced information is a public consultation document and will be used to inform Government decisions. The information and analysis forms part of the Evidence Base created by Defra's Market Transformation Programme.

1 Introduction

- The Best Available Technology (BAT) Scenario is a hypothetical projection of what would happen if the best available technologies on the (current and future) market were bought or installed from now on.
- The best available technologies are defined as the most efficient, or lowest energy consuming technologies available on the market, or those which are close to market (where the development stage is completed, but it is not necessary available as a designed product).

1.1 Product definition

- Electric motors are machines that convert electrical energy into mechanical energy for powering various types of equipment. There are many motor designs available on the market, which range in size from a few watts (W) through to several megawatts (MW). Electric motors considered by MTP include those typically used in industry and commercial applications and that are applied to pumps, fans, compressors, materials handling, lifting and hoisting and other applications.
- The primary motor types considered under the Government Standards include AC induction, DC, permanent magnet, and switched reluctance designs. The range considered includes motors:
 - in the size range 0.75 – 400kW
 - with a rated voltage (U_N) up to 1000V.

- Electric motor efficiency is defined as the ratio of electrical input power supplied to the motor to the mechanical output power delivered at the motor shaft. The International Electrotechnical Commission (IEC) labelling standard IEC 60034-30 classifies fixed speed AC induction motors into four efficiency classes, namely IE1 through IE4, where IE1 is the least efficient and IE4 the most efficient. This standard supersedes the CEMEP (Comité Européen de Constructeurs de Machines Electriques et d'Electronique de Puissance) motor labelling scheme where motors were labelled EFF3 through EFF1, where EFF3 was the least efficient and EFF1 the most efficient. The EFF1 and IE2 classes are roughly equivalent.
- Government Standards also cover electric motor controls, and specifically variable speed drives (VSDs) (also known as adjustable speed drives (ASDs)). These adapt the electrical power supplied to the electric motor in order to control the mechanical power output according to the characteristics of the load being driven by the motor

2 Scenario outputs

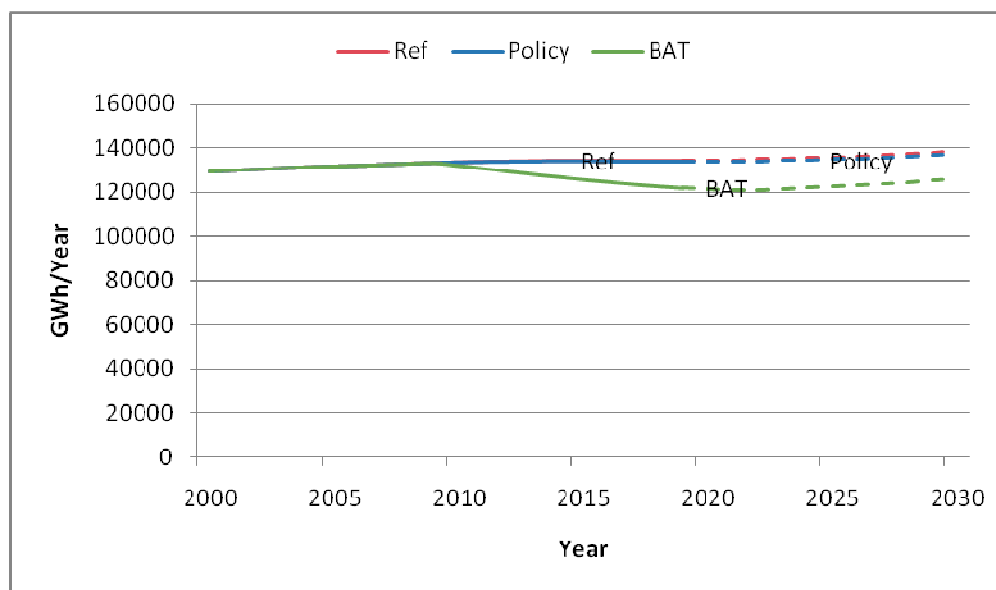


Figure 1: Total energy consumption, electric motors (0.75 – 400 kW)

- The outputs of the BAT Scenario are provided in Table 1.

