



BNM M02: Electric Motors Government Standards Evidence Base 2009: Reference Scenario

Version 1.1

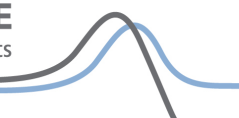
This Briefing Note and referenced information is a public consultation document and will be used to inform Government decisions. The information and analysis forms part of the Evidence Base created by Defra's Market Transformation Programme.

1 Introduction

- The Reference Scenario is a projection of what is likely to happen to energy consumption of each product if no new policies are implemented. All agreed and formally signed-off policies are included in the Reference Scenario.
- For cross-cutting policies such as CERT and Building Regulations, which are agreed but where the likely impact for specific products is unknown, assumptions are made about the impact per product, and detailed in the following sections. Where possible, separate projections of the reference line are made with and without such policies.

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

- The outputs of the Reference Scenario are provided in Table 1.
- Energy consumption for all motors (i.e. including those motors below 0.75kW and above 400 kW) in 2009 has been calibrated against DUKES¹ figures at 147TWh in 2003 and 149TWh in 2006; consumption in 2009 is estimated at 150TWh. The motors modelled by MTP are assumed to account for 89% of this total consumption (i.e. 133TWh).

Table 1: Reference Scenario energy consumption² and carbon emissions³, electric motors (0.75 – 400 kW)

Energy Consumption (GWh)	2009	2020	2030
PM&SR-more-than-30	0	400	1180
Induct-3to4	22070	21660	21680
Induct-5to11	45040	44680	44920

¹ http://www.dti.gov.uk/energy/inform/energy_stats/electricity/dukes5_1.xls, superseded by: <http://www.berr.gov.uk/energy/statistics/publications/dukes/page45537.html>, and <http://www.berr.gov.uk/files/file47215.xls>

² 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:

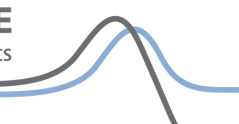
- existing product stock;
- existing product efficiency;
- product usage.

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.

³ Refer to BNXS01 Carbon Dioxide Emission Factors for UK Energy Use for details on factors used.

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Energy Consumption (GWh)	2009	2020	2030
Induct-15to30	10000	9970	10060
Induct-37to132	35010	35170	35570
Induct-075to2	9040	8790	8770
Induct-150to400	530	540	550
AC&DC-075to30	2220	2380	2550
AC&DC-more-than-30	9390	10090	10810
PM&SR-075to30	10	930	2770
TOTAL	133320	134590	138850
CO₂ Emissions (MtCO₂)			
PM&SR-more-than-30	0.00	0.17	0.51
Induct-3to4	9.49	9.31	9.33
Induct-5to11	19.37	19.21	19.32
Induct-15to30	4.30	4.29	4.32
Induct-37to132	15.06	15.12	15.30
Induct-075to2	3.89	3.78	3.77
Induct-150to400	0.23	0.23	0.24
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	0.40	1.19
TOTAL	57.33	57.87	59.71

- Figure 1 below shows a graph of the total energy consumption in TWh for all motors (0.75 – 400 kW) for the period 2000 to 2030 under the Reference Scenario.

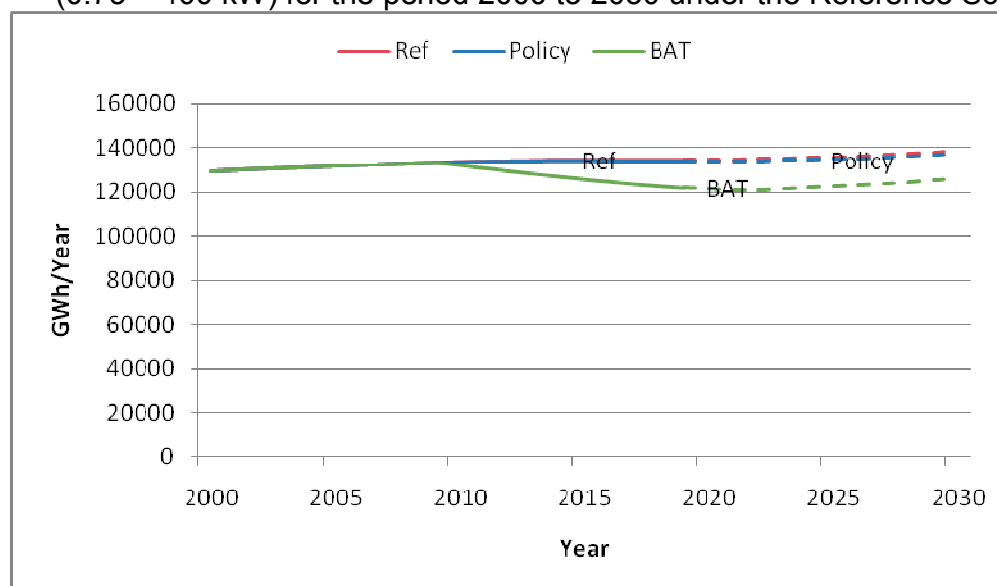
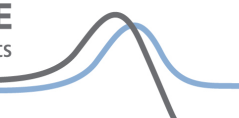


