Supplementary Material

1. Parameters for calculating CAFE standards

Error! Reference source not found. gives the parameters used for calculating CAFE standards with respect to fuel efficiency and GHG emissions. All parameters to be achieved by 2020 are given in the report 'Vehicle Fuel Economy and CO_2 Emissions: Data and Analyses' by the Korea Energy Agency (http://bpms.kemco.or.kr/transport_2012/pds/month_pds.aspx). In particular, the assumption of α' in 2030 (84) in **Error! Reference source not found.** is assumed based on information on historical standards as:

During the second period (2012-2015), the target was achieving 17km/liter or 140g/km.

During the third period (2016-2020), the target was achieving 24.3km/liter or 97g/km.

The ratio of the targets between the second and third period: 17/24.3 = 0.6996 and 97/140 = 0.6929. Now we know the new target as 28.1 km/liter with no information of GHG emission standards yet. This study assumes α' in 2030 as 84 = 97 * (24.3/28.1). Likewise, the other parameters can also be assumed in such a way. The 2025 parameters are applied as median values between the values in 2020 and 2030, except for w (curb weight).

Table 1. Parameters for calculating CAFE standards.

Year	Parameters for Calculating Average Fuel Efficiency			Parameters for Calculating Average GHG Emissions			
	α	β	δ	α'	β'	w	δ'
2016	31.136	0.008548	22.0	127	0.0533	1421.8	108.2
2017	32.140	0.008824	22.7	123	0.0517	1421.8	104.8
2018	32.810	0.009008	23.2	120	0.0504	1421.8	102.3
2019	35.823	0.009835	25.3	110	0.0462	1421.8	93.7
2020	40.678	0.11168	28.7	97	0.0407	1421.8	82.7
2025				90.5	0.0380	1420	77.2
2030				84	0.0352	1420	71.6

2. Assumptions for calculating CAFE performance

Based on the sales of car models in 2018, the representative car models are selected for calculating average GHG emission performance of CAFE standards and performance using GCAM, as shown in **Error! Reference source not found.**.

Table 2. Representative car models selected by modes (source: Hyundai (https://www.hyundai.com/kr/en/main) and Kia (https://www.kia.com/kr/main.html)).

Mode	Model	Sales Volumes in 2018	Curb Weight (kg)	Fuel Efficiency (km/liter)	CO_2 Emissions (g/km)
SUV	SANTAFE	99,143	1925	12.3	156
Large Sedan	GRANDEUR	88,533	1575	11.9	129
Medium Sedan	SONATA	61,724	1415	12.9	106
Small Sedan	MORNING	59,042	910	15.7	104

3. Assumptions for Socioeconomics

According to definitions (SSP1: Sustainability, SSP2: Middle of the Road, SSP3: Fragmentation, SSP4: Inequality, SSP5: Conventional Development), this study adopts the SSP2 scenario for its moderate pathway, which is represented in **Error! Reference source not found.**. For more details and references, please visit: http://jgcri.github.io/gcam-doc/macro-econ.html and http://jgcri.github.io/gcam-doc/ssp.html

Table 3. Assumptions for socioeconomics.

year	Population (Thousand)	GDP (Million 2015US$)	GDP per Capita (Thousand 2015US$)
2020	49,378	1,671,164	33.84
2025	49,641	1,954,094	39.36
2030	49,661	2,215,327	44.60
2035	49,342	2,448,359	49.62
2040	48,630	2,652,051	54.53
2045	47,560	2,830,948	59.52
2050	46,183	2,981,477	64.55

4. Assumptions for vehicle costs

Assumptions for vehicles costs are taken from previous studies (Lutsey and Nicholas, 2019; Morrison et al., 2018; Ruffini and Wei, 2018; Soulopoulos, 2017). **Error! Reference source not found.** summarizes ICEVs and BEVs' cost assumptions in previous studies and in this study. **Error! Reference source not found.** summarizes BEVs and FCEVs' cost assumptions in previous studies and in this study. **Error! Reference source not found.** summarizes the overall cost assumptions used in this study.

