



## White Paper:

### Segway i2 Personal Transporter Carbon Footprint Calculation (Update)

**Ben Hedley** – Director, Clear, the carbon offset company  
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# 1 Introduction

This White Paper calculates the g/km equivalent carbon footprint figure for the Segway i2 personal transporter, recharged from a typical UK mains power supply.

A figure of **24.9 g/km** is calculated based on real world experience, rather than manufacturer claims and compared to typical g/km figures for other substitutional modes of transport.

A simple guide to the i2, published by Segway PT is shown below:



## 2 Calculation

### 2.1 Sources

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#### 2.1.1 Electricity

UK National Grid Rolling Average = 0.53702 kgCO<sub>2</sub>e per KWH (2008 Guidelines to DEFRA's GHG Conversion Factors)

#### 2.1.2 Range / Power Consumption

The range of the Segway PT for a given charge was calculated in two parts:

1. 8 data points based on use of a Segway PT by Clear Directors. These involved multiple users (both experienced and complete beginners) over a variety of distances and charges.
2. A complete charge and discharge cycle by Isidore Margaronis as part of his commute to work and back. More details available in the notes section (5.4).

Official Segway PT figures suggest a range of between 16 and 24 miles on a complete (1 to 1.04 kwh) charge, We have taken the average here of 20 miles, and a figure of 1 kwh to be a reasonable mid-point.

All data points were achieved by riding a fully charged Segway PT for variable distances, then completely charging the Segway PT using a power meter to measure the kwh required.

## 2.2 Calculation

The calculation is based on the TOTAL distance for all the clear data points and I.Margaronis's complete cycle.

### 2.2.1 Data Points

All data points are shown below.

Miles	KWH to fill	Power (kwh / km)*	g CO <sub>2</sub> / km	Source
1.8	0.22	0.076	40.79	Clear data test points
2.6	0.30	0.072	38.51	Clear data test points
3.9	0.38	0.061	32.52	Clear data test points
3.9	0.36	0.057	30.81	Clear data test points
4.9	0.48	0.061	32.69	Clear data test points
7.8	0.76	0.061	32.52	Clear data test points
11	0.86	0.049	26.09	Clear data test points
15	0.94	0.039	20.92	Clear (Dr Elliott's journey see 4.4.1)
19.9	0.99	0.031	16.60	I Margaronis
20	1.00	0.031	16.69	Segway Official
<b>TOTAL**</b>	<b>70.8</b>	<b>5.29</b>	<b>0.046</b>	<b>24.94 Average</b>

16.60 Best case  
40.79 Worse case

#### Notes

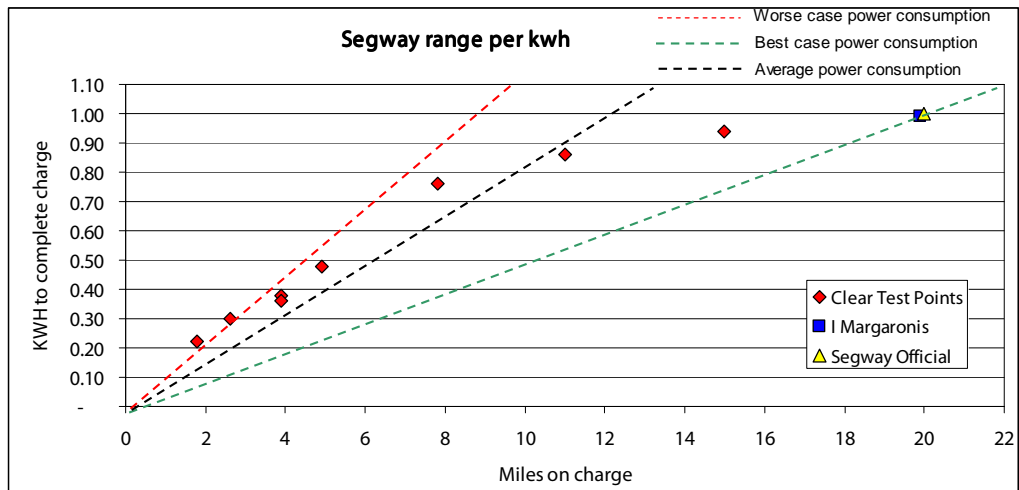
kg CO<sub>2</sub> / Kwh

0.53702 DEFRA

\* Note change from miles to km

\*\* Based on Clear + I.Margaronis Data Points

### 2.2.2 Graphical results



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### 3 Conclusions

#### 3.1 g/km figure

Agreeing closely with manufacturer's figures, **24.9 g/km** appears to be a reasonable real-world measurement for the carbon footprint of a Segway PT in the UK\* when in use by a range of users. Clear's estimate of the realistic accuracy of figures would be +/- 2 g/km of CO<sub>2</sub>.

