APPENDIX 1 THE PRINCIPLES and the VALUES

Interpreting the data. It is the efficiency ratios and the emission ratios shown in blue at the bottom of the spread sheets A or (B) that compare the vehicles' energy consumptions and emissions. Sensitivity tests can be carried out rapidly by varying the parameters used.

The data that determines the relative fuel efficiency and carbon emissions of the vehicles are:

(1) The energy lost refining and transporting fuel to filling stations.
(2) The thermal efficiency of the internal combustion (IC) engines.
(3) The proportion of the energy burnt in power stations that reaches the plug.
(4) The efficiency of the charging, battery and motor combination.
(5) The drive chain losses.
(6) The energy lost in braking.
(7) The energy, if any, recovered from braking.
(8) The rolling loss.
(9) The weight of the vehicle.
(10) The idling losses, if any.
(11) The carbon emitted per KWh of primary energy burnt.

The values used are as follows:

Losses power station to plug set to 64.1%, see footnote to spread sheets

Losses in refineries and attributable to transporting the fuel to filling stations set to 10%

Charging losses are set to 8%

Battery discharging losses are set to 10% for current EVs falling to 5% for improved ones

Electric motor losses are set to 10%.

Engine efficiencies for diesels have two sets of five values. These are linear interpolations covering (a) the current realistic range of 25% to 30% and (b) the improved range of 36% to 40% where the higher value of each pair may be appropriate for constant speed or rural running and the lower value for variable speed and the most congested urban conditions. The range for the MUSIC is set to 43.2% to 48% following MUSI Engineering's advice.

Drive chain losses have been set to (a) 25% for existing EV and ICV and (b) 0% for the future or improved EVs on the basis the wheels and motors will then be combined as one so eliminating mechanical transmission losses.

Braking losses will vary greatly according to the driving conditions. We have provided the range 5% (representing uncongested rural conditions) to 40% (representing congested urban conditions).

Regenerative braking for EVs appears to be established and is said to recover 50% of braking energy losses. For conventional vehicles Flybrid systems have a flywheel based arrangement which they claim may recover up to 70% of braking losses and which may be available in 4 to 6 years on standard vehicles. Where applicable we have used 50% for both systems.

Rolling loss has been set to 50% of the energy reaching the wheel, leaving the balance for overcoming wind resistance.

Weight: EVs are said to weigh 25% more than conventional ones. Flybrid's mechanical regenerative braking may add 5% to the vehicle weight. Hence, where applicable, the mechanical transmission, braking and rolling losses are inflated by those amounts.

Idling losses on EVs need not arise. Idling losses for conventional vehicles have been assigned the range 2.5%, when the braking loss is 5%, through to 20%, when the braking loss is 40%, except that, where regenerative braking is assumed, the idling loss has been set to zero (following the BMW system which switches the engine off when the vehicle is stationary).

Energy used in battery manufacture: The energy used in manufacture has been set (a) equal to that transmitted during the battery's life and (b) equal to half that transmitted. The basis for that is in the main text.

Fuel costs: Tables 4(1) to 4(3) provide a range of costs per KWh available to overcome wind resistance for the various scenarios examined. In all cases it is clear that the price of diesel, currently 60 pence per litre of 6 pence per KWh void of tax, would have to rise a great deal before the cost of the EV's fuel would be the cheaper

NOTES TO CALCULATIONS

The principles. There are various points in the chain from primary burn to end point at which the fuel efficiency of a vehicle could be calculated. Our previous calculation did that with respect to the upstream end of the vehicle's drive chain (immediately downstream from the engine or motor). The present calculation does that with respect to the downstream side of rolling. That provides the ratio of (a) the energy available to overcome wind resistance to (b) the energy used in the primary burn. The ratio is subsequently referred to as the vehicles efficiency. The reason is that transmission loses within the vehicles and the rolling resistances are proportional to vehicle weight and an EV is heavier than its ICV competitor on account of the batteries.

Dividing the efficiency of one vehicle by the same for another vehicle provides the relative energy consumptions needed to power the down steam requirements. I.e. if the ratio of vehicle **one's** efficiency to vehicle **two's** is 1.5 then vehicle **two** uses 50% **more** energy than vehicle **one.**

In more detail we define the losses across each phase in percentage terms as follows:

Refinery/Generating industry burn to plug losses		L1 leaving residual of (1-L1) =E1
Battery charging losses	)	
Battery discharging losses	)	
Electric motor losses	)	L2 leaving residual of (1-L2) =E2
IC engine losses	)	
Transmission losses		L3 leaving residual of (1-L3) =E3
Braking losses		L4 leaving residual of (1-L4) =E4
Rolling losses		L5 leaving residual of (1-L5) =E5

Hence, if P is the primary energy burnt and if X is the residual for overcoming wind resistance we have an efficiency, defined as X/P = E1 x E2 x E3 x E4 x E5 ....(1)

If there is regenerative braking returning R% of the initial braking loss, L4, then the actual braking loss becomes (L4 - (L4 x R)) and E4 should be replaced by (1 - (L4 - (L4 x R)))
which reduces to: 1 + L4(R-1) ....**(1a)**
Hence the spread calculations use the formula:
Efficiency, X/P = (1-L1) x (1-L2) x (1-L3) x (1+L4(R-1)) x (1-L5)................ **(1b)**
Where L4 is the braking loss prior to regeneration.

Weight: If energy **losses** in transmission, braking and rolling are proportional to weight then before comparing the efficiency of a heavy vehicle, such as an electric powered car, with a conventional one the energy at the drive chain of the heavier vehicle should be increased by **adding** the additional losses attributable to the greater weight.

