international association for hydrogen energy
Clean and Abundant Energy for Sustainability

Analysis of Conversion of Transportation Sector to Hydrogen Economy through Merit Factor Application

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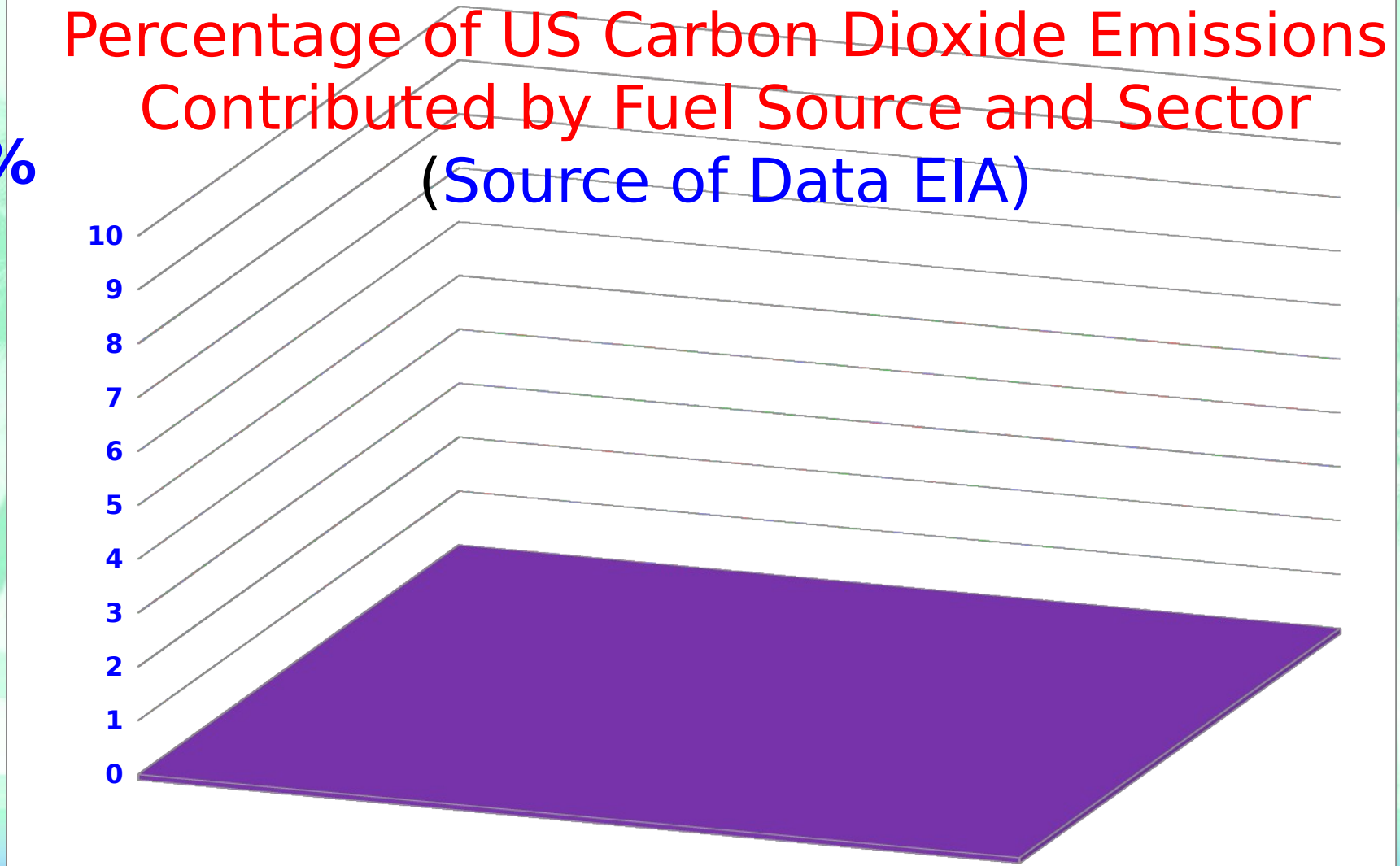
Description of the project

Hydrogen Economy is the permanent solution to the depletion of fossil fuels and to the global environmental problems caused by their utilization. Government, industry, non-governmental organizations (NGOs), interest groups, and people acting both as citizens and consumers all have an important role to play in developing a political environment that is committed to a Hydrogen Economy. In this study, we use Merit Factor Analysis to determine the countries, of those transportation sector could convert to Hydrogen Economy easier and/or earlier and those having handicaps.

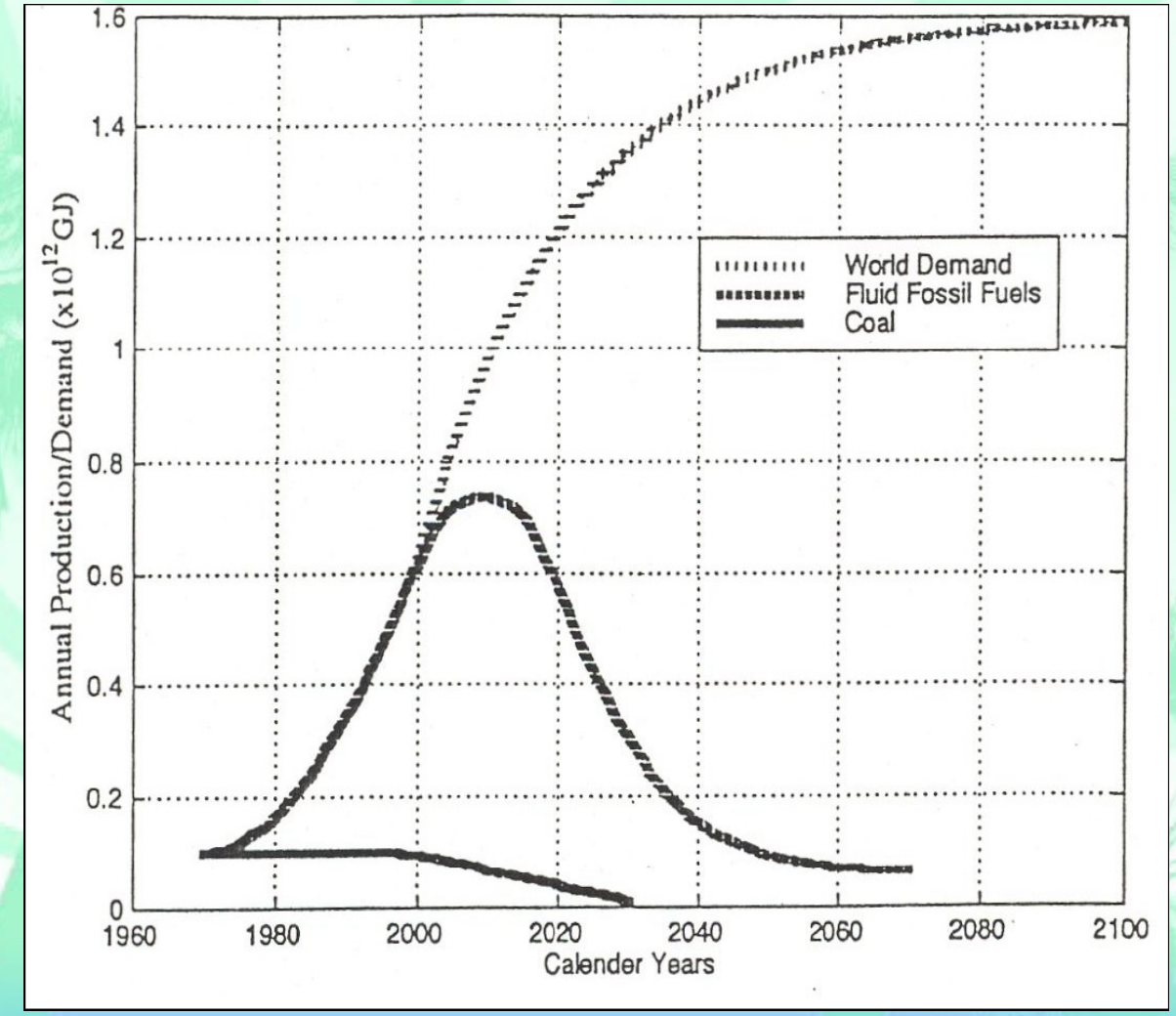
Percentage of US Carbon Dioxide Emissions Contributed by Fuel Source and Sector (Source of Data EIA)



Fossil fuel depletion: The demand for energy continues to rise because of two main reasons (Veziroglu, 2000):

- Continuing increase in world population.
- Growing demand by the developing countries in order to improve their living standards.

