Composite Weather Variable: Temperature and Weather Analysis

Introduction

Gas demand in the UK varies depending on a number of factors. One main factor is the weather and in particular temperature and wind speed. The Composite Weather (*CW*) is defined so that temperature and wind speed are accounted for using the effective temperature (*ET*), seasonal normal effective temperature (*SNET*) and the wind chill. The *CW* is defined as,

$$CW = I_1 ET_D + (1 - I_1) SNET_D - I_2 \max(0, WS - W_0) \max(0, T_0 - AT), \tag{1}$$

where,

$ET_D = (ET_{D-1} + AT)/2$	is the effective temperature for day D,	(2)
AT	is the actual temperature for day D,	
T_0	is the wind chill temperature cut-off,	
I_1	is the effective temperature weight,	
I_2	is the wind chill weight,	
WS	is the wind speed and	
W_0	is the wind chill cut-off.	

To model gas demand as a linear relationship to weather, *CW* is used to define the Composite Weather Variable (*CWV*) such that,

$$CWV = \begin{cases} V_1 + q(V_2 - V_1), & CW \geq V_2 \\ V_1 + q(CW - V_1), & V_1 < CW < V_2 \\ CW, & V_0 \leq CW \leq V_1' \\ CW + I_3(CW - V_0), & CW < V_0 \end{cases} \tag{3}$$

where,

q	is the slope relating to warm weather cut-off,	(4)
V_0	is the cold weather upturn threshold,	
V_1	is the lower warm weather cut-off,	
V_2	is the upper warm weather cut-off and	
I_3	is the cold weather sensitivity.	

The *CWV* is calculated on an LDZ (local distribution zone) by LDZ basis whereby each of the parameters in (2) and (4) take different values for each LDZ. In the analysis presented, a weighted average of these parameters is used as given in (5), see appendix B.

$T_0 = 14.00$,	$I_1 = 0.70$,	$V_0 = 2.80$,	(5)
$W_0 = 0.00$,	$I_2 = 0.01$,	$V_1 = 14.39$,	
$q = 0.42$,	$I_3 = 0.18$,	$V_2 = 17.87$.	

Assumptions in Analysis

To analyse the relationship between temperature and wind speed on *CW* and *CWV*, equation (1) needs to be generalised in terms of actual temperature, *AT* and wind speed, *WS*. First, assume that the temperature from one day to the next does not vary too greatly, meaning,

$$ET_{D-1} \approx AT. \tag{6}$$

Secondly, assume that *AT* is close to the *SNET* on any given day,

$$SNET \approx AT - \delta, \text{ where } \delta \in \mathbb{R}. \tag{7}$$

Reduced Equations and Parameters

Applying equations (6) and (7) into equations (1) and (2) and because $W_0 = 0$, $\max(0, WS - W_0) \equiv WS$ then,

$$CW = AT + \delta(I_1 - 1) - I_2\, WS \max(0, T_0 - AT). \tag{8}$$

Results

In all the results presented, $\delta = 0.5$ and all other parameters are as given in (5). There are five regions of interest for *CWV*,

$$\begin{array}{llcl} \text{(a)} & & CWV < & V_0 \\ \text{(b)} & V_0 & \leq CWV < & CWV(AT = T_0) \\ \text{(c)} & CWV(AT = T_0) & \leq CWV \leq & V_1 \\ \text{(d)} & V_1 & < CWV < & V_1 + q(V_2 - V_1) \\ \text{(e)} & V_1 + q(V_2 - V_1) & \leq CWV & \end{array} \tag{9}$$

Regions (a) and (b) are dependent on temperature and wind speed, regions (c) and (d) are dependent on temperature only and region (e) is independent of temperature and wind speed and is constant.

Fixed Wind Speed, Variable Temperature

Wind speed has the greatest effect on *CWV* at low temperatures. Wind speed becomes less of a driver when $AT > (V_0 - \delta(I_1 - 1) + I_2 WST_0)(1 + I_2 WS)^{-1}$. In both regions (a) and (b), higher wind speeds give lower *CWV* and a greater change in *CWV*. As temperature increases to T_0 wind speed becomes less of a factor to determine *CWV* and for temperatures above or equal to T_0 wind speed has no effect as *CWV* has transitioned into region (c). As temperature continues to increase through regions (c) and (d) it becomes less of a driving factor until having no impact on *CWV* in region (e). In regions (a-d) rising temperatures gives a higher *CWV* as there is a continual dependence on temperature to determine *CWV*. See Appendix A, Figure 1 for an illustration of fixed wind speed and generalised equations for all critical points.