For example, if the **losses** in transmission amounted to e.g. L3% of the energy available to the drive chain then, if the downstream energy is to remain the same when the weight is increased by W% the upstream energy should be increased by **adding** (L3 x W) to the upstream energy's so providing a multiplier to the light vehicle upstream energy of: 1 + (L3 x W) ... (2)
The overall efficiency of the heavier vehicle for comparison with the lighter vehicle would then be the lighter vehicle's efficiency divided by (1 + (L3 x W)) .... (3)

Hence the divisor yielding the comparative heavier vehicle efficiency, reference (1) and (1b) above, would be [(1 + (L3 x W)) x (1 + (L4 x W)) x (1 + (L5 x W))] .... (4)

That could be extended to:
[(1 + (L3 x K3 x W)) x (1 + (L4 x (R-1) x K4 x W)) x (1 + (L5 x K3 x W))] .... (5)
Supposing anyone can estimate the K values.

Emissions: Dividing the carbon emission per KWh produced by the primary burn by the fuel efficiency provides the carbon emission per KWh available to overcome the downstream requirements. The ratios of carbon those carbon emissions then compare the vehicles.

Carbon emissions – electricity generation

Table 5C of the DUKES provides 497 tonnes per GWh supplied. According to Julian Prime of the BERR that value relates to the supply of 373,322 GWh in table 5.6. Instead of using the 497 we note the energy burnt (including nuclear) was 952,722 GWh of which **342,127** reached "the plug". Hence there were 542 Tonnes of CO_2 per GWh **at the plug** and 195 Tonnes per GWh burnt in the power stations.

The difference between the 497 and the 542 highlights what appears to be a systematic error in the ARUP and other reports as to the emissions associated with the KWh consumed by end users. Those reports overlook either the grid losses or energy industry use or both.

We also note that the values do not take account of the emissions attributable to mining and delivering the fuel to the power stations.

Carbon emissions from diesel

The 3.15 Kg of CO_2 are emitted per Kg of diesel burnt. The KWh per Kg diesel is to 13.1. Hence there are 0.24 Kg of CO_2 per KWh of diesel burnt. This value does not take account of the emissions in refineries or attributable to transporting the fuel to filling stations but those are captured by the efficiency calculations.

Fuel costs

Tables 4(1) to 4(3) provide the costs per KWh of the residual energy available to overcome wind resistance for each of the various scenarios using the following.

The overall efficiency between primary burn or input to refinery and overcoming wind resistance, E, is the product of the intermediate efficiencies. Hence the efficiency of the element between the plug or the filling station and overcoming wind resistance is the overall efficiency divided by the efficiency, E1, of the link between power station and plug or refinery and filling station. Dividing the price at the plug or filling station by that efficiency yields the cost per kWh to overcome wind resistance.

In summary, if (a) p is the cost per KWh at the plug or at the filling station (b) E is the overall efficiency and (c) E1 is the efficiency, power station burn to plug, or refinery to filling pump then the price per KWh available to overcome the wind is p/E/E1.

It is the comparison of those costs which compares the vehicles.

SPREAD SHEETS (A) Energy used in battery manufacture set to 50% of the energy transmitted by the battery during its life.

Table 1(A). CURRENT EVs and existing diesels

ELECTRIC CAR DATA	From urban....................................... to rural						GENERAL NOTES
Power Sta. to plug loss (i)	64.1%						(a) If motors were wheel-mounted the transmission loss may be zero for the EV.
Charging loss	8.0%						
Battery discharging loss	10.0%						
Motor loss	10.0%						
Transmission loss, (a)	25%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	50.0%						
Rolling loss R	50%	50%	50%	50%	50%		(b) Ignoring energy in battery manufacture
Added weight	25%					**Means**	
Efficiency (b)	8.03%	8.53%	9.03%	9.53%	9.78%	**8.98%**	
WEIGHT- NORMALISED	6.39%	6.88%	7.37%	7.87%	8.13%	**7.33%**	
kg C02 per KWh for the wind	3.049	2.836	2.646	2.476	2.398	**2.681**	
Battery manufacture (c)	**50.0%**						(c) Ratio of manufacturing energy to lifetime delivery
Efficiency inc battery manufacture	5.35%	5.68%	6.02%	6.35%	6.52%	**5.99%**	
WEIGHT- NORMALISED	4.26%	4.58%	4.91%	5.25%	5.42%	**4.89%**	
kg C02 per KWh for the wind	4.574	4.254	3.969	3.714	3.597	**4.022**	
DIESELS: Present day efficiencies, no Regenerative braking or idling suppression							
Loss: refinery to filling station	10.0%						
	From urban ---------------------------- to rural					**Means**	
BTE Diesel	25.0%	26.3%	27.5%	28.8%	30.0%	**27.50%**	
Transmission loss	25%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	0.0%						
Rolling loss	50%	50%	50%	50%	50%		
Added weight %	0%						
Idling losses	20.0%	15.0%	10.0%	5.0%	2.5%		
Fuel efficiency (wind energy divided by primary burn)							
Not weight normalised	4.05%	5.27%	6.68%	8.30%	9.38%	**6.74%**	
Weight Normalised	4.05%	5.27%	6.68%	8.30%	9.38%	**6.74%**	
CO_2 emissions per KWh available to wind resistance							
CO_2 Weight Normalised	5.937	4.562	3.598	2.898	2.564	**3.912**	
EFFICIENCY RATIOS: WEIGHT- NORMALISED data							
Diesel / EV: ignoring battery (d)	0.633	0.767	0.907	1.053	1.153	**0.919**	(d) Ignoring and including energy or emission due to manufacture
Diesel / EV: Including battery (d)	0.950	1.150	1.360	1.580	1.730	**1.378**	
EMISSION RATIOS: WEIGHT- NORMALISED data							
EV / Diesel: ignoring battery (d)	0.514	0.622	0.735	0.854	0.935	**0.685**	
EV / Diesel: Including battery (d)	0.770	0.933	1.103	1.282	1.403	**1.028**	
EMISSION PARAMETERS							
KWh per Kg of diesel			13.1				
CO_2 per Kg of diesel			3.15				
Kg CO_2 per KWh burnt -electric (ii)			0.195				

(i) Table 5.6, of the Digest of UK energy statistics, DUKES, provides for 2008, 952,722 GWh energy burnt in power stations and in table 5.5 net usage (as delivered to "the plug") of 342,127 GWh. Hence the ratio of power used by end users to fuel burnt is 0.359.

