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EEDI Assessment of Recently Built Tankers in Turkey

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Abstract

In recent years, sustainability is the core concern of industries and companies take actions to protect the environment. In this context, there are also several new regulations in the shipping industry. The Energy Efficiency Design Index (EEDI) has been developed and adopted by the International Maritime Organization (IMO) as an amendment to MARPOL Annex VI. According to EEDI, the energy efficiency of ships is defined as the ratio of the mass of CO_2 emissions from main, auxiliary engines and additional shaft per unit of transport work for a particular ship design. Other regulations are Energy Efficiency Operational Indicator (EEOI) and Ship Efficiency Management Plan (SEEMP) to be applied to existing vessels. In this study, design data for 84 tankers smaller than 25000 DWT built in Turkish Shipyards between 2009 and 2012 is utilized to calculate and compare their attained EEDI values against the values of the EEDI baseline designated for tankers. The results indicate that most of the delivered vessels do not meet the current EEDI baseline and new vessel designs will be soon necessary for achieving EEDI compliance. This study can also be extended to the application of EEOI with the provision of accurate vessel operational characteristics.

JEL Classification: Q40; Q56; Z00.
Keywords: Energy Efficiency; Shipping; Environmental Management; Emission.

1. Introduction

The EEDI was adopted as a mandatory (technical) measure by the Marine Environment Protection Committee (MEPC) of IMO at its 62nd session on July, 2011 and guidelines on the method of calculation of attained EEDI were agreed at its 63rd session in early 2012 (MEPC, 2012). According to the adopted EEDI regulation, all ships larger than 400 GT of a specific type and size range which are to be built during 2015-19 should be up to 10% more efficient, up to 20% more efficient for the 2020-24 new buildings and up to 30% more efficient from 2025 onwards. This tightening of efficiency level with time will make EEDI compliance a decisive promoter of continuous development in ship technology towards curbing CO_2 emissions from shipping.

Within the framework of discussion and deliberation leading to the EEDI adoption and beyond, considerable work has been contacted in order to prepare a suitable EEDI formulation and pave the way towards its adoption by the shipping industry. Anink and Krikke (2009) analyzed the EEDI formula and correlation between the index values for all individual ship types for several types of vessels. Deltamarine (2009) evaluated the calculation of EEDI for conventional vessels, Ro-Ro and Ro-pax ships. The International Council on Clean Transportation (2011) issued a study indicating the key components of the calculation, benefits of the index and future expectations. United States Environmental Protection Agency (EPA, 2011) investigated the EEDI standard and its benefits. Hughes (2011) presented the EEDI, EEOI and SEEMP regulations and Hemming (2011) evaluated the EEDI with questions and answers. BLUE Communications (2011) edited news of popular magazines in the world regarding IMO emissions regulations and BIMCO produced an EEDI calculator. Longva (2011) studied CO_2 emissions from ships, the latest IMO regulatory developments (EEDI and SEEMP) and their implications for bulk carriers. Det Norske Veritas assists yards, designers, owners and operators to prepare the EEDI Technical File package with necessary documentation ready for verification (DNV, 2012). Lloyds Register (2012) prepared a guidebook for owners, operators and shipyards. Cheng (2012) evaluated IMO technical measures in reducing greenhouse gas emissions from ships from the perspective of Lloyds Register. Rightship (2012), calculated and compared CO_2 emissions from the global maritime fleet. Bergholtz and Wiström (2012) made a Swedish proposal for the inclusion of the Ro-Ro ship segment into the IMO energy efficiency regulatory framework. Hjortberg (2012) analyzed the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP) in the Scandinavian Maritime Conference, whereas Germanischer Lloyd (2012) also produced a relevant guidebook.

In an attempt to contribute further into the influence of the EEDI adoption upon future new buildings, the examination of the current new building status provides an indication of the design adaptation requirements towards future EEDI compliance and the case of recently delivered tankers by Turkish shipyards constitutes a suitable reference in meeting this objective.

Originally, existing ships are not been targeted in EEDI regulation however, this study has been presented in order to investigate the conformity of existing designs with the new regulation for illustration purposes and take precautions for adopting EEDI methodology to new designs.