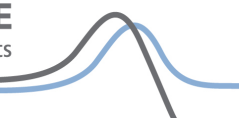


Table 1 BAT Scenario summary energy consumption¹ and carbon emissions² and savings, all electric motors (0.75 – 400 kW)

Energy Consumption (GWh)	2009	2020	2030
PM&SR-more-than-30	0	13570	15520
Induct-3to4	22070	11360	10820
Induct-5to11	45040	23440	22480
Induct-15to30	10000	5240	5050
Induct-37to132	35010	18490	17920
Induct-075to2	9040	4610	4360
Induct-150to400	530	280	280
AC&DC-075to30	2220	2380	2550
AC&DC-more-than-30	9390	10090	10810
PM&SR-075to30	10	31920	36500
TOTAL	133320	121390	126290
Energy Savings (GWh)			
PM&SR-more-than-30	0	-13170	-14340
Induct-3to4	0	10290	10860
Induct-5to11	0	21230	22440
Induct-15to30	0	4730	5010
Induct-37to132	0	16680	17650
Induct-075to2	0	4180	4410
Induct-150to400	0	260	270
AC&DC-075to30	0	0	0
AC&DC-more-than-30	0	0	0
PM&SR-075to30	0	-30980	-33730
TOTAL	0	13210	12560
CO₂ Emissions (MtCO₂)			
PM&SR-more-than-30	0.00	5.84	6.67
Induct-3to4	9.49	4.89	4.65

¹ Energy consumption figures for the non-domestic sector in the 2009/2010 Product policy analysis and projections document 'Saving energy through better products and appliances' were scaled down to match DECC projections for overall energy demand (www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx).

MTP data represents the best currently available information based on a bottom-up modelling approach. MTP's data is the basis for detailed energy calculations in the 2009/2010 Product policy analysis and projections document. However, DECC projections indicate that overall energy demand in the non-domestic sector is lower than projected by MTP's detailed models. MTP has assumed that the differences between the DECC overall projections and its detailed bottom-up projections are due to incomplete data on the following inputs for some of its non-domestic products:

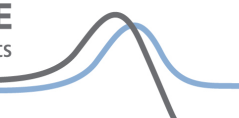
- existing product stock;
- existing product efficiency;
- product usage.

The energy consumption figures in these GSBNs have **not** been scaled down, in order to enable constructive stakeholder comment on the MTP input data, and therefore differ from the ones presented in the 2009/2010 Product policy analysis and projections document.

² Refer to BNXS01 Carbon Dioxide Emission Factors for UK Energy Use for more details on factors used.

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Energy Consumption (GWh)	2009	2020	2030
Induct-5to11	19.37	10.08	9.67
Induct-15to30	4.30	2.25	2.17
Induct-37to132	15.06	7.95	7.71
Induct-075to2	3.89	1.98	1.88
Induct-150to400	0.23	0.12	0.12
AC&DC-075to30	0.95	1.02	1.10
AC&DC-more-than-30	4.04	4.34	4.65
PM&SR-075to30	0.01	13.72	15.69
TOTAL	57.33	52.20	54.30
CO ₂ Emissions Savings (MtCO ₂)			
PM&SR-more-than-30	0.00	-5.67	-6.17
Induct-3to4	0.00	4.43	4.67
Induct-5to11	0.00	9.13	9.65
Induct-15to30	0.00	2.03	2.15
Induct-37to132	0.00	7.17	7.59
Induct-075to2	0.00	1.80	1.89
Induct-150to400	0.00	0.11	0.12
AC&DC-075to30	0.00	0.00	0.00
AC&DC-more-than-30	0.00	0.00	0.00
PM&SR-075to30	0.00	-13.32	-14.50
TOTAL	0.00	5.68	5.40

3 Efficiency

3.1 Summary

- Table 2 presents a summary of typical efficiencies per efficiency class of electric motors when grouped by motor type and size range.
- The efficiency groups (EFF3 through IE4) are aligned with the efficiency classes described in the International Electrotechnical Commission (IEC) labelling standard IEC 60034-30 for fixed speed motors and the historical CEMEP motor labelling scheme.
- A further group of variable speed motors is defined; the efficiency values presented comprise the efficiency of both the motor and associated electronic controller, and it is assumed that on average the efficiency of this combination is 6% less than the fixed speed equivalent.
- Table 3 presents the split of electric motor sales by motor type and efficiency class for the years 2009 – 2030 for AC induction and permanent magnet & switched



reluctance motors. These motors account for 92% of total sales, the remaining 8% made up of 'other AC & DC motors'. Sales and efficiencies of 'other AC & DC motors' remain unchanged across the Reference, Policy and BAT scenarios.

- Table 4 presents the average efficiency of electric motors sold according to the size groupings and by key years. The average efficiency has been obtained by multiplying the distribution in sales by efficiency class for each motor type by the corresponding average efficiency of the respective motor (Table 2).