(ii) Table 5C of the 2009 Digest of UK energy statistics provides 497 tonnes per GWh supplied gross. That value relates to the 373,322 GWh (table 5.6 - supplied). Fuel burnt (including non-thermal) was 952,722 GWh of which 342,127 reached "the plug" (Table 5.5) Hence we have 542 Tonnes per GWh at the plug and 195 Tonnes per GWh burnt in the power stations.

Table 2(A). <u>Improved EVs and improved diesels</u>

ELECTRIC CAR DATA	From urban...				to rural		**GENERAL NOTES**
Power Sta. to plug loss (i)	64.1%						(a) If motors were wheel-mounted the transmission loss may be zero for the EV.
Charging loss	8.0%						
Battery discharging loss	5.0%						
Motor loss	10.0%						
Transmission loss, (a)	0%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	50.0%						
Rolling loss R	50%	50%	50%	50%	50%		(b) Ignoring energy in battery manufacture
Added weight	25%					**Means**	
Efficiency (b)	11.30%	12.00%	12.71%	13.41%	13.77%	**12.64%**	
WEIGHT- NORMALISED	9.56%	10.28%	11.02%	11.78%	12.16%	**10.96%**	
kg C02 per KWh for the wind	2.039	1.896	1.769	1.656	1.604	**1.793**	
Battery manufacture (c)	**50.0%**						(c) Ratio of manufacturing energy to lifetime delivery
Overall efficiency	7.53%	8.00%	8.47%	8.94%	9.18%	**8.42%**	
WEIGHT- NORMALISED	6.37%	6.85%	7.35%	7.85%	8.11%	**7.31%**	
kg C02 per KWh for the wind	3.059	2.845	2.654	2.484	2.405	**2.689**	
DIESELS: Present day efficiencies, no Regenerative braking or idling suppression							
Loss: refinery to filling station	10.0%						
	From urban ---------------------------------				to rural	**Means**	
BTE Diesel	36.0%	37.0%	38.0%	39.0%	40.0%	**38.00%**	
Transmission loss	25%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	50.0%						
Rolling loss	50%	50%	50%	50%	50%		
Added weight %	5%						
Idling losses	0.0%	0.0%	0.0%	0.0%	0.0%		
Fuel efficiency (wind energy divided by primary burn)							
Not weight normalised	9.72%	10.61%	11.54%	12.50%	13.16%	**11.51%**	
Weight Normalised	9.27%	10.15%	11.07%	12.02%	12.67%	**11.04%**	
CO_2 emissions per KWh available to wind resistance							
CO_2 Weight Normalised	2.593	2.369	2.173	2.001	1.898	**2.207**	
EFFICIENCY RATIOS: WEIGHT- NORMALISED data							
Diesel / EV: ignoring battery (d)	0.970	0.987	1.004	1.021	1.042	**1.007**	(d) Ignoring and including energy or emission due to manufacture
Diesel / EV: Including battery (d)	1.455	1.481	1.506	1.531	1.562	**1.510**	
EMISSION RATIOS: WEIGHT- NORMALISED data							
EV / Diesel: ignoring battery (d)	0.786	0.801	0.814	0.828	0.845	**0.812**	
EV / Diesel: Including battery (d)	1.180	1.201	1.222	1.242	1.267	**1.219**	

EMISSION PARAMETERS	
KWh per Kg of diesel	13.1
CO_2 per Kg of diesel	3.15
Kg CO_2 per KWh burnt -electric (ii)	0.195

(i) Table 5.6, of the Digest of UK energy statistics, DUKES, provides for 2008, 952,722 GWh energy burnt in power stations and in table 5.5 net usage (as delivered to "the plug") of 342,127 GWh. Hence the ratio of power used by end users to fuel burnt is 0.359.

(ii) Table 5C of the 2009 Digest of UK energy statistics provides 497 tonnes per GWh supplied gross. That value relates to the 373,322 GWh (table 5.6 - supplied). Fuel burnt (including non-thermal) was 952,722 GWh of which 342,127 reached "the plug" (Table 5.5) Hence we have 542 Tonnes per GWh at the plug and 195 Tonnes per GWh burnt in the power stations.