Figure 1: Total energy consumption, electric motors (0.75 – 400 kW)



3 Current policy & measures

Table 2 Current policies & measures, Reference Scenario

Policy name	Period in force	Description	Impact
EU Ecodesign for Energy related Products directive (ErP)	2011 - 2017	Mandatory minimum performance standards for AC induction motors: by 2017, only IE3 motors or IE2 motors which are equipped with a VSD can remain on the market, representing a shift to the most efficient AC motor technology	<p>Stage 1 – June 2011: induction motors with efficiency levels below IE2 are removed from the market</p> <p>Stage 2 – Jan 2015: induction motors sized 7.5kW – 375kW in fixed speed applications with efficiency levels below IE3 are removed from the market</p> <p>Stage 3 – Jan 2017: induction motors sized 0.75kW – 5.5kW in fixed speed applications with efficiency levels below IE3 are removed from the market</p>
Enhanced Capital Allowances (ECA)	2001 ongoing	The ECA scheme covers single speed AC induction motors, integrated motor drive units, variable speed drives and switched reluctance drives. The minimum performance criteria for induction motors are currently set at EFF1 levels (equivalent to IE2).	Sales of EFF1 motor attributed to the ECA scheme have risen from approximately 5% in 2001 and have now reached a plateau at 15%. Further growth is estimated to reach 17% by 2020.
The Government Quick Wins Scheme	2008 ongoing	Where an energy rating of EFF1 (equivalent to IE2) is required.	Less than 1% of sales are attributable to the Quick Wins Scheme, and further growth is anticipated to remain <2% by 2020.
Building Regulations	2006-2010	Encourages greater use of variable speed drives (VSDs) in mechanical ventilation systems (which use fans and electric motors).	Estimated 90% of mechanical ventilation systems now supplied with VSDs, which correlates with 21% of motor sales.
Motor labelling	1999 ongoing	CEMEP (European Committee of Manufacturers of Electrical Machines and Power Electronics) motor labelling scheme has been superseded by IEC labelling standard IEC	On its own, the labelling standard is estimated to have a maximum impact of a <1% increase in take up for the best in class motor categories (currently 'IE2'). The labelling standard does however facilitate other measures such as the ECA scheme and mandatory minimum standards under the Energy using

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Policy name	Period in force	Description	Impact
		60034-30:2008 for ac induction motors, which is a globally harmonised labelling standard.	Products (ErP) Directive.

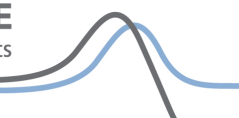
3.1 Policy timeline

- The following policy timeline identifies when policies come into effect, including future revisions that are formally signed off:

Policy name	Current specification in force	2009	2010	2011	2012	2013	2014	2015	2016-2020
EU Ecodesign for Energy related Products directive (ErP)	2011			Minimum levels for AC induction motors set at IE2 levels				Minimum levels for AC induction motors 7.5-375kW set at IE3 levels unless with VSD	
Enhanced Capital Allowances (ECA)	2001	ECAs like all tax reliefs, are kept under review. There is potential for future revision of ECAs to reflect technology development and qualifying products.							
The Government Quick Wins Scheme	May 2008	No future revisions agreed							
Building Regulations	2006	No future revisions agreed							
Motor Labelling Standard	Oct 2008	No future revisions agreed							

Table 3 Test Standards

Test Standard name	Date in force	Description	Comments
IEC60034-2	1996	Test standard for motors	Used in support of the CEMEP



Test Standard name	Date in force	Description	Comments
		including AC induction motors	labelling scheme and the ECA scheme
IEC60034-2-1	Sept 2008	Globally harmonised test standard for motors including AC induction motors. Supersedes IEC60034-2 and includes more accurate measurement methods	Used in support of the IEC labelling standard (IEC 60034-30), ErP and the ECA scheme