- ICEV costs

Lutesy and Nicholas (2019) and Soulopoulos (2017) expect ICEV costs to increase slightly because of light-weighting and other measures taken for reducing emissions. Ruffini and Wei (2015) expect ICEV costs to be constant during 2020-2050. In our study ICEV costs are kept constant over all periods.

- Cost parity (BEV vs ICEV)

Lutesy and Nicholas (2019), Soulopoulos (2017), and Ruffini and Wei (2015) expect BEVs to reach cost parity with ICEVs during 2020-2030. In our study BEVs will reach cost parity with ICEVs in 2025.

- BEV costs since 2030

Ruffini and Wei (2015) expect BEV costs not to decline any more after 2030. In our study BEV costs are kept constant since 2030.

- Cost parity (BEV vs FCEV)

Morrison et al. (2018), found that FCEVs will reach cost parity with BEVs-150 (BEVs with a 150-mile range) around 2025. In our study FCEVs will reach cost parity with BEVs in 2025.

Table 4. ICEV and BEV cost assumptions in previous studies and in this study.

Source	Vehicle	2020	2030	2040	2050
Lutesy and Nicholas (2019)	ICEV	42	43	-	-
	BEV	51	36	-	-
	Ratio (BEV/ICEV)	125%	84%	-	-

Soulopoulos (2017)	ICEV		28	30	-	-
	BEV		35	26	-	-
	Ratio (BEV/ICEV)		121%	84%		
Ruffini and Wei (2018)	ICEV		52.5	52.5	52.5	52.5
	BEV		54	49	49	49
	Ratio (BEV/ICEV)		103%	93%	93%	93%
This study	Small Sedan	ICEV	22.3	22.3	22.3	22.3
		BEV	26.8	19.0	19.0	19.0
		Ratio (BEV/ICEV)	120%	85%	85%	85%
	Medium Sedan	ICEV	31.7	31.7	31.7	31.7
		BEV	38.1	27.0	27.0	27.0
		Ratio (BEV/ICEV)	120%	85%	85%	85%
	Large Sedan	ICEV	53.7	53.7	53.7	53.7
		BEV	64.4	45.6	45.6	45.6
		Ratio (BEV/ICEV)	120%	85%	85%	85%
	SUV	ICEV	55.2	55.2	55.2	55.2
		BEV	66.2	46.9	46.9	46.9
		Ratio (BEV/ICEV)	120%	85%	85%	85%

Table 5. BEV and FCEV cost assumptions in previous studies and in this study.

Source	Size	Vehicle	2020	2025	2030	2035	2040
Morrison et al. (2018) Units: $/mile BEV-150 (BEV with a 150-mile range) is selected for reference	Compact	BEV	0.53	0.45	0.38	0.33	0.32
		FCEV	0.62	0.44	0.32	0.28	0.29
		Ratio (FCEV/BEV)	117%	98%	84%	85%	91%
	Midsize	BEV	0.56	0.48	0.41	0.36	0.34
		FCEV	0.62	0.49	0.34	0.30	0.30
		Ratio (FCEV/BEV)	111%	102%	83%	83%	88%
	Small SUV	BEV	0.61	0.53	0.46	0.39	0.37
		FCEV	0.77	0.52	0.38	0.33	0.32
		Ratio (FCEV/BEV)	126%	98%	83%	85%	86%
	Large SUV	BEV	0.66	0.58	0.49	0.43	0.40
		FCEV	0.82	0.57	0.40	0.37	0.34
		Ratio (FCEV/BEV)	124%	98%	82%	86%	85%
This Study Units: thousand $/veh	Small Sedan	BEV	26.8	22.3	19.0	19.0	19.0
		FCEV	31.3	22.3	15.9	15.9	15.9
		Ratio (FCEV/BEV)	117%	100%	84%	84%	84%
	Medium Sedan	BEV	38.1	31.7	27.0	27.0	27.0
		FCEV	42.3	31.7	22.4	22.4	22.4
		Ratio (FCEV/BEV)	111%	100%	83%	83%	83%