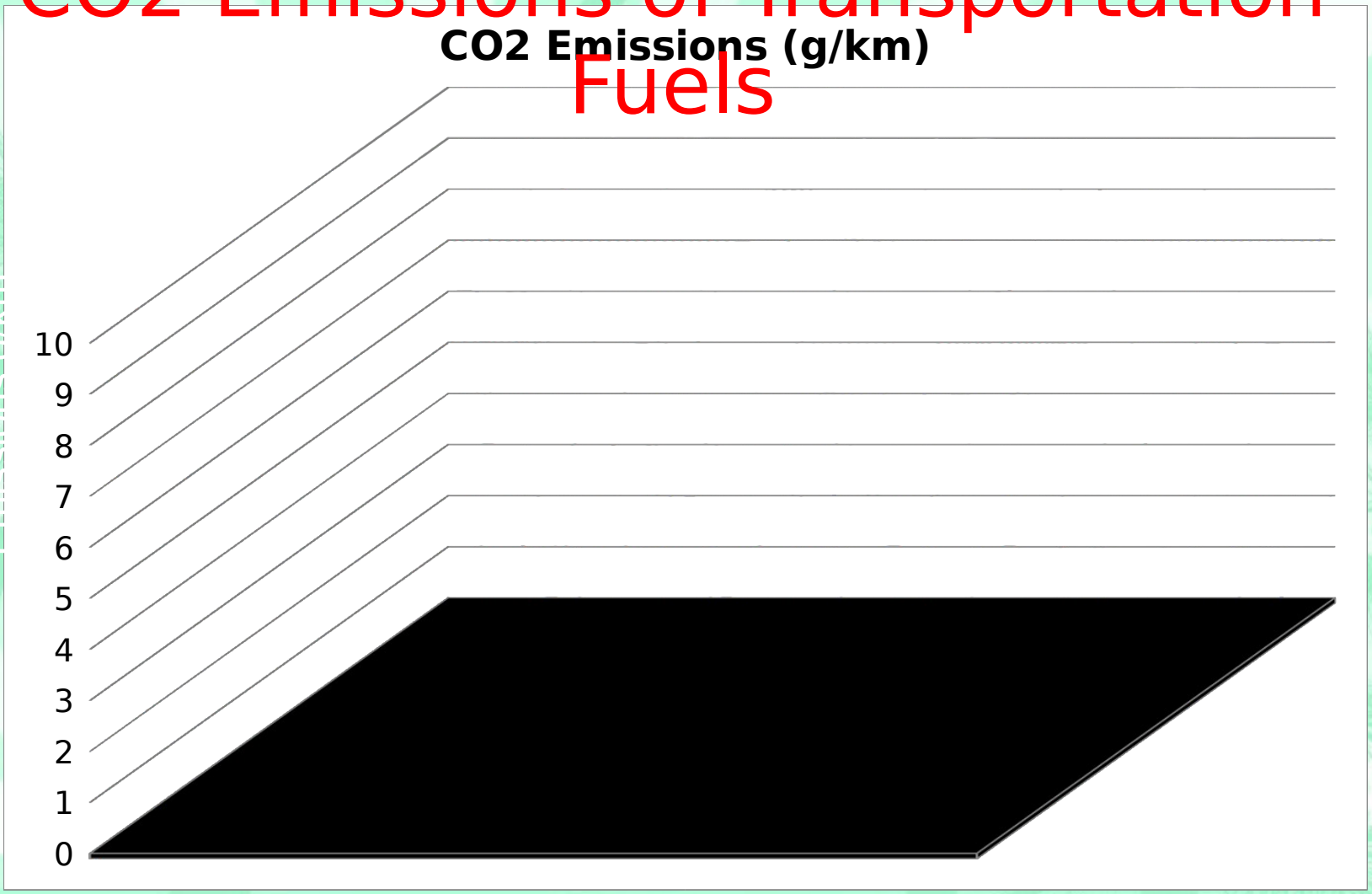
Fossil Fuel Production/Consumption



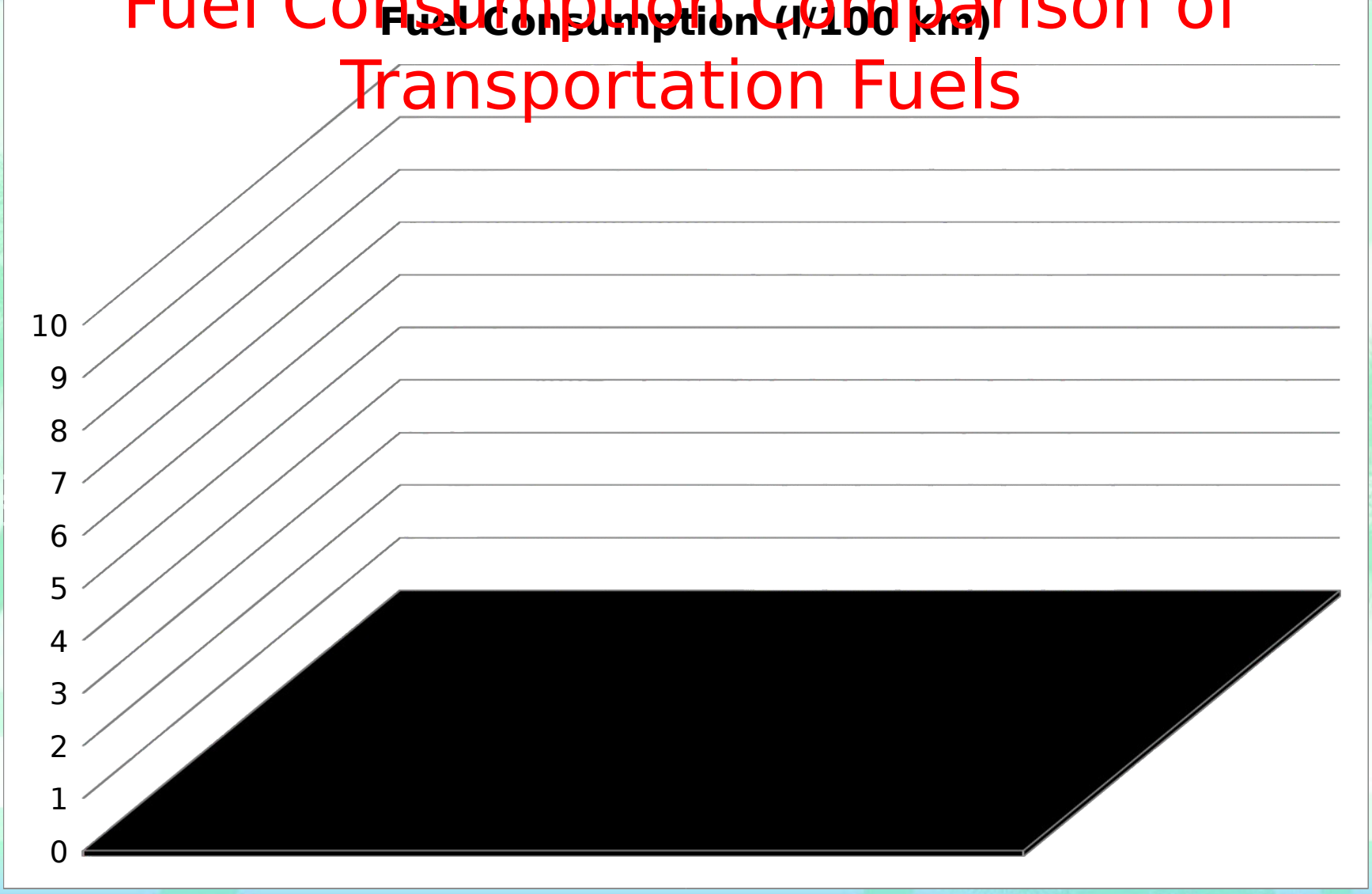
Comparison of Transportation Fuels

	Parameters	Gasoline (I.C.E.V)	Diesel (I.C.E.V)	*FCV + Fuel Reformer (on-board reforming)	FCV H2
1	CO2 Emissions (g/km)	2.1753	0.5594	0.01	0
2	NOx Emissions (g/km)	0.4661	2.9211	0.01	0
3	H.C. Emissions (g/km)	0.2424	0.9453	0.01	0
4	P.M. Emissions (g/km)	0.0994	0.0249	0.01	0