Fixed Temperature, Variable Wind Speed

For all temperatures below $AT = V_0 - \delta(I_1 - 1) = 2.95°$ *CWV* reduces faster for increasing wind speed in region (a) than in any other region. To be in region (b) temperatures are between 2.95° and T_0 and an increasing wind speed reduces the CWV but not as quickly until the wind speed reaches a critical value of $WS = (AT + \delta(I_1 - 1) - V_0)\big(I_2(T_0 - AT)\big)^{-1}$ whereby the rate of decline in *CWV* for increasing wind speed returns to that of temperatures below 2.95°. In region (c) and (d) *CWV* is dependent on temperature only giving constant *CWV* for all wind speeds. Region (e) is independent of both temperature and wind speed meaning that *CWV* is constant for all temperatures and wind speeds. In general, in regions (a-d) increasing wind speeds gives a lower *CWV*, however, with the current parameter set it is only regions (a) and (b) where this is the case, because of the value of T_0. See Appendix A, Figure 2 for an illustration of fixed temperature and generalised equations for all critical points.

Appendix A

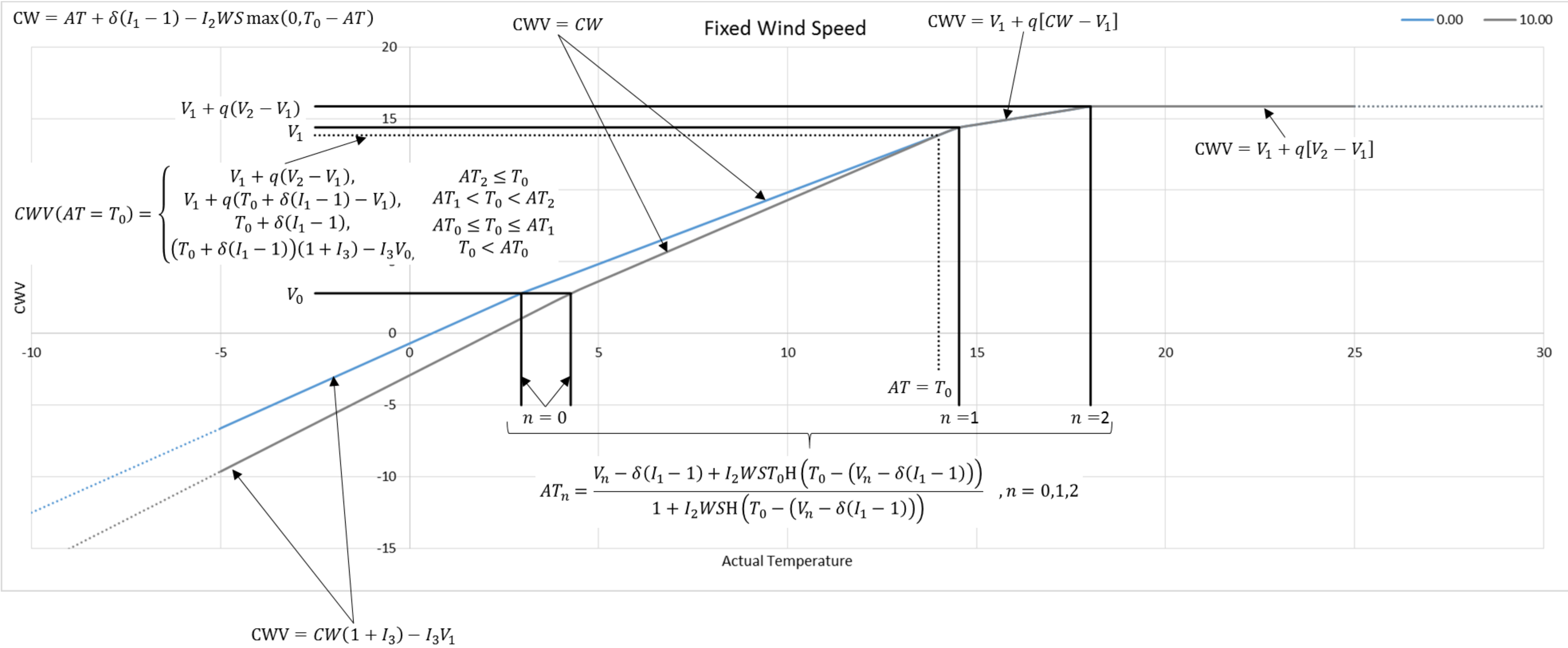

Figure 1: *Fixed wind speed for varying temperature.*

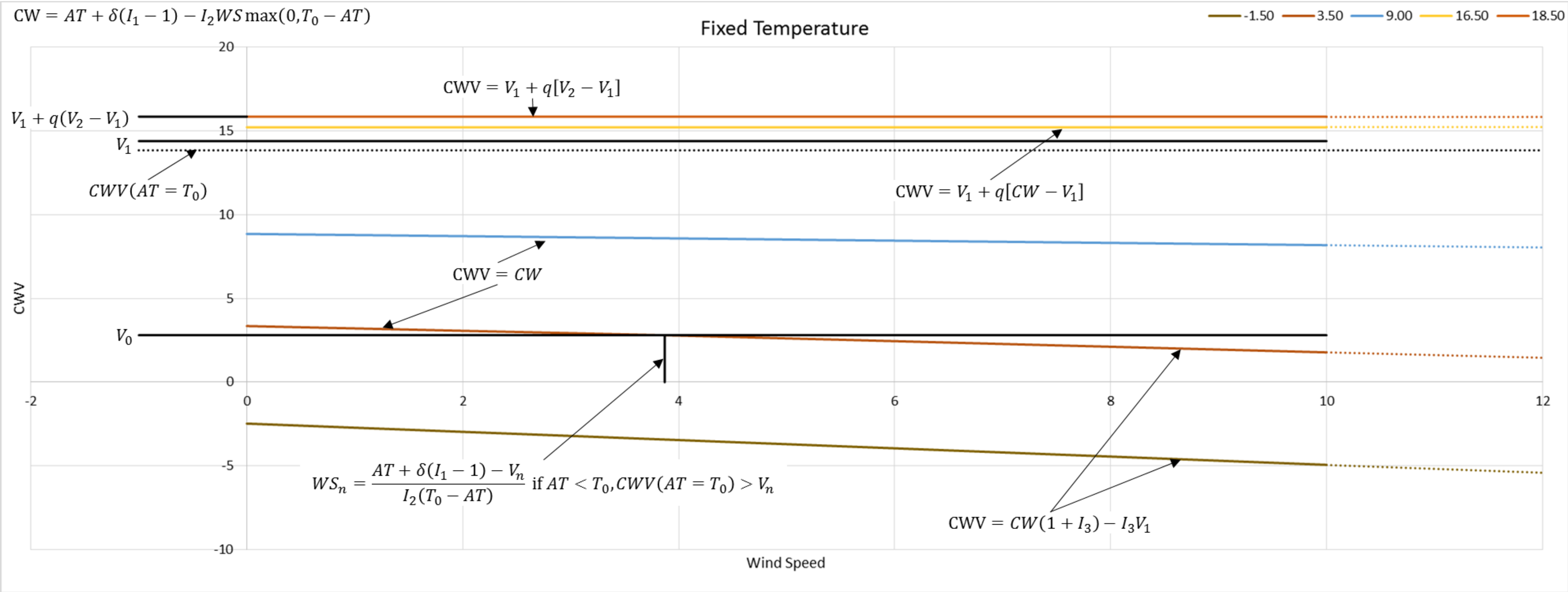