Table 3(A). Improved EVs and MUSIC power vehicles

ELECTRIC CAR DATA	From urban...... to rural						GENERAL NOTES
Power Sta. to plug loss (i)	64.1%						(a) If motors were wheel-mounted the transmission loss may be zero for the EV.
Charging loss	8.0%						
Battery discharging loss	5.0%						
Motor loss	10.0%						
Transmission loss, (a)	0%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	50.0%						
Rolling loss R	50%	50%	50%	50%	50%		(b) Ignoring energy in battery manufacture
Added weight	25%					**Means**	
Theoretical efficiency (b)	11.30%	12.00%	12.71%	13.41%	13.77%	**12.64%**	
WEIGHT- NORMALISED	9.56%	10.28%	11.02%	11.78%	12.16%	**10.96%**	
kg C02 per KWh for the wind	2.039	1.896	1.769	1.656	1.604	**1.793**	
Battery manufacture (c)	**50.0%**						(c) Ratio of manufacturing energy to lifetime delivery
Realistic efficiency	7.53%	8.00%	8.47%	8.94%	9.18%	**8.42%**	
WEIGHT- NORMALISED	6.37%	6.85%	7.35%	7.85%	8.11%	**7.31%**	
kg C02 per KWh for the wind	3.059	2.845	2.654	2.484	2.405	**2.689**	
MUSIC: Even higher efficiency + Regenerative braking + idling suppressed							
Loss: refinery to filling station	10.0%						
	From urban ---------------------------------- to rural					**Means**	
BTE MUSIC	43.2%	44.4%	45.6%	46.8%	48.0%	**45.60%**	
Transmission loss	25%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	50.0%						
Rolling loss	50%	50%	50%	50%	50%		
Added weight %	5%						
Idling losses	0.0%	0.0%	0.0%	0.0%	0.0%		
Fuel efficiency (wind energy divided by primary burn)							
Not weight normalised	11.66%	12.74%	13.85%	15.01%	15.80%	**13.81%**	
Weight Normalised	11.13%	12.18%	13.28%	14.42%	15.20%	**13.24%**	
CO2 emissions per KWh available to wind resistance							
CO2 Weight Normalised	2.161	1.974	1.811	1.667	1.582	**1.839**	
EFFICIENCY RATIOS: WEIGHT- NORMALISED DATA							
Diesel / EV: ignoring battery (d)	1.164	1.185	1.205	1.225	1.250	**1.208**	(d) Ignoring and including energy or emission due to manufacture
Diesel / EV: Including battery (d)	1.746	1.777	1.808	1.837	1.875	**1.812**	
EMISSION RATIOS: WEIGHT- NORMALISED DATA							
EV / Diesel: ignoring battery (d)	0.944	0.961	0.977	0.993	1.014	**0.975**	
EV / Diesel: Including battery (d)	1.416	1.441	1.466	1.490	1.520	**1.462**	

EMISSION PARAMETERS	
KWh per Kg of diesel	13.1
CO2 per Kg of diesel	3.15
Kg CO2 per KWh burnt -electric (ii)	0.195

(i) Table 5.6, of the Digest of UK energy statistics, DUKES, provides for 2008, 952,722 GWh energy burnt in power stations and in table 5.5 net usage (as delivered to "the plug") of 342,127 GWh. Hence the ratio of power used by end users to fuel burnt is 0.359.

(ii) Table 5C of the 2009 Digest of UK energy statistics provides 497 tonnes per GWh supplied gross. That value relates to the 373,322 GWh (table 5.6 - supplied). Fuel burnt (including non-thermal) was 952,722 GWh of which 342,127 reached "the plug" (Table 5.5) Hence we have 542 Tonnes per GWh at the plug and 195 Tonnes per GWh burnt in the power stations.

Table 4(1)(A) Fuel costs of existing EVs and existing diesels

EVs						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	4.3%	4.6%	4.9%	5.2%	5.4%	4.9%
Efficiency plug to wind	11.9%	12.8%	13.7%	14.6%	15.1%	13.6%
Pence per KWh at the plug	Cost per KWh available to wind resistance,					
10	84.2	78.3	73.1	68.4	66.2	**73.5**
15	126.3	117.5	109.6	102.6	99.3	**110.2**
20	168.4	156.6	146.1	136.8	132.4	**146.9**
25	210.5	195.8	182.7	171.0	165.5	**183.7**
30	252.6	234.9	219.2	205.1	198.7	**220.4**
Current diesels						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	4.05%	5.27%	6.68%	8.30%	9.38%	6.74%
Efficiency Filling station pump to wind	4.50%	5.86%	7.43%	9.22%	10.42%	4.50%
Pump price, pence per litre ex. tax	Cost per KWh available to wind resistance					
20	41.5	31.9	25.2	20.3	17.9	**25.0**
30	62.3	47.9	37.8	30.4	26.9	**37.5**
40	83.1	63.8	50.3	40.6	35.9	**50.0**
50	103.8	79.8	62.9	50.7	44.8	**62.4**
60	124.6	95.7	75.5	60.8	53.8	**74.9**
70	145.4	111.7	88.1	71.0	62.8	**87.4**
80	166.1	127.7	100.7	81.1	71.8	**99.9**
90	186.9	143.6	113.3	91.2	80.7	**112.4**
100	207.7	159.6	125.9	101.4	89.7	**124.9**
110	228.5	175.5	138.5	111.5	98.7	**137.4**
120	249.2	191.5	151.0	121.7	107.6	**149.9**
130	270.0	207.4	163.6	131.8	116.6	**162.3**
140	290.8	223.4	176.2	141.9	125.6	**174.8**
150	311.5	239.3	188.8	152.1	134.5	**187.3**

KWh/litre	10.7

Comment – In 2011 the price of diesel per litre is circa 133 pence/litre. Excise duty is 59 pence. Vat, at 20%, is changed on the untaxed price plus Excise duty. Hence the price per litre void of tax is 52 pence. A fair estimate of the cost of electricity to domestic users has the range is 10 pence to 15 pence per KWh. Hence viewing the emboldened data coloured blue it is clear that at current prices the difference in resource cost of the two fuels is significantly in favour of the ICV.