5	Fuel Consumption (l/100 km)	6.8	4.3	8.31	3.21
6	Power Train Investment Cost (US$)	2730	2925	6800	6300
7	Vehicle Efficiency (%)	18	22	25	38
8	Fuel Chain Efficiency (%)	14.8	19.4	17.2	12.9
9	Energy Consumption (MJ/km)	21	28	1.9	2.4
10	Greenhouse Effect: CO2 Emissions (g/km)	199	153	115	0

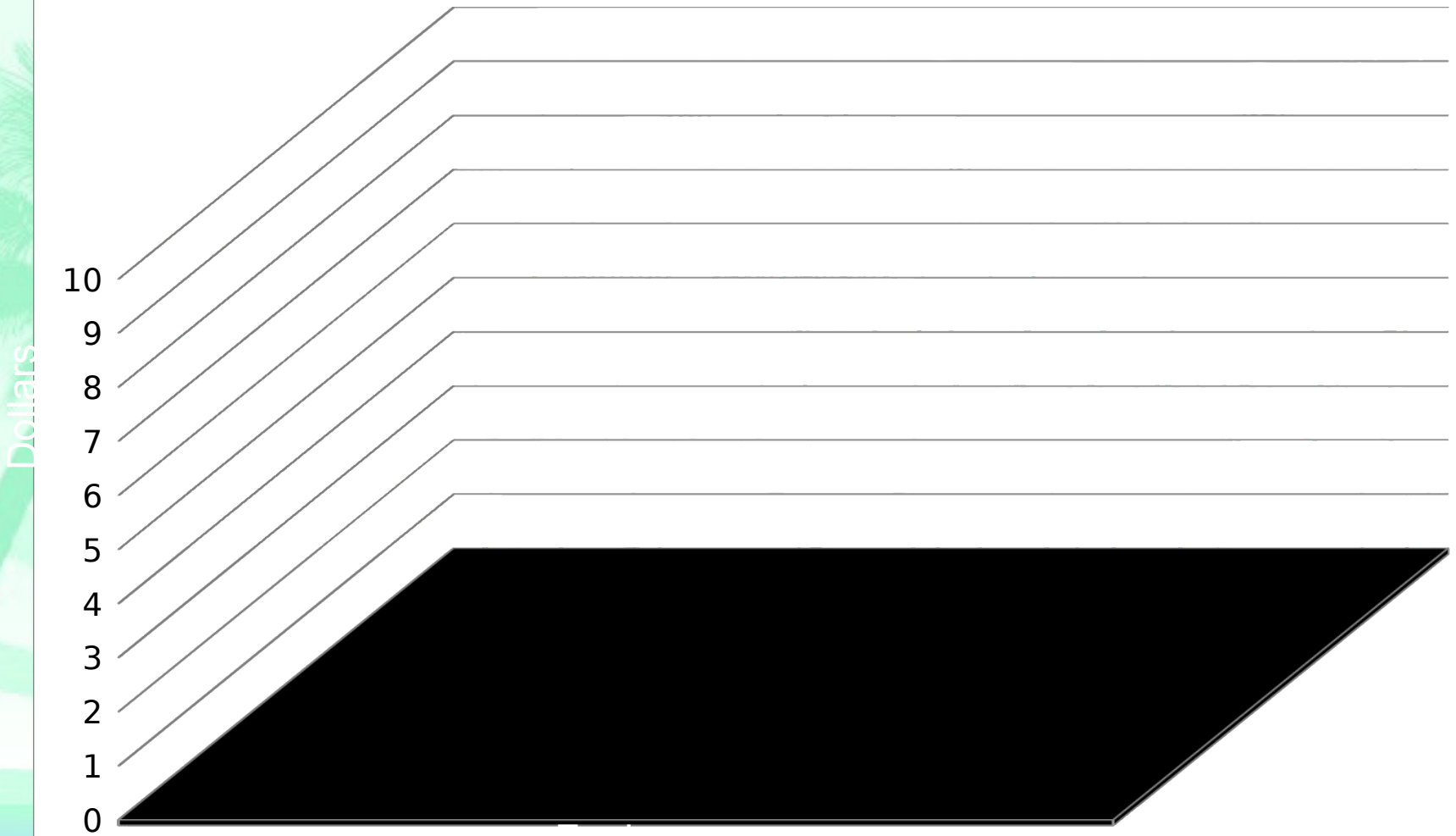
CO2 Emissions of Transportation Fuels



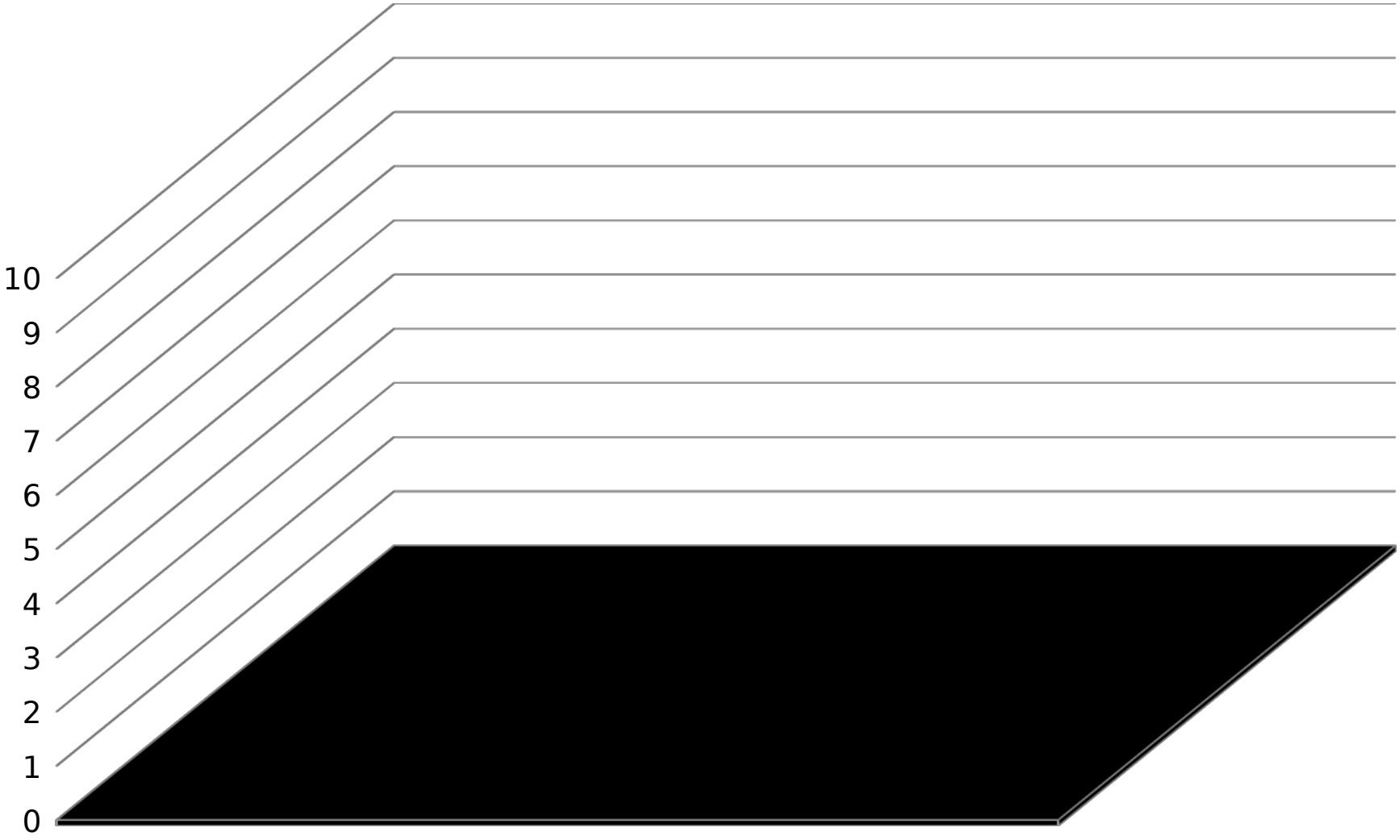
Fuel Consumption Comparison of Transportation Fuels