1.1 EEDI calculation for tankers built in Turkey

According to Deltamarine (2009), the EEDI simply expresses the environmental damage (expressed in terms of GHG emissions) of ships in relation to their value for society, as follows:

$$\begin{aligned} EEDI &= (\text{Impact to the environment / Benefit for the society}) \\ &= (\text{Ship } CO_2 \text{ emissions / Performed work}) \end{aligned} \tag{1}$$

Where, further analysis of

$$EEDI = (CO_{2ME} + CO_{2AE}) / (Capacity.V_{ref}) \quad (2)$$

A more detailed formulation of EEDI is presented MEPC.63/23 Annex 8, 2012 as follows:

$$EEDI = \frac{\prod_{j=1}^{M} f_j.(\sum_{i=1}^{nME} P_{ME(i)}.C_{FME(i)}.SFC_{ME(i)}) + (P_{AE}.SFC_{AE}.C_{FAE}) + ((\prod_{j=1}^{n} f_j.\sum_{0=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} feff(i)P_{AEeff(i)}).C_{FAE}.SFC_{AE}) + (\sum_{0=1}^{neff} feff(i).P_{eff(i)}.C_{FME}.SFC_{ME})}{f_i.f_c.Capacity.f_w.V_{ref}}$$

(3)

In the above formula, C_F non-dimensional conversion factor relating burned fuel with derived CO_2 emissions based on the fuel's carbon content and SFC is the engine specific fuel consumption. Power (P), power take-off in application (P_{PTI}), the special technologies of the vessels such as having energy saving technologies onboard that reduce the power (P_{eff}, P_{AEeff}) are also considered.

Having special ship design criteria (such as ice class, etc.) increases the ship's engine power requirements. Furthermore, a weather correction factor f_w for speed adjustments and a cubic capacity correction factor (f_o) are also added to the formula as above.

The value of *CF* is 3.206000 t-CO_2/t-fuel for diesel/gas oil and 3.114400 t-CO_2/t-fuel for fuel oil (MEPC.63/23 Annex 8, 2012). The unit of EEDI is gCO_2/tnm. *fj* is a correction factor to account for ship specific design elements. The *fj* for ice-classed ships is determined by the standard *fj* in Table 1 (MEPC.63/23 Annex 8, 2012). *fi* is the capacity factor for any technical/regulatory limitation on capacity and can be assumed one (1.0) if no necessity of the factor is granted. *fi* for ice-classed ships is determined by the standard *fi* in Table 2 (MEPC.63/23 Annex 8, 2012).

Particulars and EEDI values of tankers in this study are presented in Table 3. In the current calculation, it is assumed that tankers do not have power take-off in application and no energy saving technology.

Reference baseline EEDI value is calculated as follows:

$$\text{Reference line value} = axb^{-c} \quad (4)$$

The values of a, b and c as in Table 4.

2. Discussions and Conclusions

The variation of attained and referenced EEDI values with respect to capacity, speed, main engine power and length of tankers is shown in Figs. 1-4, respectively. As can be seen from the figures that EEDI value is decreasing exponentially with the increase of capacity, main engine power and length and linearly with the increase of speed. According to Fig. 1, tankers smaller than 10000 DWT has considerably bigger index values than for the bigger ships and a sharp decrease has been observed in this range.

When the attained and referenced EEDI values are compared, it is seen that the attained EEDI value is bigger than referenced EEDI value for all values of ship's capacity, speed, and length. The attained EEDI value is lower than the referenced EEDI value up to the main engine power of 2000 kW, whereas it is higher for main engine power in excess of 2000 kW with reference to tankers without power take-off.

In general, it is concluded that existing ships do not meet the EEDI criteria since obtained EEDI value should be smaller than the reference value and the development of future ship designs is not only necessary but it will be challenging too.

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Appendix

Table 1. Correction factor value for ice-classed tankers (MEPC.63/23 Annex 8, 2012)

Ship Type	f_{j0}	Limits depending on the ice class. ($f_{j,min}$)			
		IA Super	IA	IB	IC
Tanker	$\frac{0.308L_{pp}^{1.920}}{\sum_{i=1}^{nME} P_{ME(i)}}$	$0.15L_{pp}^{0.30}$	$0.27L_{pp}^{0.21}$	$0.45L_{pp}^{0.13}$	$0.70L_{pp}^{0.06}$

Table 2. Capacity correction factor value for ice-classed tankerş (MEPC.63/23 Annex 8, 2012)

Ship Type	f_{i0}	Limits depending on the ice class ($f_{i,max}$)			
		IA Super	IA	IB	IC
Tanker	$\frac{0.00138L_{pp}^{3.331}}{capacity}$	$2.10L_{pp}^{0.11}$	$1.71L_{pp}^{0.08}$	$1.47L_{pp}^{0.06}$	$1.27L_{pp}^{0.04}$

Table 3. Particulars and EEDI values of tankers (Kurtulus, 2012)