4 Efficiency

4.1 Summary

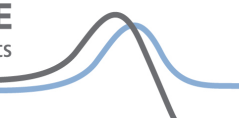
- Table 4 presents a summary of typical efficiencies per efficiency class of electric motors when grouped by motor type and size range.
- The efficiency groups (EFF3 through IE4) are aligned with the efficiency classes described in the International Electrotechnical Commission (IEC) labelling standard 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 5 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 6 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 4)

Table 4 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

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Motor Type	Size Range (kW)	Average Efficiency (%) (Fixed Speed Motors)					Average Efficiency (%) (Variable Speed Motors, including controllers)					
		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 5 Split of electric motor sales by efficiency class, AC induction and PM & SR motors (0.75 – 400kW), % sales

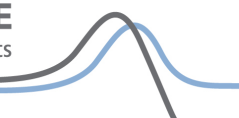
	Fixed Speed Motors					Variable Speed Motors					
	AC Induction					AC Induction					Permanent Magnet & Switched Reluctance
	EEF3	IE1	IE2	IE3	IE4	EEF3	IE1	IE2	IE3	IE4	
2009	0.40	63.26	16.98	0.20	0.00	0.00	15.73	3.22	0.01	0.00	
2010	0.40	61.97	17.15	0.24	0.00	0.00	16.54	3.39	0.01	0.00	0.30
2011	0.39	60.65	17.31	0.31	0.00	0.00	17.44	3.45	0.02	0.00	0.42
2012	0.39	58.96	17.84	0.39	0.00	0.00	18.36	3.50	0.02	0.00	0.55
2013	0.38	57.66	17.97	0.46	0.00	0.00	19.37	3.43	0.05	0.00	0.69
2014	0.38	56.31	18.07	0.53	0.00	0.00	20.87	2.85	0.05	0.00	0.95
2015	0.19	55.15	18.15	0.59	0.00	0.00	21.90	2.72	0.07	0.00	1.23
2016	0.18	53.81	18.22	0.66	0.00	0.00	22.96	2.56	0.08	0.00	1.54
2017	0.18	52.12	18.63	0.72	0.00	0.00	24.01	2.38	0.11	0.00	1.85
2018	0.18	50.88	18.66	0.70	0.00	0.00	24.81	2.46	0.11	0.00	2.19
2019	0.17	49.30	18.68	1.04	0.00	0.00	25.72	2.40	0.14	0.00	2.54
2020	0.17	47.74	18.69	1.36	0.00	0.00	26.65	2.33	0.15	0.00	2.91
2021	0.17	46.66	19.34	1.70	0.00	0.00	26.58	2.33	0.17	0.00	3.05
2022	0.17	46.25	19.65	1.69	0.00	0.00	26.69	2.18	0.17	0.00	3.19
2023	0.17	46.01	19.79	1.69	0.00	0.00	26.62	2.17	0.20	0.00	3.33
2024	0.17	45.44	19.93	2.03	0.00	0.00	26.73	2.03	0.20	0.00	3.47
2025	0.17	44.51	19.76	1.99	0.00	0.00	27.52	2.09	0.24	0.00	3.73
2026	0.17	44.27	19.90	1.99	0.00	0.00	27.44	2.09	0.27	0.00	3.87
2027	0.17	43.38	20.03	2.65	0.00	0.00	27.37	2.08	0.30	0.00	4.02
2028	0.17	43.15	20.17	2.65	0.00	0.00	27.33	2.08	0.30	0.00	4.16
2029	0.16	41.59	19.98	3.25	0.00	0.00	28.13	2.14	0.31	0.00	4.43
2030	0.16	41.36	20.11	3.24	0.00	0.00	28.09	2.14	0.31	0.00	4.58

Table 6 Average sales-weighted electric motor efficiency by motor size

	Average Efficiency (%) - (Fixed Speed Motors)	Average Efficiency (%) - (Variable Speed Motors)
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Motor Type	AC Induction						AC Induction						Permanent Magnet & Switched Reluctance		Other AC & DC	
	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	87.4	89.4	85.4	89.3	81.4	87.5
2010	82.1	85.1	88.0	90.8	93.7	95.5	74.9	78.2	81.3	84.3	87.4	89.4	85.4	89.3	81.4	87.5
2015	85.5	87.9	90.1	93.0	95.1	96.1	79.0	81.4	83.6	86.1	88.5	89.9	85.4	89.3	81.5	87.5
2020	86.4	88.8	90.7	93.0	95.1	96.1	79.2	81.6	83.7	86.1	88.5	89.9	85.4	89.3	81.5	87.5
2030	86.4	88.8	90.7	93.0	95.1	96.1	79.2	81.6	83.7	86.1	88.5	89.9	85.4	89.3	81.7	87.6

4.2 Data sources – efficiency & sales weighting

Table 7 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	Interpretation of expert knowledge of market.	2009	MTP expert opinion	Based on knowledge of market	Medium
1999	www.cemep.org	1999	CEMEP	Industry standard	High
2008	IEC 60034-30 Ed.1 test standard	September 2008	IEC	Motor efficiency classification industry standard	High

4.3 Methodology & key assumptions – efficiency & sales weighting

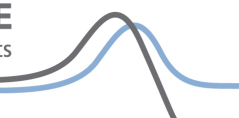
4.3.1 Historic data

Table 8 Interpolation & background calculations – efficiency & sales weighting

Year	Methodology & assumptions
1960 - 2008	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.