Power Train Investment Cost (US$)



Vehicle Efficiency (%)



Why H2 is the best transportation fuel

- Emission-free
- No moving parts in fuel cells (quiet)
- Renewable and abundant (as water)
- Compatible with cold weather
- Compact and lightweight fuel source
- 3 times as efficient as gasoline
- Incredible driving range
- Quick Refueling
- Safe

Merit Factor Analysis

Merit Factor Analysis is used in analyzing complex systems. It considers several factors influencing the problem and reduces them to one quantity (i.e, merit factor) to be used in comparisons.

Influence Factors for Conversion to Hydrogen Fuel Transportation

Influence Factor	Symbol	Measurement Units
Size	S	km2
Population	P	number
Income per Capita	I	$/capita
Educational Level	E	educational expenditures: % of GDP
Borders	B	number
Petroleum Dependence	D	barrels/day
Price of Gasoline	G	$/gallon
Vehicles per Capita	V	number/per 1000
Hydrogen Filling Stations	F	number

Effects of Influence Factors

Positive Effects	Negative Effects
Income per Capita, I	Size, S
Educational Level, E	Population, P
Price of Gasoline, G	Borders, B
Vehicles per Capita, V	Petroleum Dependence, D
Hydrogen Filling Stations, F	

Influence Factors for Countries I

Countries	S km2	P #	I $ per Capita	E % of GDP
Afghanistan	647,500	32,738,376	1,000	2.3
Algeria	2,381,740	33,769,669	6,500	4.47
Angola	1,246,700	12,531,357	5,600	2.8
Argentina	2,766,890	40,481,998	13,300	4
Armenia	29,800	2,968,586	4,900	3.2
Australia	7,687,453	21,007,310	36,300	4.9
Austria	83,858	8,205,533	38,400	5.7
Azerbaijan	86,600	8,177,717	7,700	3.2

Influence Factors for Countries II

Countries	B	D	G	V
	number	Barrels per day	$ per Gallon	# per 1000
Afghanistan	6	4,500	2.3	1
Algeria	5	233,000	6.3	56
Angola	4	48,000	2.02	9
Argentina	5	470,000	3.56	128
Armenia	4	41,000	4.28	45
Australia	0	877,300	4.66	519
Austria	8	282,000	7.85	512
Azerbaijan	5	120,000	2.46	59

Non-dimensionalizing the influence Factors

$$\overline{Y}_z = \frac{Y_z}{Y_{max}}$$

Y_z = Influence Factor

Y_{max} = Maximum Influence Factor

$\overline{Y}_z$ = Non-dimensionalized Influence Factor

Dimensionless Data I

Countries	$\overline{S}$	$\overline{P}$	$\overline{I}$	$\overline{E}$
Afghanistan	0.038	0.025	0.012	0.123
Algeria	0.139	0.025	0.08	0.239
Angola	0.073	0.009	0.069	0.15
Argentina	0.162	0.03	0.164	0.214
Armenia	0.002	0.002	0.061	0.171
Australia	0.45	0.016	0.449	0.262
Austria	0.005	0.006	0.475	0.305
Azerbaijan	0.005	0.006	0.095	0.171

Dimensionless Data II

Countries	$\bar{B}$	$\bar{D}$	$\bar{G}$	$\bar{V}$	$\bar{F}$
Afghanistan	0.429	0	0.206	0.001	0
Algeria	0.357	0.011	0.564	0.076	0
Angola	0.286	0.002	0.181	0.012	0
Argentina	0.357	0.023	0.318	0.175	0
Armenia	0.286	0.002	0.383	0.061	0
Australia	0	0.042	0.417	0.708	0.015
Austria	0.571	0.014	0.702	0.698	0
Azerbaijan	0.357	0.006	0.22	0.08	0