Vessel No	*L_{BP} (m)*	*V_{ref} (knots)*	*Capacity (tonnes)*	*P_{ME} (kW. at 100%MCR)*	*SFC_{ME} (g/kWh)*	*PAE (kW)*	*SFCAE (g/kWh)*	*Ice Class Notation*	*fj*	*fi*	*Attained EEDI (gCO_2/tnm)*	*Reference EEDI (gCO_2/tnm)*
1	59.15	11	1524	895	210	413	126.44	X	1.00	1.00	36.17	34.09
2	69.80	12	1692	610	215	290	140.87	X	1.00	1.00	21.54	32.39
3	62.00	10.50	1770	746	210	520	102.45	X	1.00	1.00	28.88	31.69
4	62.35	11	1795	1200	193	716	97.75	X	1.00	1.00	38.76	31.47
5	62.34	11	1800	1200	193	540	97.75	X	1.00	1.00	35.87	31.43

(to be continued)

6	72.00	13	1975	704	185	732	81.50	X	1.00	1.00	19.30	30.04
7	72.74	11	2150	1200	193	780	97.75	X	1.00	1.00	33.21	28.82
8	72.50	11	2412	1200	193	540	97.75	X	1.00	1.00	26.77	27.25
9	73.29	12	2468	1280	193	720	82.76	X	1.00	1.00	25.93	26.94
10	66.25	11	2513	1114	210	930	86.94	1C	1.00	1.06	29.14	26.71
11	78.00	13	2900	1200	184	815	82.33	X	1.00	1.00	19.39	24.90
12	77.97	13	3074	1880	200	1355	75.13	1B	0.94	1.00	30.69	24.21
13	77.97	13	3074	1880	200	1450	71.63	1B	0.94	1.00	30.87	24.21
14	82.74	14	3146	2000	194	1161	78.54	X	1.00	1.00	27.21	23.93
15	82.74	14	3150	2000	192	1165	78.54	X	1.00	1.00	26.99	23.92
16	77.97	13	3150	1880	200	1355	75.13	1B	0.94	1.00	29.95	23.92
17	8660	13.50	3500	2040	185	1093	79.59	1C	1.00	1.06	24.56	22.72
18	86.95	13.50	3500	1960	192	1524	72.00	1C	1.00	1.09	26.05	22.72
19	88.55	14	3800	1960	192	1394	74.04	1C	1.00	1.06	22.74	21.83
20	91.65	14	4114	1710	192	1239	79.19	X	1.00	1.00	18.78	21.00
21	91.65	14	4121	1710	192	1203	81.51	X	1.00	1.00	18.74	20.98
22	91.66	14	4121	1710	192	1194	81.51	X	1.00	1.00	18.70	20.98
23	91.65	14	4127	1710	185	1215	81.82	X	1.00	1.00	18.31	20.97
24	94.09	13.50	4500	1961	174	1288	61.94	X	1.00	1.00	17.33	20.10
25	94.00	14	4755	1960	192	1179	82.33	X	1.00	1.00	17.88	19.57
26	94.76	13	4865	2205	192	1320	78.89	1C	1.00	1.06	20.91	19.35
27	99.84	14	5250	2640	182	1210	82.13	1C	1.00	1.06	19.60	18.64
28	93.70	14	5260	4000	182	2020	60.89	1A	0.70	1.00	30.74	18.62
29	94.00	14.50	5513	2999	174	1341	78.18	X	1.00	1.00	19.45	18.20
30	99.80	13	5543	3000	182	1308	77.48	X	1.00	1.00	22.21	18.15
31	99.80	13	5554	3000	182	1308	77.48	X	1.00	1.00	22.16	18.14

(to be continued)