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Year	Methodology & assumptions
	<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>EFF3 motors dominate the market from 1960 until 1989, after which the IE1 (EFF2) class start to take market share. In 1999 the European motor manufacturers introduced the CEMEP labelling scheme and committed to removing EFF3 motors from the market. Since 2000, IE2 has started to take small market share, supported by the ECA scheme. Take up of IE2 has started to plateau since 2005 and future growth is assumed to be limited (based on evidence from the US market for motors that show that the maximum penetration of high performance motors under voluntary mechanisms and incentives can only reach 20%).</p> <p>Variable speed drives entered the market in the late 1980's but have only shown notable growth since 2000.</p>

4.3.2 Future analysis

Table 9 Extrapolation & background calculations – efficiency & sales weighting

Year	Methodology & assumptions
2009-2030	<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>IE1 motors are assumed to represent the majority of the market to 2030, whilst take up of IE2 fixed speed motors (current best in class) is anticipated to remain near constant and a very small percentage of IE3 motors enters the market (no incentives to drive their take up).</p> <p>Take up of variable speed drives increases slowly, mainly due to the effect of both current Building Regulations, which recommend the use of variable speed drives in fan applications, and the ECA scheme. Variable speed AC induction motors are assumed to reach around 30% of total sales by 2030.</p> <p>The 2011 introduction of the Stage 1 phase of the ErP regulation will result in sales of IE2 motors climbing from 20% in 2009 to a peak of 80% in 2012. Stage 2 of the regulation (2015 and 2017) will result in IE3 motor sales climbing from 7% in 2011 to 61% in 2017</p> <p>Take up of Permanent magnet motors is limited as these compete with AC induction motors with variable speed drives and initially are more expensive due to low volume sales. These motors are assumed to reach 5% of total sales by 2030.</p>

4.4 Data issues – efficiency & sales weighting

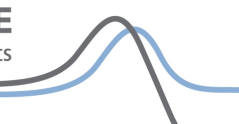


Table 10 Data issues – efficiency

Issue/risk	Approach taken/rationale
Market data on sales of motors by efficiency type are old (2003) and assumptions on the split of sales 2003 – 2009 could be inaccurate	Assumptions are based on anecdotal evidence and industry publications collated during the course of the previous year. More data have been purchased from IMS Research however this was not ready at the time of compilation of the models. These data will be incorporated into future model iterations
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

4.5 Confidence level – efficiency & sales weighting

- Efficiency data are based on internationally accepted motor efficiency standards. The original sales weighting data are derived from BSRIA data which are based on a comprehensive market study; in the interim MTP has not found any further data with which to align growth patterns and future projections and so these have been based on expert opinion and anecdotal evidence.

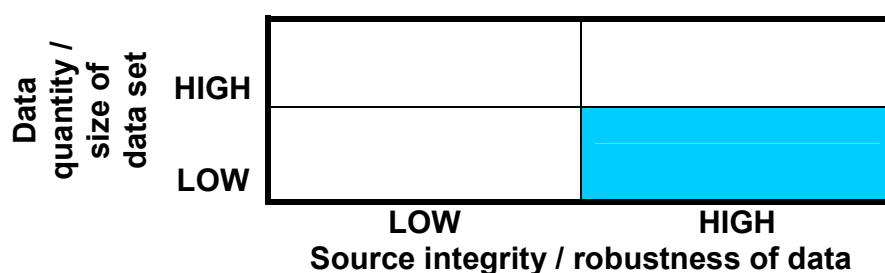
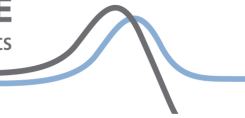


Figure 2 Confidence indicator for efficiency data

Related MTP information

- BNM M01: Electric Motors Government Standards Evidence Base 2009: Key Inputs
- BNM M03: Electric Motors Government Standards Evidence Base 2009: Policy Scenario
- BNM M04: Electric Motors Government Standards Evidence Base 2009: Best Available Technology (BAT) 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>