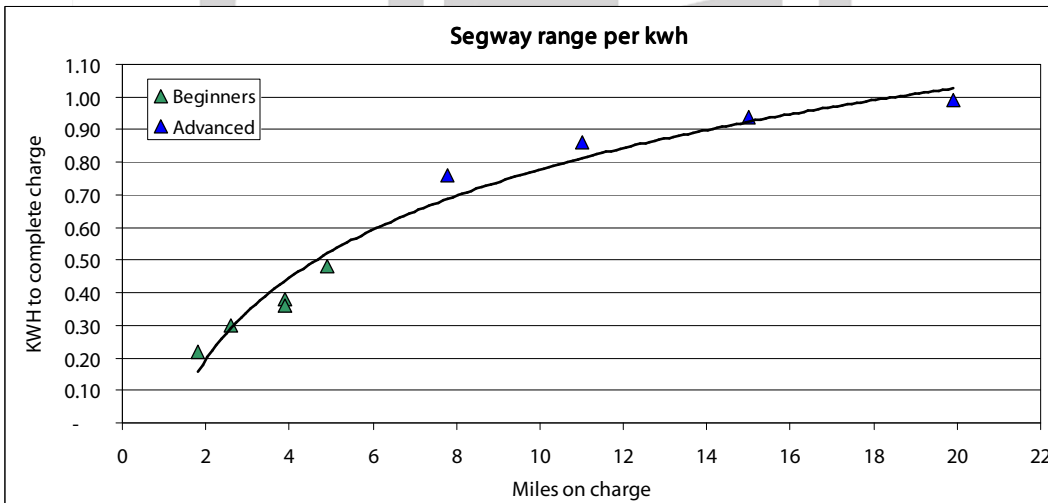
\*Obviously this will be different for other countries which have different mixes of electricity generation and hence kgCO<sub>2</sub>e figures. For example France has a very low g/kwh figure due to a high proportion of nuclear power generation.

#### 3.2 Experience of riders / non-linear energy use

Experience of riders appears to be a significant driver of Segway PT energy consumption. Bruce Elliott and Isidore Margaronis (see section 5.4.1 / 5.4.2) both achieved significantly greater ranges than when the PT was used for beginners / lower experienced riders. As an observer it is easy to see that beginners travel more slowly, spending more of their time (and the PT's energy supply) on balancing, whereas experienced users tend to spend most of their time at, or very close to top speed (12.5 mph).

If differentiation was to be made between the experience of users, then Clear would suggest experienced riders were more likely to be between **16.6 and 20.9 g/km**, whereas beginners are more likely to create between **26.1 and 40.1 g/km**.

This would also appear to be shown in the data points. The longer journeys (8miles and over) tended to be taken by more experienced users and had a distinct A to B purpose, whereas the shorter stints were beginners learning to use the device, not specifically travelling anywhere and not accumulating distance as quickly.



### 3.3 g/km figures for other industrial nations

Figures have been sourced for indicative g/kwh figures for other G8 countries from "IEA (2007) CO2 emissions from fuel combustion". The calculation method is different to that used by DEFRA which is believed to be the most accurate, hence the IEA figures have been rebased to make them comparable, and converted into Segway g/km figures.