TWO METHODS OF MERIT FACTOR ANALYSIS

1. Basic Merit Factor Analysis

2. Weighted Merit Factor Analysis

1. Basic Merit Factor Analysis

$$M = \sum \bar{Y}^{+} - \sum \bar{Y}^{-}$$

M_z = Merit Factor for Country Z

$\bar{Y}^{+}_z$ = Sum of Positive Influences

$\bar{Y}^{-}_z$ = Sum of Negative Influences

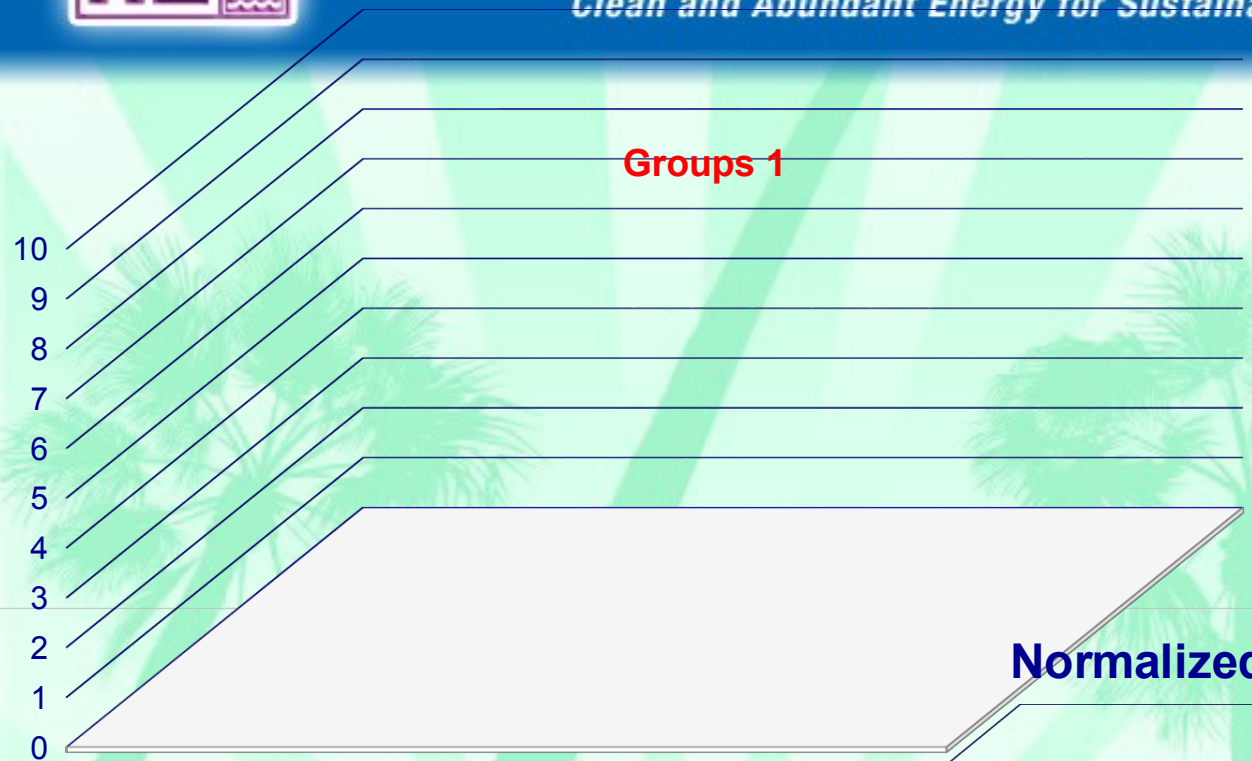
Normalized Merit Factors

$$\overline{M_z} = \frac{M}{M_{max}}$$

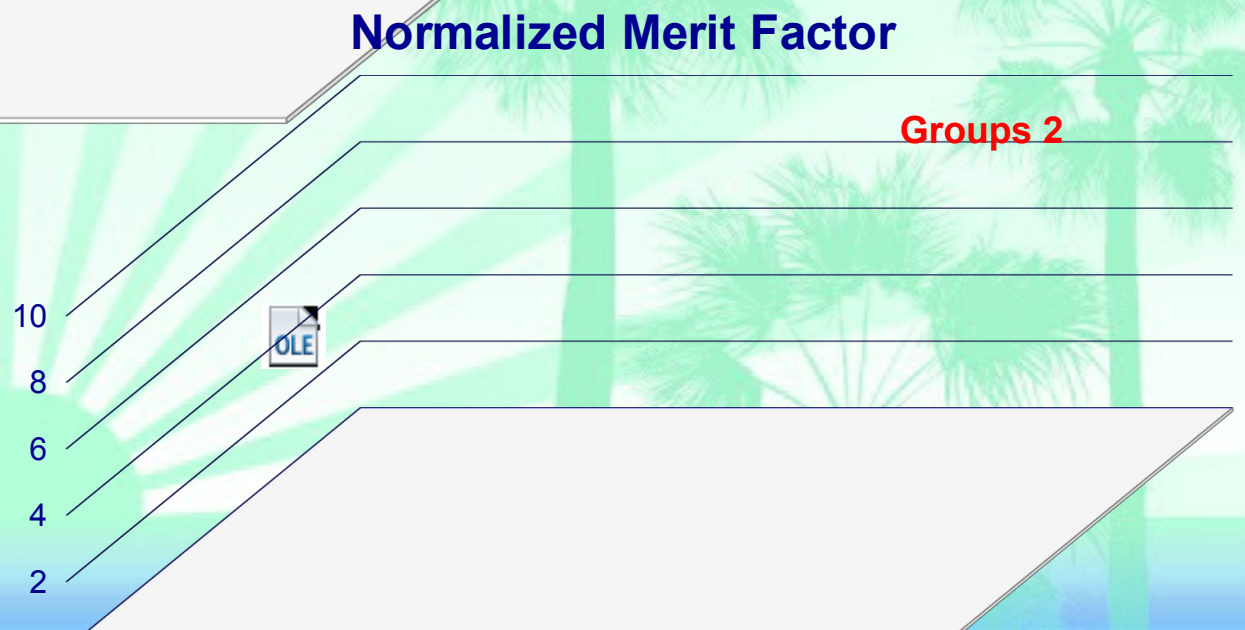
Where Mz is the Merit Factor for the country z, and M max is the maximum merit factor. Hence, the maximum normalized Merit Factor becomes unity or 1.

Merit Factors & Normalized Merit Factors

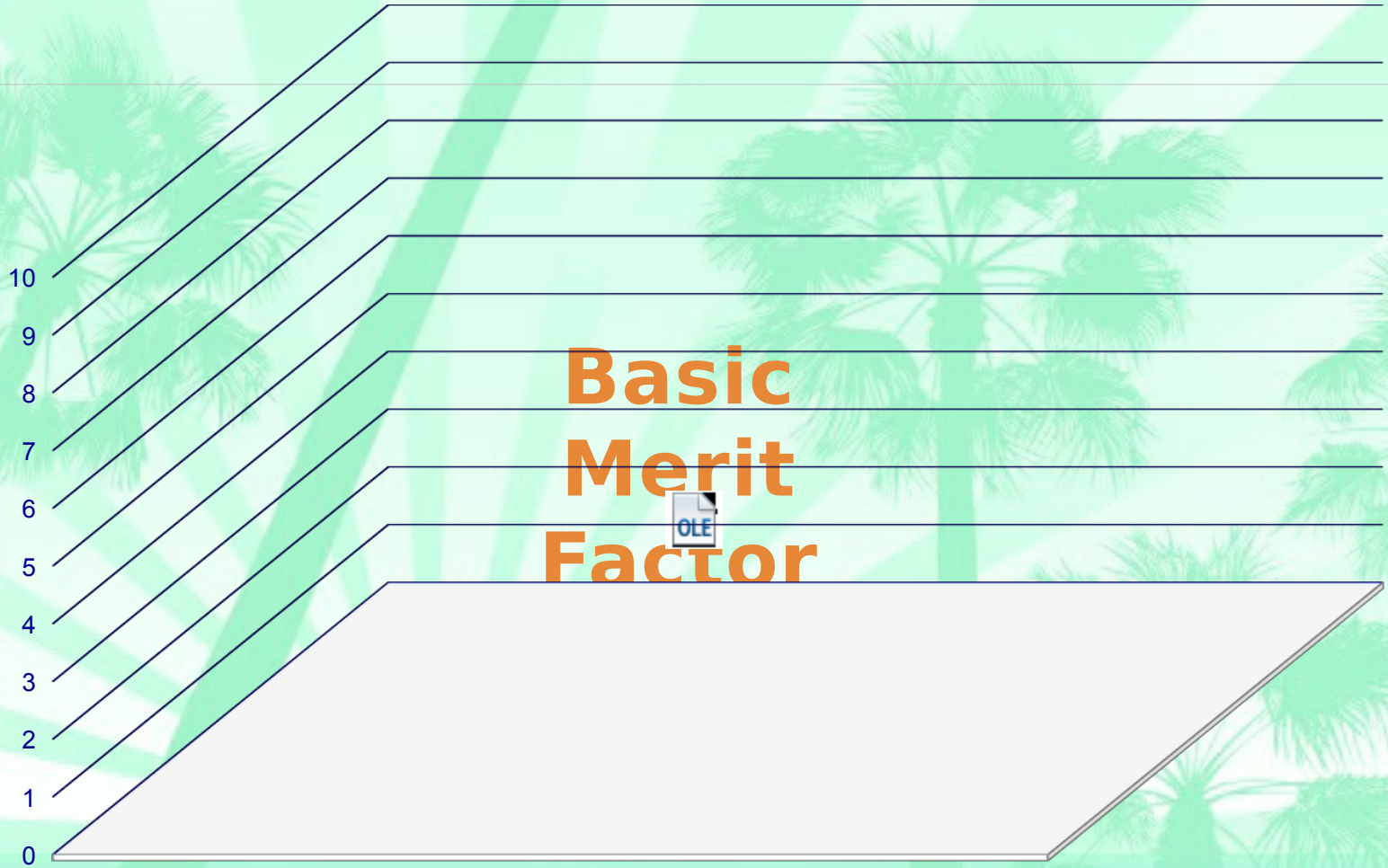
Countries	Merit Factor	Normalized Merit Factor
Afghanistan	-0.151	-0.123
Algeria	0.296	0.241
Angola	0.022	0.018
Argentina	-0.005	-0.004
Armenia	0.265	0.216
Australia	0.011	0.009
Austria	0.214	0.174