Table 2 Efficiency metrics for electric motors (0.75 – 400kW)

Motor Type	Size Range (kW)	Average Efficiency (%) (Fixed Speed Motors)					Average Efficiency (%) (Variable Speed Motors, including controllers)				
		EEF3	IE1	IE2	IE3	IE4	EEF3	IE1	IE2	IE3	IE4
AC Induction	0.75-2.2	75.3	80.0	85.2	86.9	88.4	69.3	74.0	79.2	80.9	82.4
	3-4	79.3	83.5	87.6	89.2	90.4	73.3	77.5	81.6	83.2	84.4
	5.5-11	83.0	86.8	89.6	91.1	92.1	77.0	80.8	83.6	85.1	86.1
	15-30	85.9	90.0	92.1	93.2	94.0	79.9	84.0	86.1	87.2	88.0
	37-132	88.8	93.2	94.5	95.3	95.8	82.8	87.2	88.5	89.3	89.8
	150-400	90.5	95.3	95.9	96.2	96.6	84.5	89.3	89.9	90.2	90.6
Other AC & DC	0.75-30	-	-	-	-	-	77.4	80.7	84.1	85.3	86.3
	30-400	-	-	-	-	-	83.8	87.3	88.5	89.3	89.8
Permanent Magnet & Switched Reluctance	0.75-30	-	-	-	-	-	-	-	-	85.3	86.3
	30-400	-	-	-	-	-	-	-	-	89.3	89.8

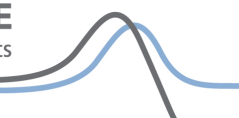


Table 3 Split of electric motor sales by efficiency class, AC induction and PM & SR motors (0.75 – 400kW), % sales

	Fixed Speed Motors					Variable Speed Motors					
	AC Induction					AC Induction					Permanent Magnet & Switched Reluctance
	EEF3	IE1	IE2	IE3	IE4	EEF3	IE1	IE2	IE3	IE4	
2000	11.5	78.7	5.8	0.0	0.0	0.5	3.3	0.2	0.0	0.0	0.0
2001	7.6	80.2	7.6	0.0	0.0	0.4	3.7	0.4	0.0	0.0	0.0
2002	3.8	81.3	9.5	0.0	0.0	0.3	4.7	0.5	0.0	0.0	0.0
2003	0.9	80.0	11.0	0.0	0.0	0.1	7.0	0.9	0.0	0.0	0.0
2004	0.5	77.0	12.6	0.0	0.0	0.0	8.8	1.2	0.0	0.0	0.0
2005	0.4	72.6	15.0	0.0	0.0	0.0	10.4	1.6	0.0	0.0	0.0
2006	0.4	69.2	16.3	0.0	0.0	0.0	12.0	2.0	0.0	0.0	0.0
2007	0.4	66.8	16.8	0.0	0.0	0.0	13.6	2.4	0.0	0.0	0.0
2008	0.4	64.4	17.2	0.0	0.0	0.0	15.1	2.9	0.0	0.0	0.0
2009	0.4	63.3	17.0	0.2	0.0	0.0	15.6	3.2	0.1	0.0	0.2
2010	0.2	28.2	19.9	1.5	0.0	0.0	28.4	19.9	1.5	0.0	0.3
2011	0.1	2.7	41.9	5.0	0.0	0.0	2.9	41.9	5.0	0.0	0.5
2012	0.1	2.7	3.1	0.0	43.7	0.0	2.9	3.1	0.0	43.7	0.6
2013	0.1	2.7	3.1	0.0	43.5	0.0	2.8	3.1	0.0	43.5	1.1
2014	0.1	2.7	3.1	0.0	43.2	0.0	2.8	3.1	0.0	43.2	1.8
2015	0.1	2.7	3.0	0.0	42.6	0.0	2.8	3.0	0.0	42.6	3.3
2016	0.1	2.6	3.0	0.0	42.2	0.0	2.8	3.0	0.0	42.2	4.2
2017	0.1	2.6	3.0	0.0	41.8	0.0	2.7	3.0	0.0	41.8	4.9
2018	0.1	2.6	2.9	0.0	41.5	0.0	2.7	2.9	0.0	41.5	5.7
2019	0.1	2.6	2.9	0.0	41.2	0.0	2.7	2.9	0.0	41.2	6.3
2020	0.1	2.5	2.9	0.0	40.7	0.0	2.7	2.9	0.0	40.7	7.6
2021	0.1	2.5	2.9	0.0	40.5	0.0	2.6	2.9	0.0	40.5	8.0
2022	0.1	2.5	2.9	0.0	40.2	0.0	2.6	2.9	0.0	40.2	8.7
2023	0.1	2.5	2.8	0.0	39.8	0.0	2.6	2.8	0.0	39.8	9.5
2024	0.1	2.5	2.8	0.0	39.5	0.0	2.6	2.8	0.0	39.5	10.2
2025	0.1	2.5	2.8	0.0	39.4	0.0	2.6	2.8	0.0	39.4	10.4
2026	0.1	2.5	2.8	0.0	39.5	0.0	2.6	2.8	0.0	39.5	10.3
2027	0.1	2.5	2.8	0.0	39.3	0.0	2.6	2.8	0.0	39.3	10.7
2028	0.1	2.5	2.8	0.0	39.3	0.0	2.6	2.8	0.0	39.3	10.6
2029	0.1	2.4	2.8	0.0	39.1	0.0	2.6	2.8	0.0	39.1	11.1
2030	0.1	2.4	2.8	0.0	38.9	0.0	2.5	2.8	0.0	38.9	11.5