(a) from Table 1

Table 4(2)(A) Fuel costs of improved EVs and improved diesels

EVs						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	6.4%	6.9%	7.3%	7.9%	8.1%	7.3%
Efficiency plug to wind	17.8%	19.1%	20.5%	21.9%	22.6%	20.4%
Pence per KWh at the plug	Cost per KWh available to wind resistance,					
10	56.3	52.4	48.9	45.7	44.3	**49.1**
15	84.5	78.6	73.3	68.6	66.4	**73.7**
20	112.6	104.7	97.7	91.5	88.6	**98.3**
25	140.8	130.9	122.2	114.3	110.7	**122.8**
30	168.9	157.1	146.6	137.2	132.8	**147.4**
Improved diesels						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	9.27%	10.15%	11.07%	12.02%	12.67%	11.04%
Efficiency Filling station pump to wind	10.3%	11.3%	12.3%	13.4%	14.1%	12.3%
Pump price, pence per litre ex. Tax	Cost per KWh available to wind resistance					
20	18.1	16.6	15.2	14.0	13.3	**15.2**
30	27.2	24.9	22.8	21.0	19.9	**22.9**
40	36.3	33.1	30.4	28.0	26.6	**30.5**
50	45.4	41.4	38.0	35.0	33.2	**38.1**
60	54.4	49.7	45.6	42.0	39.8	**45.7**
70	63.5	58.0	53.2	49.0	46.5	**53.4**
80	72.6	66.3	60.8	56.0	53.1	**61.0**
90	81.6	74.6	68.4	63.0	59.8	**68.6**
100	90.7	82.9	76.0	70.0	66.4	**76.2**
110	99.8	91.1	83.6	77.0	73.0	**83.8**
120	108.8	99.4	91.2	84.0	79.7	**91.5**
130	117.9	107.7	98.8	91.0	86.3	**99.1**
140	127.0	116.0	106.4	98.0	93.0	**106.7**
150	136.1	124.3	114.0	105.0	99.6	**114.3**

KWh/litre	10.7

Comment – As previously, in 2011 the price of diesel per litre is circa 133 pence/litre. Excise duty is 59 pence. Vat at 20% is changed on the untaxed price plus Excise duty. Hence the price per litre void of tax is 52 pence. A fair estimate of the cost of electricity to domestic users has the range is 10 pence to 15 pence per KWh. Hence viewing the emboldened data coloured blue it is clear that at current prices the difference in resource cost of the two fuels is significantly in favour of the ICV.

(a) from Table (2)

Table 4(3)(A) Fuel costs of improved EVs and the MUSIC

EVs						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	6.4%	6.9%	7.3%	7.9%	8.1%	7.3%
Efficiency plug to wind	6.4%	19.1%	20.5%	21.9%	22.6%	20.4%
Pence per KWh at the plug	Cost per KWh available to wind resistance,					
10	156.9	52.4	48.9	45.7	44.3	49.1
15	235.3	78.6	73.3	68.6	66.4	73.7
20	313.7	104.7	97.7	91.5	88.6	98.3
25	392.2	130.9	122.2	114.3	110.7	122.8
30	470.6	157.1	146.6	137.2	132.8	147.4
The MUSIC						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	11.13%	12.18%	13.28%	14.42%	15.20%	13.24%
Efficiency Filling station pump to wind	12.4%	13.5%	14.8%	16.0%	16.9%	14.7%
Pump price, pence per litre ex. tax	Cost per KWh available to wind resistance					
20	15.1	13.8	12.7	11.7	11.1	12.7
30	22.7	20.7	19.0	17.5	16.6	19.1
40	30.2	27.6	25.3	23.3	22.1	25.4
50	37.8	34.5	31.7	29.2	27.7	31.8
60	45.4	41.4	38.0	35.0	33.2	38.1
70	52.9	48.3	44.3	40.8	38.7	44.5
80	60.5	55.2	50.7	46.7	44.3	50.8
90	68.0	62.1	57.0	52.5	49.8	57.2
100	75.6	69.0	63.3	58.3	55.3	63.5
110	83.1	76.0	69.7	64.2	60.9	69.9
120	90.7	82.9	76.0	70.0	66.4	76.2
130	98.3	89.8	82.3	75.8	71.9	82.6
140	105.8	96.7	88.7	81.6	77.5	88.9
150	113.4	103.6	95.0	87.5	83.0	95.3

KWh/litre	10.7

Comment – As previously, in 2011 the price of diesel per litre is circa 133 pence/litre. Excise duty is 59 pence. Vat at 20% is changed on the untaxed price plus Excise duty. Hence the price per litre void of tax is 52 pence. A fair estimate of the cost of electricity to domestic users has the range is 10 pence to 15 pence per KWh. Hence viewing the emboldened data coloured blue it is clear that at current prices the difference in resource cost of the two fuels is significantly very much in favour of the MUSIC

(a) from Table (3)

SPREAD SHEETS (B) Energy used in battery manufacture set to 100% of the energy transmitted by the battery during its life.

Table 1(B). CURRENT EVs and existing diesels

ELECTRIC CAR DATA	From urban... to rural						**GENERAL NOTES**
Power Sta. to plug loss (i)	64.1%						(a) If motors were wheel-mounted the transmission loss may be zero for the EV.
Charging loss	8.0%						
Battery discharging loss	10.0%						
Motor loss	10.0%						
Transmission loss, (a)	25%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	50.0%						
Rolling loss R	50%	50%	50%	50%	50%		(b) Ignoring energy in battery manufacture
Added weight	25%					**Means**	
Efficiency (b)	8.03%	8.53%	9.03%	9.53%	9.78%	**8.98%**	
WEIGHT- NORMALISED	6.39%	6.88%	7.37%	7.87%	8.13%	**7.33%**	
kg C02 per KWh for the wind	3.049	2.836	2.646	2.476	2.398	**2.681**	
Battery manufacture (c)	**100.0%**						(c) Ratio of manufacturing energy to lifetime delivery
Efficiency inc battery manufacture	4.01%	4.26%	4.51%	4.77%	4.89%	**4.49%**	
WEIGHT- NORMALISED	3.20%	3.44%	3.68%	3.94%	4.07%	**3.66%**	
kg C02 per KWh for the wind	6.099	5.672	5.292	4.952	4.796	**5.362**	
DIESELS: Present day efficiencies, no Regenerative braking or idling suppression							
Loss: refinery to filling station	10.0%						
	From urban ----------------------------------- to rural					**Means**	
BTE Diesel	25.0%	26.3%	27.5%	28.8%	30.0%	**27.50%**	
Transmission loss	25%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	0.0%						
Rolling loss	50%	50%	50%	50%	50%		
Added weight %	0%						
Idling losses	20.0%	15.0%	10.0%	5.0%	2.5%		
Fuel efficiency (wind energy divided by primary burn)							
Not weight normalised	4.05%	5.27%	6.68%	8.30%	9.38%	**6.74%**	
Weight Normalised	4.05%	5.27%	6.68%	8.30%	9.38%	**6.74%**	
CO2 emissions per KWh available to wind resistance							
CO2 Weight Normalised	5.937	4.562	3.598	2.898	2.564	**3.912**	
EFFICIENCY RATIOS: WEIGHT- NORMALISED data							
Diesel / EV: ignoring battery (d)	0.633	0.767	0.907	1.053	1.153	**0.919**	(d) Ignoring and including energy or emission due to manufacture
Diesel / EV: Including battery (d)	1.267	1.533	1.814	2.107	2.306	**1.838**	
EMISSION RATIOS: WEIGHT- NORMALISED data							
EV / Diesel: ignoring battery (d)	0.514	0.622	0.735	0.854	0.935	**0.685**	
EV / Diesel: Including battery (d)	1.027	1.243	1.471	1.709	1.870	**1.371**	