Basic Merit Factor Groups 1&2



Normalized Merit Factor



2. Weighted Merit Factor Analysis

$$W_z = \sum \alpha_y \bar{Y}^{+}_{z} - \sum \alpha_y \bar{Y}^{-}_{z} \quad \text{.....(5.5)}$$

W_z = Weighted Merit Factor for Country Z

$\bar{Y}^{+}_{z}$ = Sum of Positive Influences

$\bar{Y}^{-}_{z}$ = Sum of Negative influences

Weighting Coefficients for Influence Factors

Dimensionless Influence Factor	Weighting Coefficient	Estimated Value of Weighting Coefficient
$\overline{S}$	α_s	3 (-)
$\overline{P}$	α_p	3 (-)
$\overline{I}$	α_i	5 (+)
$\overline{E}$	α_e	5(+)
$\overline{B}$	α_b	4 (-)
$\overline{D}$	α_d	3 (+)
$\overline{G}$	α_g	4 (+)
$\overline{V}$	α_v	2 (-)
$\overline{F}$	α_f	4 (+)

Normalized Weighted Merit Factor

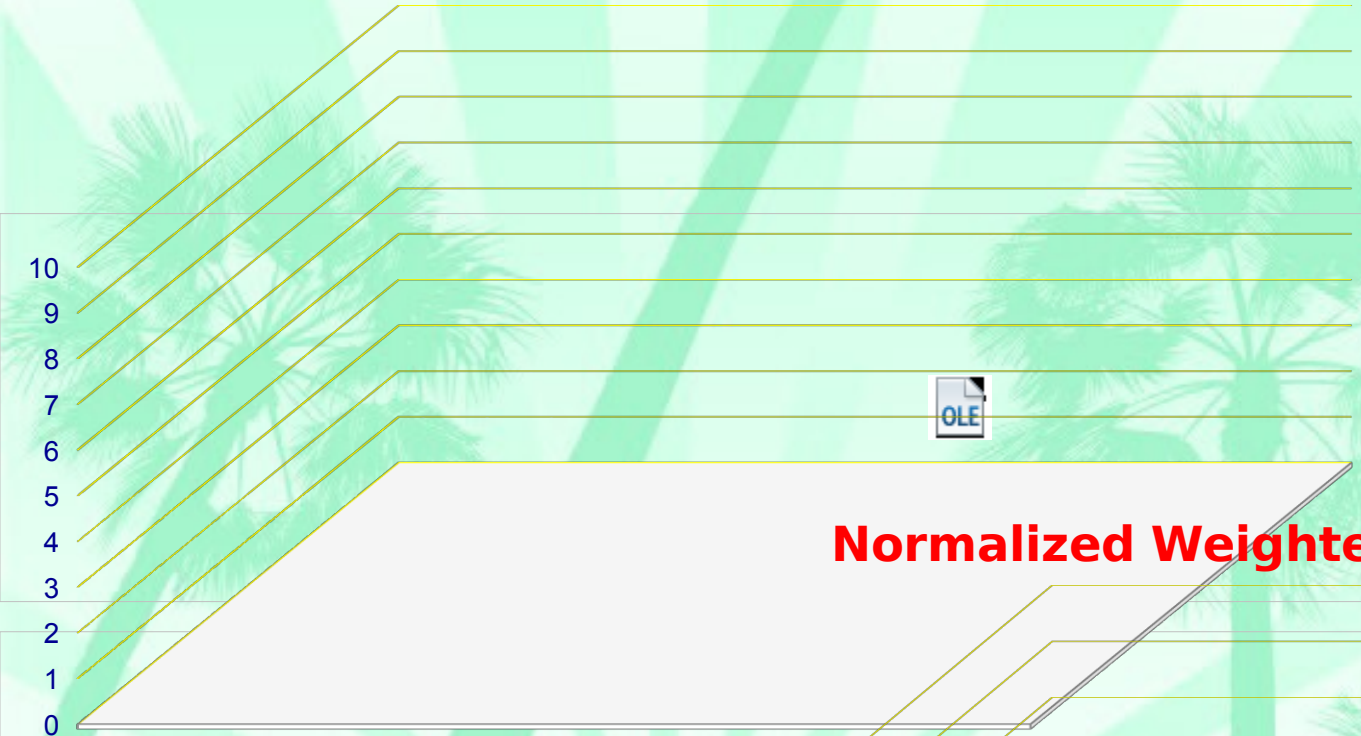
$$\overline{W_z} = \frac{W_z}{W_{max}}$$

Where Wz is the Weighted Merit Factor for the country z, and Wmax is the maximum Weighted Merit Factor. Hence, the maximum Normalized Weighted Merit Factor becomes unity or 1.

Weighted Merit Factors and Normalized Weighted Factors

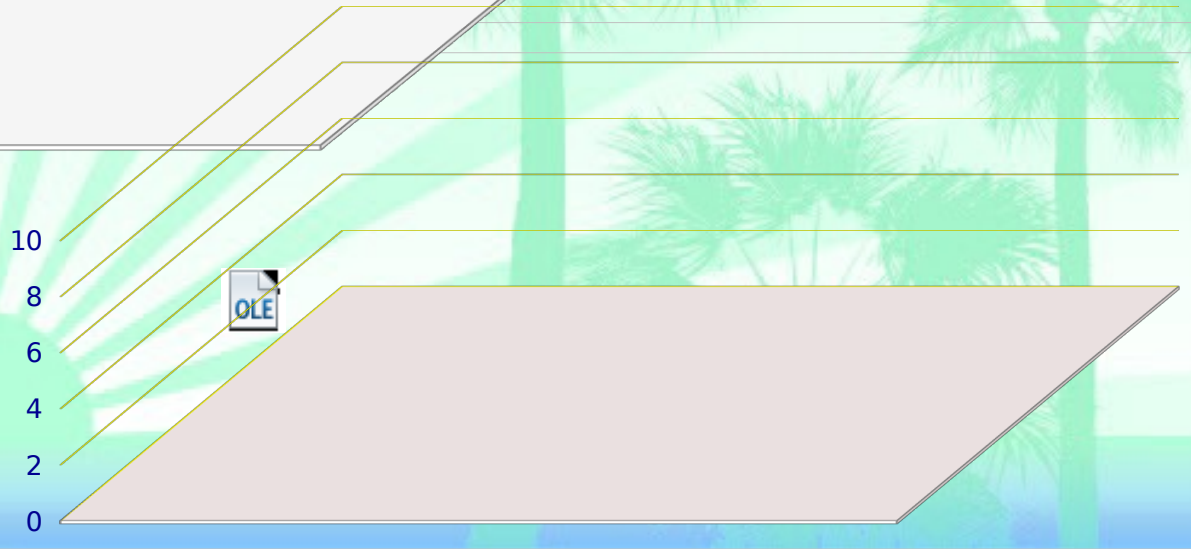
Countries	Weighted Merit Factor	Normalized Weighted Merit Factor
	M	N
Afghanistan	-0.404	-0.056
Algeria	1.809	0.252
Angola	0.41	0.057
Argentina	0.878	0.122
Armenia	1.418	0.198
Australia	2.593	0.362
Austria	3.031	0.422
Azerbaijan	0.606	0.084