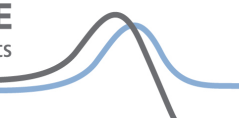


Table 4 Average sales-weighted electric motor efficiency by motor size

Motor Type	Average Efficiency (%) - (Fixed Speed Motors)						Average Efficiency (%) - (Variable Speed Motors)									
	AC Induction						AC Induction						Permanent Magnet & Switched Reluctance		Other AC & DC	
Motor Size Group (kW)	0.75-2.2	3-4	5.5-11	15-30	37-132	150-400	0.75-2.2	3-4	5.5-11	15-30	37-132	150-400	0.75-30	30-400	0.75-30	30-400
2009	81.1	84.4	87.4	90.4	93.5	95.4	74.9	78.2	81.3	84.3	87.5	89.4	85.4	89.3	81.4	87.5
2010	82.3	85.3	88.1	90.9	93.8	95.5	76.3	79.3	82.1	84.9	87.8	89.6	85.4	89.3	81.4	87.5
2015	87.7	89.8	91.6	93.6	95.5	96.5	81.7	83.8	85.6	87.6	89.6	90.5	85.4	89.3	81.5	87.5
2020	87.7	89.8	91.6	93.6	95.5	96.5	81.7	83.8	85.6	87.6	89.6	90.5	85.4	89.3	81.5	87.5
2030	87.7	89.8	91.6	93.6	95.5	96.5	81.7	83.8	85.6	87.6	89.6	90.5	85.4	89.3	81.7	87.6

3.2 Data sources – efficiency & sales weighting

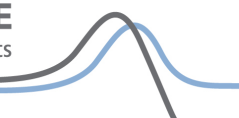
Table 5 Efficiency & sales weighting data sources

Year	Reference	Reference date	Author	Justification	Confidence in sources (High/Low)
2003	BSRIA UK Motor Market Survey (2003)	2004	BSRIA	Most authoritative data available	High
2009	Expert assumption - changes in sales split	2009	MTP expert opinion	Based on knowledge of market	Medium
1999	www.cemep.org	1999	CEMEP	Industry standard	High

Note: Historic data sources are included in BNM MO2 – Reference Scenario

3.3 Methodology & key assumptions – efficiency & sales weighting

- Methodology & key assumptions for historic data are included in BNM M02: Reference Scenario



3.3.1 Future analysis

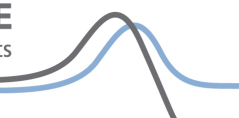
Table 6 Extrapolation & background calculations – efficiency & sales weighting

Year	Methodology & assumptions
2009-2030	<p>Fixed speed motor efficiency values are based on the IEC 60034-30 efficiency classification system and the CEMEP labelling system. Variable speed efficiency values are aligned with the fixed speed values but assume a 6% drop in each efficiency class due to energy losses associated with variable speed drives. Weighted efficiency values are calculated using sales weighted values (based on BSRIA data) for the efficiencies in each motor size category.</p> <p>Motor efficiencies in each size group are assumed to remain constant over time although the sales of each efficiency class vary over time, resulting in a change in sales-weighted average efficiency of motors sold.</p> <p>All data are centred around the BSRIA motor Market study (2003) and growth pre and post 2003 have been extrapolated from this point, based on anecdotal evidence from the market.</p> <p>From 2012 41% of induction motors supplied are IE4 rated, and these are supplied into fixed speed and variable speed applications. Permanent magnet and switched reluctance motors have efficiencies matching IE4 levels and these technologies take market share from induction motors, climbing from less than 1% in 2009 to over 7% by 2020.</p>

3.4 Data issues – efficiency & sales weighting

Table 7 Data issues – efficiency & sales weighting

Issue/risk	Approach taken/rationale
MTP does not have stock or sales data on new motor types - permanent magnet and split reluctance. There are little market data on these emerging technologies.	Expert assumptions made on sales growth rate for these motor types. It is assumed these motor types will take market share from AC induction motors.



Related MTP information

- BNM M01: Electric Motors Government Standards Evidence Base 2009: Key Inputs
- BNM M02: Electric Motors Government Standards Evidence Base 2009: Reference Scenario
- BNM M03: Electric Motors Government Standards Evidence Base 2009: Policy Scenario
- BNM M05: Electric Motors Government Standards Evidence Base 2009: Key Outputs

Changes from previous version

- Minor changes to the template.

Consultation and further information

Stakeholders are encouraged to review this document and provide suggestions that may improve the quality of information provided, email info@mtprog.com quoting the document reference, or call the MTP enquiry line on +44 (0) 845 600 8951.

For further information on related issues visit <http://efficient-products.defra.gov.uk>