EMISSION PARAMETERS	
KWh per Kg of diesel	13.1
CO2 per Kg of diesel	3.15
Kg CO2 per KWh burnt -electric (ii)	0.195

(i) Table 5.6, of the Digest of UK energy statistics, DUKES, provides for 2008, 952,722 GWh energy burnt in power stations and in table 5.5 net usage (as delivered to "the plug") of 342,127 GWh. Hence the ratio of power used by end users to fuel burnt is 0.359.

(ii) Table 5C of the 2009 Digest of UK energy statistics provides 497 tonnes per GWh supplied gross. That value relates to the 373,322 GWh (table 5.6 - supplied). Fuel burnt (including non-thermal) was 952,722 GWh of which 342,127 reached "the plug" (Table 5.5) Hence we have 542 Tonnes per GWh at the plug and 195 Tonnes per GWh burnt in the power stations.

Table 2(B). Improved EVs and improved diesels

ELECTRIC CAR DATA	From urban	...	...	...	to rural		GENERAL NOTES
Power Sta. to plug loss (i)	64.1%						(a) If motors were wheel-mounted the transmission loss may be zero for the EV.
Charging loss	8.0%						
Battery discharging loss	5.0%						
Motor loss	10.0%						
Transmission loss, (a)	0%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	50.0%						
Rolling loss R	50%	50%	50%	50%	50%		(b) Ignoring energy in battery manufacture
Added weight	25%					**Means**	
Efficiency (b)	11.30%	12.00%	12.71%	13.41%	13.77%	**12.64%**	
WEIGHT- NORMALISED	9.56%	10.28%	11.02%	11.78%	12.16%	**10.96%**	
kg C02 per KWh for the wind	2.039	1.896	1.769	1.656	1.604	**1.793**	
Battery manufacture (c)	**100.0%**						(c) Ratio of manufacturing energy to lifetime delivery
Overall efficiency	5.65%	6.00%	6.35%	6.71%	6.88%	**6.32%**	
WEIGHT- NORMALISED	4.78%	5.14%	5.51%	5.89%	6.08%	**5.48%**	
kg C02 per KWh for the wind	4.078	3.793	3.539	3.312	3.207	**3.586**	
DIESELS: Present day efficiencies, no Regenerative braking or idling suppression							
Loss: refinery to filling station	10.0%						
	From urban	-------	-------	-------	to rural	**Means**	
BTE Diesel	36.0%	37.0%	38.0%	39.0%	40.0%	**38.00%**	
Transmission loss	25%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	50.0%						
Rolling loss	50%	50%	50%	50%	50%		
Added weight %	5%						
Idling losses	0.0%	0.0%	0.0%	0.0%	0.0%		
Fuel efficiency (wind energy divided by primary burn)							
Not weight normalised	9.72%	10.61%	11.54%	12.50%	13.16%	**11.51%**	
Weight Normalised	9.27%	10.15%	11.07%	12.02%	12.67%	**11.04%**	
CO2 emissions per KWh available to wind resistance							
CO2 Weight Normalised	2.593	2.369	2.173	2.001	1.898	**2.207**	
EFFICIENCY RATIOS: WEIGHT- NORMALISED data							
Diesel / EV: ignoring battery (d)	0.970	0.987	1.004	1.021	1.042	**1.007**	(d) Ignoring and including energy or emission due to manufacture
Diesel / EV: Including battery (d)	1.939	1.975	2.008	2.041	2.083	**2.014**	
EMISSION RATIOS: WEIGHT- NORMALISED data							
EV / Diesel: ignoring battery (d)	0.786	0.801	0.814	0.828	0.845	**0.812**	
EV / Diesel: Including battery (d)	1.573	1.601	1.629	1.655	1.689	**1.625**	

EMISSION PARAMETERS	
KWh per Kg of diesel	13.1
CO2 per Kg of diesel	3.15
Kg CO2 per KWh burnt -electric (ii)	0.195

(i) Table 5.6, of the Digest of UK energy statistics, DUKES, provides for 2008, 952,722 GWh energy burnt in power stations and in table 5.5 net usage (as delivered to "the plug") of 342,127 GWh. Hence the ratio of power used by end users to fuel burnt is 0.359.

(ii) Table 5C of the 2009 Digest of UK energy statistics provides 497 tonnes per GWh supplied gross. That value relates to the 373,322 GWh (table 5.6 - supplied). Fuel burnt (including non-thermal) was 952,722 GWh of which 342,127 reached "the plug" (Table 5.5) Hence we have 542 Tonnes per GWh at the plug and 195 Tonnes per GWh burnt in the power stations.