Large Sedan	BEV	64.4	53.7	45.6	45.6	45.6
	FCEV	81.1	53.7	37.9	37.9	37.9
	Ratio (FCEV/BEV)	126%	100%	83%	83%	83%
SUV	BEV	66.2	55.2	46.9	46.9	46.9
	FCEV	82.1	55.2	38.4	38.4	38.4
	Ratio (FCEV/BEV)	124%	100%	82%	82%	82%

Table 6. Cost assumptions (thousand 2015$/veh).

Mode	Tech	variable	2020	2025	2030	2035	2040	2045	2050
Small Sedan	ICEV	Capital costs (infrastructure)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Capital costs (other)	2.2	2.2	2.2	2.2	2.2	2.2	2.2
		Capital costs (purchase)	12.1	12.1	12.1	12.1	12.1	12.1	12.1
		Operating costs (maintenance)	4.3	4.3	4.3	4.3	4.3	4.3	4.3
		Operating costs (registration and insurance)	3.7	3.7	3.7	3.7	3.7	3.7	3.7
	BEV	Capital costs (infrastructure)	0.9	0.8	0.7	0.7	0.7	0.7	0.7
		Capital costs (other)	3.2	2.7	2.3	2.3	2.3	2.3	2.3
		Capital costs (purchase)	17.2	14.4	12.2	12.2	12.2	12.2	12.2
		Operating costs (maintenance)	2.6	2.2	1.8	1.8	1.8	1.8	1.8
		Operating costs (registration and insurance)	2.8	2.4	2.0	2.0	2.0	2.0	2.0
	FCEV	Capital costs (infrastructure)	4.8	3.4	2.5	2.5	2.5	2.5	2.5
		Capital costs (other)	3.1	2.2	1.6	1.6	1.6	1.6	1.6
		Capital costs (purchase)	16.7	11.9	8.5	8.5	8.5	8.5	8.5
		Operating costs (maintenance)	3.4	2.4	1.7	1.7	1.7	1.7	1.7
		Operating costs (registration and insurance)	3.3	2.4	1.7	1.7	1.7	1.7	1.7
Medium Sedan	ICEV	Capital costs (infrastructure)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Capital costs (other)	3.4	3.4	3.4	3.4	3.4	3.4	3.4
		Capital costs (purchase)	18.5	18.5	18.5	18.5	18.5	18.5	18.5
		Operating costs (maintenance)	4.8	4.8	4.8	4.8	4.8	4.8	4.8

		Operating costs (registration and insurance)	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	BEV	Capital costs (infrastructure)	1.0	0.9	0.7	0.7	0.7	0.7	0.7
		Capital costs (other)	4.6	3.8	3.3	3.3	3.3	3.3	3.3
		Capital costs (purchase)	24.8	20.7	17.6	17.6	17.6	17.6	17.6
		Operating costs (maintenance)	3.3	2.7	2.3	2.3	2.3	2.3	2.3
		Operating costs (registration and insurance)	4.3	3.6	3.0	3.0	3.0	3.0	3.0
	FCEV	Capital costs (infrastructure)	5.2	3.9	2.8	2.8	2.8	2.8	2.8
		Capital costs (other)	4.4	3.3	2.3	2.3	2.3	2.3	2.3
		Capital costs (purchase)	23.7	17.8	12.6	12.6	12.6	12.6	12.6
		Operating costs (maintenance)	4.1	3.1	2.2	2.2	2.2	2.2	2.2
		Operating costs (registration and insurance)	4.8	3.6	2.5	2.5	2.5	2.5	2.5
Large Sedan	ICEV	Capital costs (infrastructure)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Capital costs (other)	7.8	7.8	7.8	7.8	7.8	7.8	7.8
		Capital costs (purchase)	31.0	31.0	31.0	31.0	31.0	31.0	31.0
		Operating costs (maintenance)	4.4	4.4	4.4	4.4	4.4	4.4	4.4
		Operating costs (registration and insurance)	10.5	10.5	10.5	10.5	10.5	10.5	10.5
	BEV	Capital costs (infrastructure)	1.0	0.8	0.7	0.7	0.7	0.7	0.7
		Capital costs (other)	10.2	8.5	7.3	7.3	7.3	7.3	7.3
		Capital costs (purchase)	41.0	34.1	29.0	29.0	29.0	29.0	29.0
		Operating costs (maintenance)	3.1	2.6	2.2	2.2	2.2	2.2	2.2
		Operating costs (registration and insurance)	9.2	7.6	6.5	6.5	6.5	6.5	6.5
	FCEV	Capital costs (infrastructure)	6.4	4.3	3.0	3.0	3.0	3.0	3.0
		Capital costs (other)	11.2	7.4	5.2	5.2	5.2	5.2	5.2
		Capital costs (purchase)	44.8	29.6	20.9	20.9	20.9	20.9	20.9
		Operating costs (maintenance)	5.1	3.4	2.4	2.4	2.4	2.4	2.4