Figure 2: *Fixed temperature for varying wind speed.*

Appendix B

LDZ Parameters and weights. (4d.p reflecting the **I_2** parameter.)

LDZ Weights	0.09	0.10	0.07	0.04	0.13	0.13	0.08	0.12	0.07	0.06	0.09	0.01	0.03	
Parameters	**EA**	**EM**	**NE**	**NO**	**NT**	**NW**	**SC**	**SE**	**SO**	**SW**	**WM**	**WN**	**WS**	**Weighted**
I_1	0.7190	0.6910	0.6760	0.6630	0.7270	0.6970	0.6350	0.7120	0.7200	0.6820	0.7200	0.6970	0.6690	0.6982
I_2	0.0144	0.0144	0.0159	0.0086	0.0151	0.0149	0.0119	0.0140	0.0134	0.0100	0.0111	0.0149	0.0101	0.0134
I_3	0.0900	0.0500	0.0000	0.1500	0.2200	0.3000	0.1500	0.3300	0.2400	0.2200	0.1400	0.3000	0.1100	0.1838
V_0	3.0000	3.0000	0.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	2.8037
V_1	15.3000	13.5000	14.7000	13.0000	15.2000	14.9000	12.2000	15.1000	14.8000	14.2000	13.7000	14.9000	14.8000	14.3878
V_2	19.2000	16.8000	17.9000	16.0000	19.2000	18.0000	16.0000	18.7000	18.2000	17.3000	17.2000	18.0000	17.9000	17.8660
q	0.3400	0.4900	0.3800	0.4600	0.3800	0.3800	0.6400	0.3800	0.3700	0.4200	0.4300	0.3800	0.4600	0.4200
W_0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
T_0	14.0000	14.0000	14.0000	14.0000	14.0000	14.0000	14.0000	14.0000	14.0000	14.0000	14.0000	14.0000	14.0000	14.0000