Normalized Weighted Merit Factors

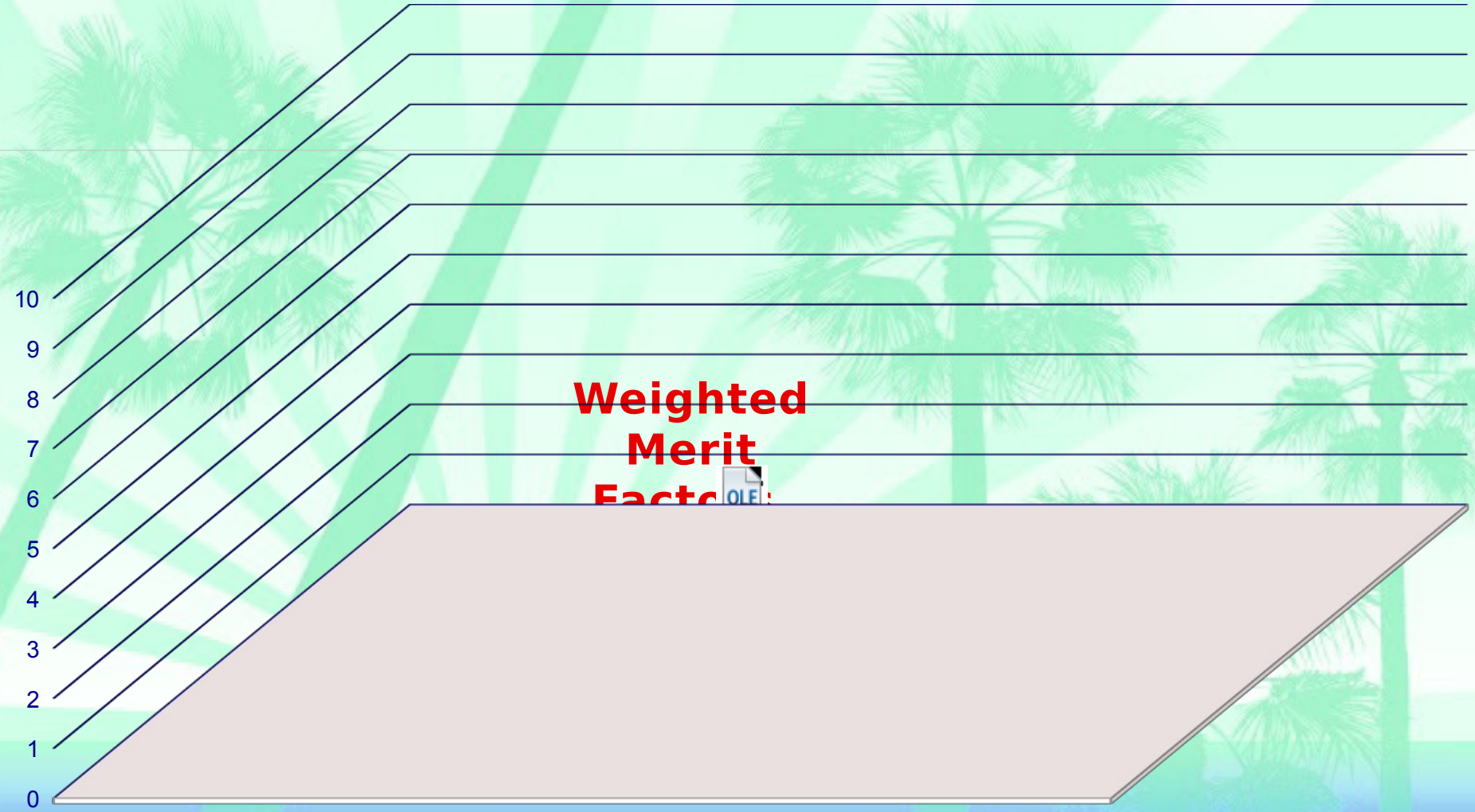


Weighted Merit Factors Groups 1 & 2

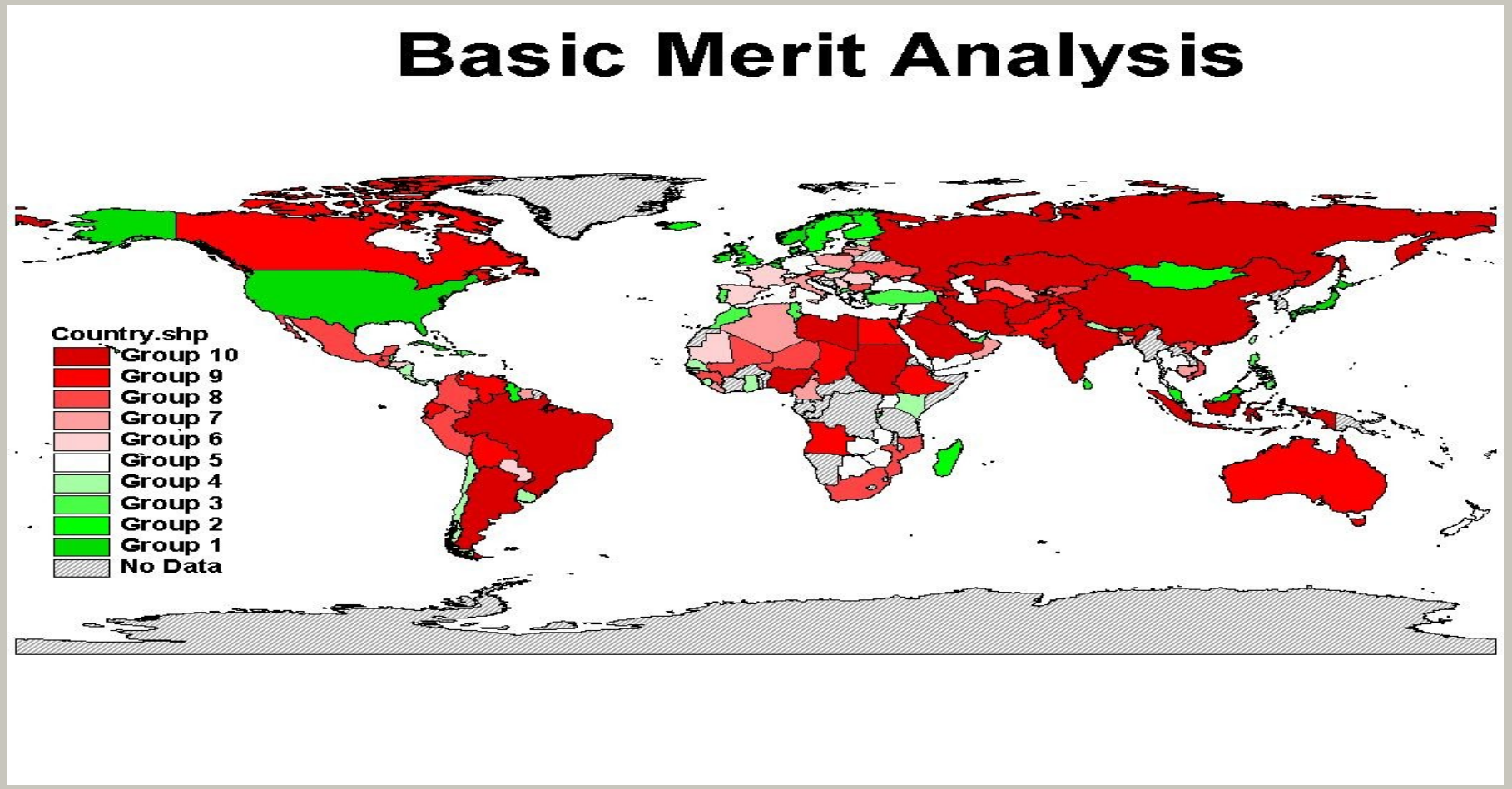
Normalized Weighted Merit Factors



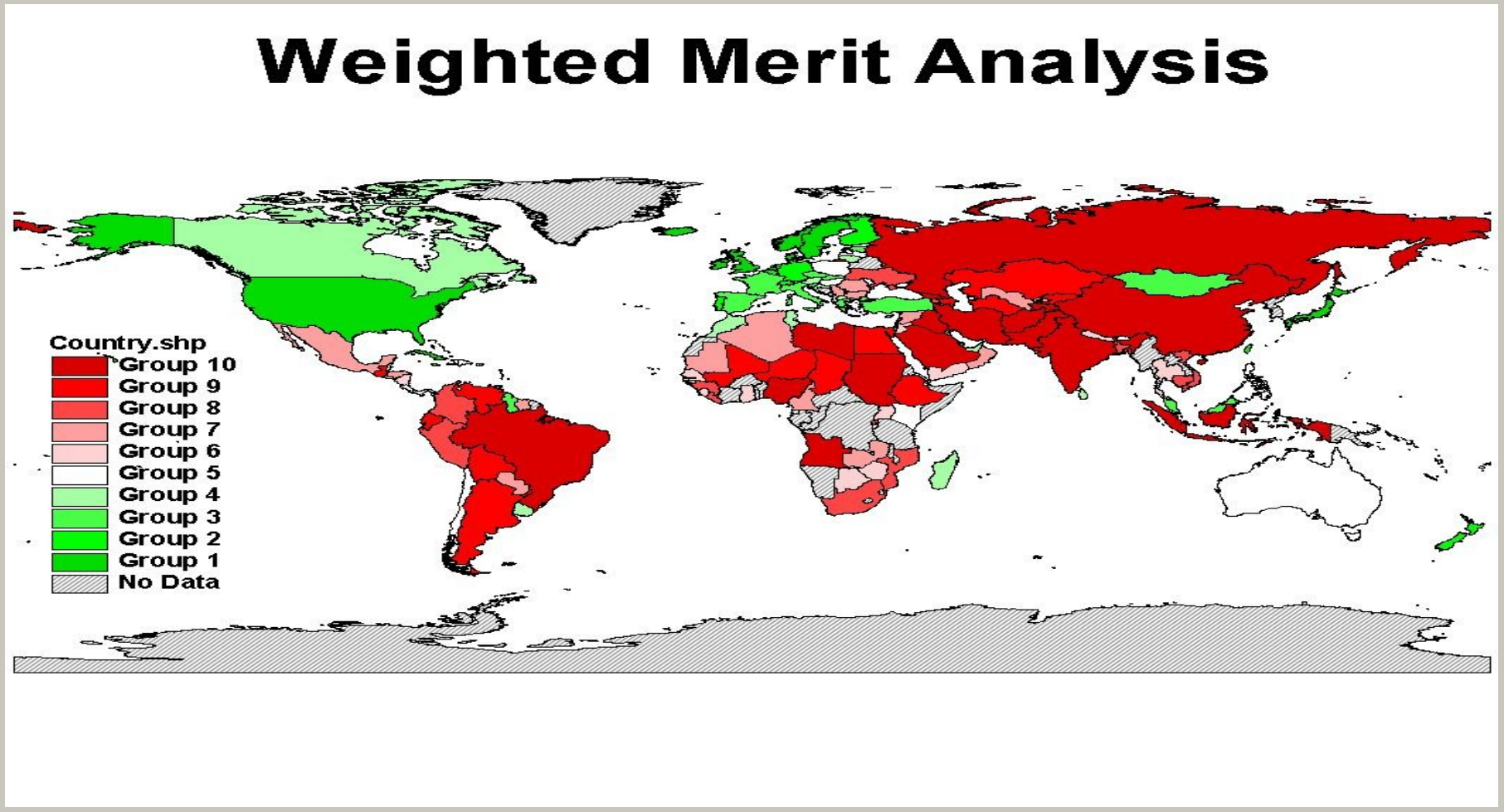
Normalized Weighted Merit Factors



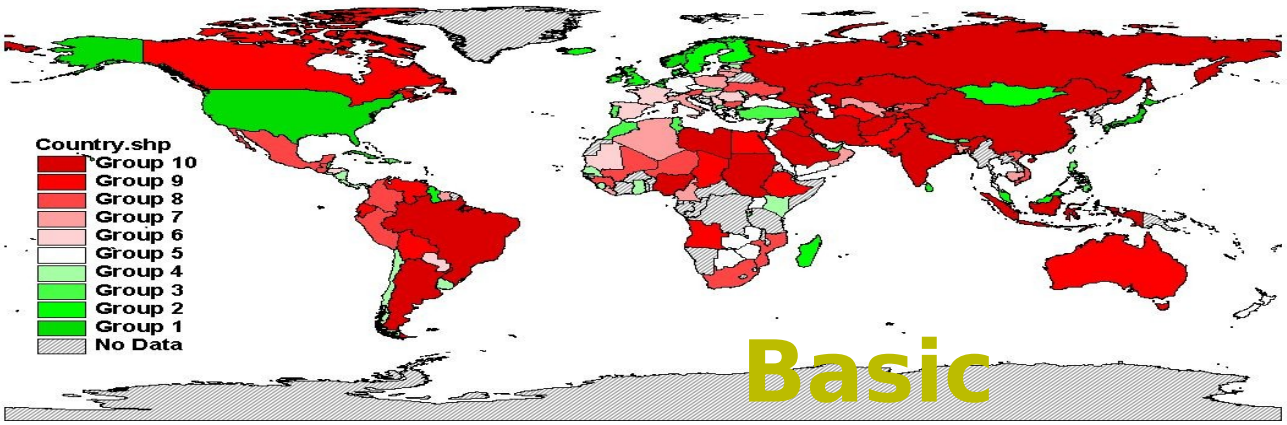
Basic Merit Factor Analysis



Weighted Merit Factor Analysis

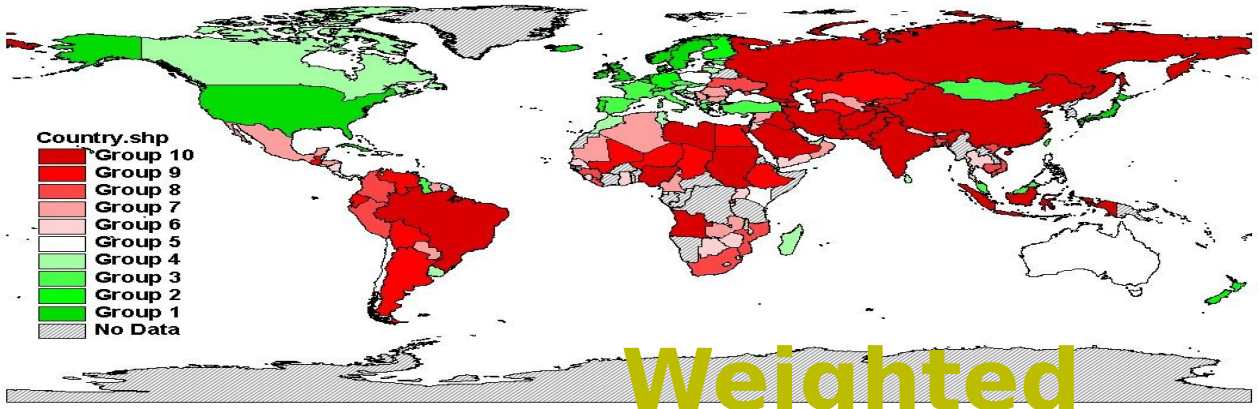


Basic Merit Analysis



Comparison of two methods

Weighted Merit Analysis



Conclusions

1. **BRIC Countries (Brazil, Russia, India and China): BRIC countries are all in the last group, that is Group 10, both in the Basic Merit Factor Analysis results and also in the Weighted Merit Factor Analysis results. It means that their conversion to hydrogen fueled transportation could be slower than other countries. This is mainly caused by their larger sizes, bigger populations, low GNP per capita and many borders.**

3. **United States, Japan, Sweden and Norway: These countries are all in Group 1, both in the**

Further Work

After Merit Factor analysis we should continue with system dynamic analysis for USA, China and India, which are the most polluting countries of the world, to provide solution to the world pollution problem through transportation policy improvements in these countries.

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