		Operating costs (registration and insurance)	13.6	9.0	6.4	6.4	6.4	6.4	6.4
SUV	ICEV	Capital costs (infrastructure)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Capital costs (other)	7.8	7.8	7.8	7.8	7.8	7.8	7.8
		Capital costs (purchase)	31.0	31.0	31.0	31.0	31.0	31.0	31.0
		Operating costs (maintenance)	4.9	4.9	4.9	4.9	4.9	4.9	4.9
		Operating costs (registration and insurance)	11.5	11.5	11.5	11.5	11.5	11.5	11.5
	BEV	Capital costs (infrastructure)	0.9	0.8	0.7	0.7	0.7	0.7	0.7
		Capital costs (other)	10.5	8.7	7.4	7.4	7.4	7.4	7.4
		Capital costs (purchase)	41.9	34.9	29.7	29.7	29.7	29.7	29.7
		Operating costs (maintenance)	3.3	2.7	2.3	2.3	2.3	2.3	2.3
		Operating costs (registration and insurance)	9.6	8.0	6.8	6.8	6.8	6.8	6.8
	FCEV	Capital costs (infrastructure)	5.7	3.8	2.6	2.6	2.6	2.6	2.6
		Capital costs (other)	11.7	7.8	5.5	5.5	5.5	5.5	5.5
		Capital costs (purchase)	46.6	31.3	21.8	21.8	21.8	21.8	21.8
		Operating costs (maintenance)	5.0	3.4	2.4	2.4	2.4	2.4	2.4
		Operating costs (registration and insurance)	13.1	8.8	6.1	6.1	6.1	6.1	6.1
Small Sedan	ICEV	Total	22.3	22.3	22.3	22.3	22.3	22.3	22.3
	BEV	Total	26.8	22.3	19.0	19.0	19.0	19.0	19.0
	FCEV	Total	31.3	22.3	15.9	15.9	15.9	15.9	15.9
Medium Sedan	ICEV	Total	31.7	31.7	31.7	31.7	31.7	31.7	31.7
	BEV	Total	38.1	31.7	27.0	27.0	27.0	27.0	27.0
	FCEV	Total	42.3	31.7	22.4	22.4	22.4	22.4	22.4
Large Sedan	ICEV	Total	53.7	53.7	53.7	53.7	53.7	53.7	53.7
	BEV	Total	64.4	53.7	45.6	45.6	45.6	45.6	45.6
	FCEV	Total	81.1	53.7	37.9	37.9	37.9	37.9	37.9
SUV	ICEV	Total	55.2	55.2	55.2	55.2	55.2	55.2	55.2
	BEV	Total	66.2	55.2	46.9	46.9	46.9	46.9	46.9
	FCEV	Total	82.1	55.2	38.4	38.4	38.4	38.4	38.4