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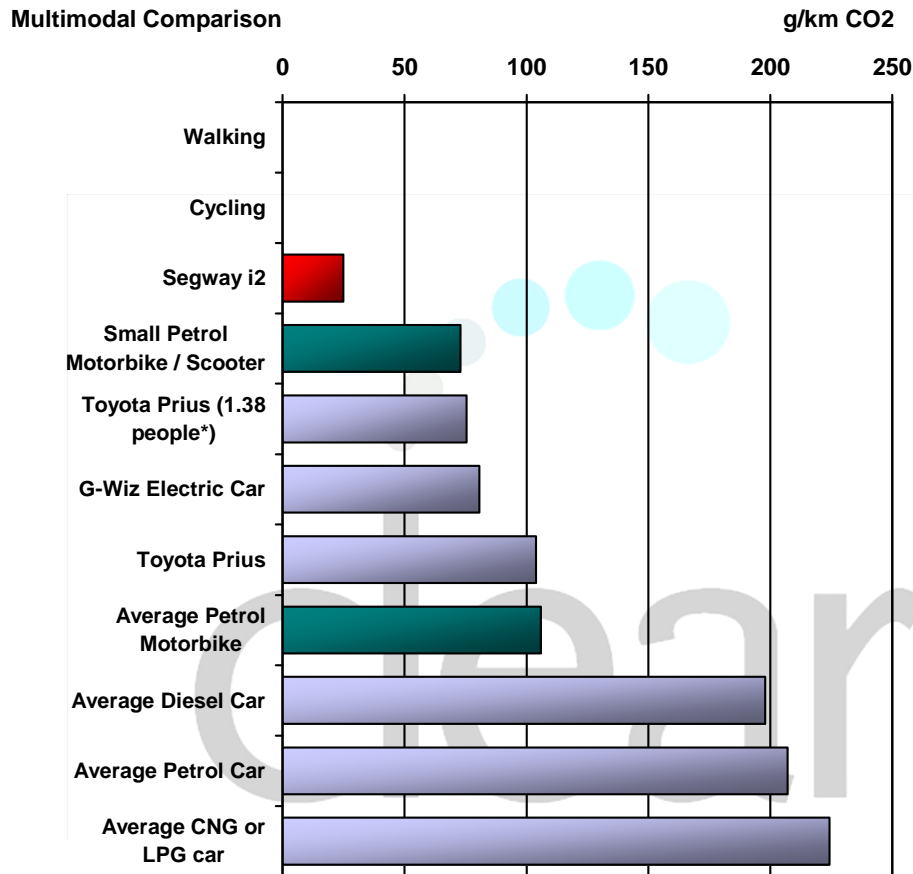
Other EU countries	IEA (2007) g/kwh	DEFRA (2008) rebased	Segway g/km
UK (DEFRA 2008)		537.02	
UK	473	537	24.94
Brazil	84	95	4.43
France	91	103	4.80
Canada	199	226	10.49
Russia	338	384	17.82
Germany	349	396	18.40
Italy	405	460	21.35
Japan	429	487	22.62
Mexico	515	585	27.15
US	573	651	30.21
China	788	895	41.55
South Africa	848	963	44.71
India	943	1071	49.72



## 4 Comparable modes of transport

### 4.1 Private Transport

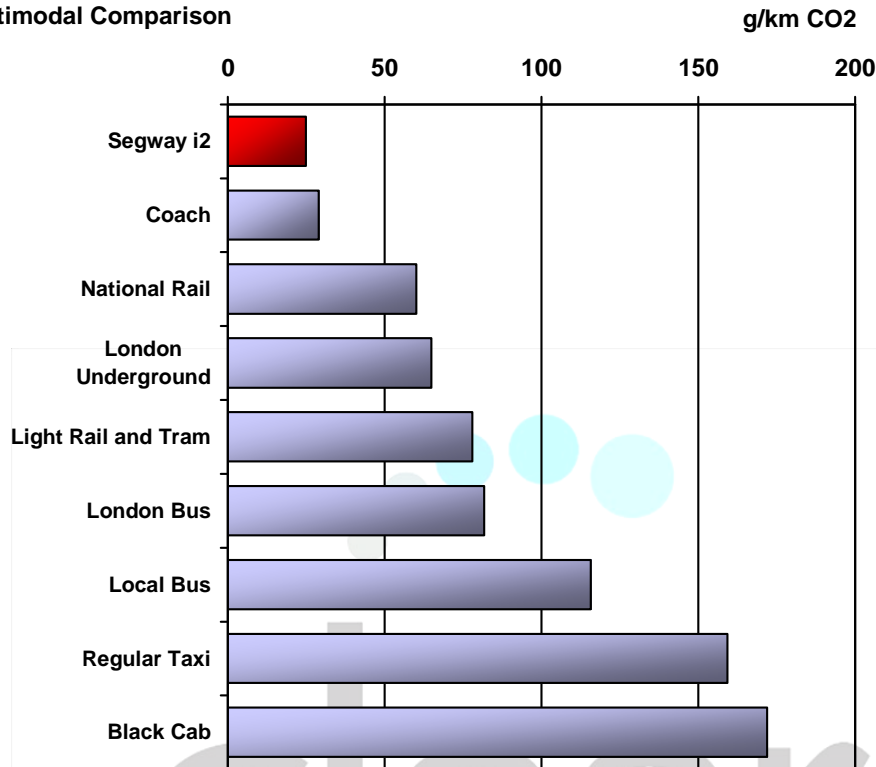
As a form of private transport in terms of CO<sub>2</sub> g/km, the Segway PT is only beaten by cycling or walking (which are currently assumed to be 0 g/km):



- 1.38 people is the average central London vehicle occupancy during peak hours in 2007.
- All other modes assume a single occupant.