Table 3(B). Improved EVs and MUSIC power vehicles

ELECTRIC CAR DATA	From urban				to rural		GENERAL NOTES
Power Sta. to plug loss (i)	64.1%						(a) If motors were wheel-mounted the transmission loss may be zero for the EV.
Charging loss	8.0%						
Battery discharging loss	5.0%						
Motor loss	10.0%						
Transmission loss, (a)	0%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	50.0%						
Rolling loss R	50%	50%	50%	50%	50%		(b) Ignoring energy in battery manufacture
Added weight	25%					**Means**	
Theoretical efficiency (b)	11.30%	12.00%	12.71%	13.41%	13.77%	**12.64%**	
WEIGHT- NORMALISED	9.56%	10.28%	11.02%	11.78%	12.16%	**10.96%**	
kg C02 per KWh for the wind	2.039	1.896	1.769	1.656	1.604	**1.793**	
Battery manufacture (c)	**100.0%**						(c) Ratio of manufacturing energy to lifetime delivery
Realistic efficiency	5.65%	6.00%	6.35%	6.71%	6.88%	**6.32%**	
WEIGHT- NORMALISED	4.78%	5.14%	5.51%	5.89%	6.08%	**5.48%**	
kg C02 per KWh for the wind	4.078	3.793	3.539	3.312	3.207	**3.586**	
MUSIC: Even higher efficiency + Regenerative braking + idling suppressed							
Loss: refinery to filling station	10.0%						
	From urban				to rural	**Means**	
BTE MUSIC	43.2%	44.4%	45.6%	46.8%	48.0%	**45.60%**	
Transmission loss	25%						
Braking loss	40.0%	30.0%	20.0%	10.0%	5.0%		
Breaking energy recovered	50.0%						
Rolling loss	50%	50%	50%	50%	50%		
Added weight %	5%						
Idling losses	0.0%	0.0%	0.0%	0.0%	0.0%		
Fuel efficiency (wind energy divided by primary burn)							
Not weight normalised	11.66%	12.74%	13.85%	15.01%	15.80%	**13.81%**	
Weight Normalised	11.13%	12.18%	13.28%	14.42%	15.20%	**13.24%**	
CO2 emissions per KWh available to wind resistance							
CO2 Weight Normalised	2.161	1.974	1.811	1.667	1.582	**1.839**	
EFFICIENCY RATIOS: WEIGHT- NORMALISED data							
Diesel / EV: ignoring battery (d)	1.164	1.185	1.205	1.225	1.250	**1.208**	(d) Ignoring and including energy or emission due to manufacture
Diesel / EV: Including battery (d)	2.327	2.369	2.410	2.449	2.500	**2.416**	
EMISSION RATIOS: WEIGHT- NORMALISED data							
EV / Diesel: ignoring battery (d)	0.944	0.961	0.977	0.993	1.014	**0.975**	
EV / Diesel: Including battery (d)	1.887	1.921	1.955	1.986	2.027	**1.950**	

EMISSION PARAMETERS	
KWh per Kg of diesel	13.1
CO2 per Kg of diesel	3.15
Kg CO2 per KWh burnt -electric (ii)	0.195

(i) Table 5.6, of the Digest of UK energy statistics, DUKES, provides for 2008, 952,722 GWh energy burnt in power stations and in table 5.5 net usage (as delivered to "the plug") of 342,127 GWh. Hence the ratio of power used by end users to fuel burnt is 0.359.

(ii) Table 5C of the 2009 Digest of UK energy statistics provides 497 tonnes per GWh supplied gross. That value relates to the 373,322 GWh (table 5.6 - supplied). Fuel burnt (including non-thermal) was 952,722 GWh of which 342,127 reached "the plug" (Table 5.5) Hence we have 542 Tonnes per GWh at the plug and 195 Tonnes per GWh burnt in the power stations.

Table 4(1)(B) Fuel costs of existing EVs and existing diesels

EVs with energy in battery manufacture equal to lifetime battery delivery						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	3.2%	3.4%	3.7%	3.9%	4.1%	3.7%
Efficiency plug to wind	8.9%	9.6%	10.3%	11.0%	11.3%	10.2%
Pence per KWh at the plug	Cost per KWh available to wind resistance,					
10	112.3	104.4	97.4	91.2	88.3	**98.0**
15	168.4	156.6	146.1	136.8	132.4	**146.9**
20	224.6	208.8	194.9	182.4	176.6	**195.9**
25	280.7	261.0	243.6	227.9	220.7	**244.9**
30	336.8	313.3	292.3	273.5	264.9	**293.9**
Current diesels						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	4.05%	5.27%	6.68%	8.30%	9.38%	6.74%
Efficiency Filling station pump to wind	4.50%	5.86%	7.43%	9.22%	10.42%	7.48%
Pump price, pence per litre ex. tax	Cost per KWh available to wind resistance					
20	41.5	31.9	25.2	20.3	17.9	**25.0**
30	62.3	47.9	37.8	30.4	26.9	**37.5**
40	83.1	63.8	50.3	40.6	35.9	**50.0**
50	103.8	79.8	62.9	50.7	44.8	**62.4**
60	124.6	95.7	75.5	60.8	53.8	**74.9**
70	145.4	111.7	88.1	71.0	62.8	**87.4**
80	166.1	127.7	100.7	81.1	71.8	**99.9**
90	186.9	143.6	113.3	91.2	80.7	**112.4**
100	207.7	159.6	125.9	101.4	89.7	**124.9**
110	228.5	175.5	138.5	111.5	98.7	**137.4**
120	249.2	191.5	151.0	121.7	107.6	**149.9**
130	270.0	207.4	163.6	131.8	116.6	**162.3**
140	290.8	223.4	176.2	141.9	125.6	**174.8**
150	311.5	239.3	188.8	152.1	134.5	**187.3**