## 4.2 Public Transport

### Multimodal Comparison



It should also be pointed out that distance travelled between the same two points can change dependent on mode. A bus route from A to B may be a greater distance than a direct route by taxi for example.

All figures assume average occupancy as per DfT assumptions.

### 4.3 Sources of Comparison

The source for all figures are the average factors provided in:  
2008 Guidelines to DEFRA's GHG Conversion Factors  
Annexes updated April 2008

- Private transport figures developed by AEA Energy & Environment and agreed with Department for Transport (2007)
- Public Transport figures developed by Department for Transport, Transport for London and AEA Energy & Environment, 2008

Average occupancy from 2007 London Travel Report – TfL – average occupancy of cars into London during peak hours = 1.38.

G-Wiz figure is based on a battery capacity of 9.66kwh, and a range of 40 miles charged on average UK mains electricity ([www.goingreen.co.uk/store/content/gwiz\\_techspec](http://www.goingreen.co.uk/store/content/gwiz_techspec))



## 5 Notes

### 5.1 About Clear, the Carbon Offset Company

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Clear was the first company in the world to achieve the UK government's (DEFRA / DECC) Quality Assurance Scheme for carbon offsetting. Clear specialises in research into new methods of carbon foot-printing, and this white paper has been produced as part of that ongoing research.

The author of this report is Ben Hedley *MEng, MA (Cantab)*, Operations Director of Clear. He holds two degrees in Manufacturing Engineering from Cambridge University, specialising in Thermodynamics and Mechanics.

Clear currently have no commercial relationship with Segway Inc, and this white paper has been created independently of any direct input from Segway Inc.

More information on Clear is available at: [www.clear-offset.com](http://www.clear-offset.com)

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### 5.2 About Segway PT

The Segway i2 is a two-wheeled, self-balancing electric vehicle invented by Dean Kamen. It is produced by Segway Inc. of New Hampshire, USA. The name "Segway" is a homophone of "segue" (a smooth transition, literally Italian for "follows"). PT is an initialism for personal transporter while the old suffix HT was an initialism for human transporter.

Computers and motors in the base of the device keep the Segway PT upright when powered on with balancing enabled. Users lean forward to go forward, lean back to go backward, and turn by using a "Lean Steer" handlebar, leaning it left or right. Segway PTs are driven by electric motors at up to 20 kilometres per hour (12 mph). Gyroscopic sensors are used to detect tilting of the device which indicates a departure from perfect balance. Motors driving the wheels are commanded as needed to bring the PT back into balance.

The Segway is powered by lithium ion batteries, recharged from a domestic electricity source.

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More information on Segway is available at: [www.segway.com](http://www.segway.com)

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### 5.3 About this report

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### 5.4 Usage during testing

#### 5.4.1 Clear Director Use

Segway UK loaned the directors of Clear a used Segway PT (c. 2000 miles) for testing purposes. The Segway was ridden by a variety of users, often beginners due to their rarity in the UK. One notable journey was by Bruce Elliott (Managing Director of Clear) from Wandsworth Common to Oxford Circus and back, a distance of 15.0 miles, which required a 0.94kwh charge. Dr Elliott maintains that although the low battery warning was flashing, there was still some charge left in the PT, as it had not entered "low battery" mode yet. If the total capacity of the battery is 1.0 kwh as

indicated by Segway figures and I.Margaronis's experience, then this would indicate a total range of about 16 miles from 1.0kwh.

Much of the beginner use indicated a range of around 10 miles from a full charge. Though not conclusive, this would suggest that as riders become more experienced (as Dr Elliott is), then less of the battery charge is required for balance, and more is used for travel than is the case with complete beginners.

#### **5.4.2 Isidore Margaronis Use**

Isidore Margaronis commutes daily from Notting Hill (W8) to Piccadilly Circus over a variety of terrain from smooth paths to potholed roads.

Isidore is an experienced Segway PT owner, having owned several, ridden approximately 10,000 miles. Isidore's Segway is not new, the batteries having completed approximately 110 charge cycles, with a typical life expectancy on this type of battery of 1000 cycles. He notes that typically Segway PT performance reduces after 18/18.5 miles as the machine switches into reduced power mode for safety.

As an experiment, Isidore fully charged his i2 Segway PT and travelled a distance of **19.9 miles** before the Segway PT indicated that it was approaching safety shutdown. He then recharged the device, measuring a power input of **0.99 kwh** for a full capacity charge.



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