KWh/litre	10.7

Comment – As previously, in 2011 the price of diesel per litre is circa 133 pence/litre. Excise duty is 59 pence. Vat at 20% is changed on the untaxed price plus Excise duty. Hence the price per litre void of tax is 52 pence. A fair estimate of the cost of electricity to domestic users has the range is 10 pence to 15 pence per KWh. Hence viewing the emboldened data coloured blue it is clear that at current prices the difference in resource cost of the two fuels is up to a factor of two in favour of the existing diesels

(a) Weight normalised data from sheet (1)

Table 4(2)(B) Fuel costs of improved EVs and improved diesels

EVs with energy in battery manufacture equal to lifetime battery delivery						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	4.8%	5.1%	5.5%	5.9%	6.1%	5.5%
Efficiency plug to wind	13.3%	14.3%	15.3%	16.4%	16.9%	15.3%
Pence per KWh at the plug	Cost per KWh available to wind resistance,					
10	75.1	69.8	65.2	61.0	59.0	**65.5**
15	112.6	104.7	97.7	91.5	88.6	**98.3**
20	150.2	139.7	130.3	121.9	118.1	**131.0**
25	187.7	174.6	162.9	152.4	147.6	**163.8**
30	225.3	209.5	195.5	182.9	177.1	**196.5**
Improved diesels						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	9.27%	10.15%	11.07%	12.02%	12.67%	11.04%
Efficiency Filling station pump to wind	10.30%	11.28%	12.30%	13.35%	14.07%	12.26%
Pump price, pence per litre ex. tax	Cost per KWh available to wind resistance					
20	18.1	16.6	15.2	14.0	13.3	**15.2**
30	27.2	24.9	22.8	21.0	19.9	**22.9**
40	36.3	33.1	30.4	28.0	26.6	**30.5**
50	45.4	41.4	38.0	35.0	33.2	**38.1**
60	54.4	49.7	45.6	42.0	39.8	**45.7**
70	63.5	58.0	53.2	49.0	46.5	**53.4**
80	72.6	66.3	60.8	56.0	53.1	**61.0**
90	81.6	74.6	68.4	63.0	59.8	**68.6**
100	90.7	82.9	76.0	70.0	66.4	**76.2**
110	99.8	91.1	83.6	77.0	73.0	**83.8**
120	108.8	99.4	91.2	84.0	79.7	**91.5**
130	117.9	107.7	98.8	91.0	86.3	**99.1**
140	127.0	116.0	106.4	98.0	93.0	**106.7**
150	136.1	124.3	114.0	105.0	99.6	**114.3**

KWh/litre	10.7

Comment – As previously, in 2011 the price of diesel per litre is circa 133 pence/litre. Excise duty is 59 pence. Vat at 20% is changed on the untaxed price plus Excise duty. Hence the price per litre void of tax is 52 pence. A fair estimate of the cost of electricity to domestic users has the range is 10 pence to 15 pence per KWh. Hence viewing the emboldened data coloured blue it is clear that at current prices the difference in resource cost of the two fuels is more than a factor of two in favour of the improved diesel

(a) Weight normalised data from sheet (2)

Table 4(3)(B) Fuel costs of improved EVs and the MUSIC

EVs with energy in battery manufacture equal to lifetime battery delivery						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	4.8%	5.1%	5.5%	5.9%	6.1%	5.5%
Efficiency plug to wind	4.8%	14.3%	15.3%	16.4%	16.9%	15.3%
Pence per KWh at the plug	Cost per KWh available to wind resistance,					
10	209.2	69.8	65.2	61.0	59.0	**65.5**
15	313.7	104.7	97.7	91.5	88.6	**98.3**
20	418.3	139.7	130.3	121.9	118.1	**131.0**
25	522.9	174.6	162.9	152.4	147.6	**163.8**
30	627.5	209.5	195.5	182.9	177.1	**196.5**
The MUSIC						
	From urban ....to rural					Means
Efficiency: primary burn to wind (a)	11.13%	12.18%	13.28%	14.42%	15.20%	13.24%
Efficiency Filling station pump to wind	12.36%	13.54%	14.76%	16.02%	16.89%	14.71%
Pump price, pence per litre ex. tax	Cost per KWh available to wind resistance					
20	15.1	13.8	12.7	11.7	11.1	**12.7**
30	22.7	20.7	19.0	17.5	16.6	**19.1**
40	30.2	27.6	25.3	23.3	22.1	**25.4**
50	37.8	34.5	31.7	29.2	27.7	**31.8**
60	45.4	41.4	38.0	35.0	33.2	**38.1**
70	52.9	48.3	44.3	40.8	38.7	**44.5**
80	60.5	55.2	50.7	46.7	44.3	**50.8**
90	68.0	62.1	57.0	52.5	49.8	**57.2**
100	75.6	69.0	63.3	58.3	55.3	**63.5**
110	83.1	76.0	69.7	64.2	60.9	**69.9**
120	90.7	82.9	76.0	70.0	66.4	**76.2**
130	98.3	89.8	82.3	75.8	71.9	**82.6**
140	105.8	96.7	88.7	81.6	77.5	**88.9**
150	113.4	103.6	95.0	87.5	83.0	**95.3**

KWh/litre	10.7

Comment – As previously, in 2011 the price of diesel per litre is circa 133 pence/litre. Excise duty is 59 pence. Vat at 20% is changed on the untaxed price plus Excise duty. Hence the price per litre void of tax is 52 pence. A fair estimate of the cost of electricity to domestic users has the range is 10 pence to 15 pence per KWh. Hence viewing the emboldened data coloured blue it is clear that at current prices the difference in resource cost of the two fuels is more than a factor of two in favour of the MUSIC

(a) Weight normalised data from sheet (3)