32	99.35	14	5659	2640	182	1249	81.02	1C	1.00	1.06	18.26	17.97
33	99.35	13.70	5699	2720	185	1350	77.48	1C	1.00	1.06	19.35	17.91
34	111.86	14	6100	2640	182	1588	69.34	X	1.00	1.00	17.28	17.33
35	111.86	14	6100	2610	193	1046	70.16	X	1.00	1.00	16.53	17.33
36	111.86	14	6267	2640	182	1515	70.16	X	1.00	1.00	16.68	17.10
37	102.30	14.50	6400	2640	182	1636	68.75	1C	1.00	1.00	15.98	16.92
38	101.60	14	6400	2720	185	1688	67.84	1C	1.00	1.04	17.22	16.92
39	101.60	14	6400	2720	185	1688	67.84	1C	1.00	1.04	17.22	16.92
40	101.60	14.50	6400	2720	185	1195	83.56	1C	1.00	1.04	16.12	16.92
41	101.30	14.00	6404	2665	182	1249	81.02	1C	1.00	1.03	16.26	16.92
42	103.10	14.50	6412	2999	174	1360	77.48	1A	1.00	1.05	16.73	16.91
43	101.30	14	6416	2665	182	1249	81.02	1C	1.00	1.03	16.22	16.90
44	103.10	14.50	6435	2640	182	1249	81.02	1C	1.00	1.06	15.51	16.88
45	94.83	14	6623	2610	192	1364	75.13	1C	0.98	1.00	16.23	16.64
46	103.18	13.50	6995	3500	182	2110	60.89	X	1.00	1.00	20.12	16.21
47	111.60	14	7000	3840	173	1615	69.83	1A	0.91	1.17	19.87	16.20
48	111.60	14	7000	3000	182	1655	67.84	1C	1.00	1.17	16.69	16.20
49	103.18	14	7000	3000	182	940	81.02	X	1.00	1.00	15.51	16.20
50	111.60	14	7000	3000	182	1015	88.49	1C	1.00	1.05	15.95	16.20
51	111.60	13	7003	2999	174	1508	72.63	1C	1.00	1.05	17.25	16.20
52	113.24	15	7598	4000	182	1930	61.98	X	1.00	1.00	18.29	15.57
53	113.24	15	7598	4000	182	1930	61.98	X	1.00	1.00	18.29	15.57
54	113.24	15	7598	4000	182	1995	60.89	X	1.00	1.00	18.34	15.57
55	115.31	12.50	7667	3000	182	1908	61.88	1A	1.00	1.17	17.26	15.50
56	115.96	14	7718	4000	182	1890	62.56	1C	0.94	1.05	19.45	15.45
57	116.04	14	7770	3840	183	1988	60.89	1A	0.98	1.06	18.71	15.40
58	115.96	14.50	8100	4000	182	1928	61.88	1A	0.94	1.06	17.93	15.09
59	116.40	14	8239	4000	182	1874	61.94	1A	0.95	1.17	18.14	14.96

(to be continued)

60	116.40	14	8269	4000	175	1905	62.61	1A	0.95	1.17	17.60	14.94
61	116.26	14	8280	4000	175	1880	62.61	1A	0.95	1.17	17.54	14.93
62	116.28	14	8400	5400	184	1885	61.94	X	1.00	1.00	22.92	14.82
63	115.97	14	8402	4000	182	1170	74.71	X	1.00	1.00	16.84	14.82
64	116.07	14	8404	4000	182	1944	62.18	X	1.00	1.00	17.75	14.82
65	116.07	14	8424	4000	182	1870	62.18	X	1.00	1.00	17.58	14.80
66	11000	13.40	8476	3060	192	1870	62.18	X	1.00	1.00	15.36	14.76
67	123.70	14.50	10500	4500	182	1925	63.78	1A	095	1.17	15.29	13.29
68	124.21	14.50	10901	4500	176	1920	62.56	1C	0.96	1.05	14.25	13.05
69	122.70	13.50	11215	3309	173	1596	70.14	1A	1.00	1.12	11.20	12.87
70	123.28	15	11545	5400	184	1920	61.98	1C	0.93	1.05	15.76	12.69
71	136.00	15.50	13000	5148	181	1591	70.70	1A	1.00	1.15	12.60	11.98
72	128.00	14	13214	4500	182	2015	60.89	X	1.00	1.00	12.47	11.88
73	134.00	14	14368	4440	173	2342	73.00	X	1.00	1.00	11.64	11.41
74	134.70	14	14484	4500	182	2470	70.85	X	1.00	1.00	12.20	11.36
75	140.00	14	18000	6000	175	2910	65.74	X	1.00	1.04	12.17	10.22
76	140.00	15	18000	5920	173	3115	63.55	X	1.00	1.00	11.21	10.22
77	140.00	15	18000	5920	173	2528	62.18	X	1.00	1.00	10.73	10.22
78	142.80	15	19964	5920	164	965	70.85	X	1.00	1.00	8.30	9.71
79	143.60	15	20000	5920	164	2465	70.85	X	1.00	1.00	9.43	9.71
80	143.30	15	20000	6960	176	2415	70.85	1A	0.81	1.00	11.78	9.71
81	143.60	15	20000	6960	172	2415	70.85	1A	0.82	1.06	11.56	9.71
82	143.60	15	20000	6960	172	2979	66.44	1A	0.82	1.06	11.91	9.71
83	151.46	14	20522	6000	175	2590	68.47	1A	1.00	1.14	10.52	9.58
84	159.08	15	25000	7200	175	3837	64.72	1A	0.96	1.14	10.05	8.70

Table 4. The values of a, b and c for EEDI reference line value (MEPC 62/24/Add.1. 2011)

Type of ship	A	B	c
Bulk carrier	961.79	DWT of the ship	0.477
Gas carrier	1120.00	DWT of the ship	0.456
Tanker	1218.80	DWT of the ship	0.488
Container ship	174.22	DWT of the ship	0.201
General cargo ship	107.48	DWT of the ship	0.216
Refrigerated cargo carrier	227.01	DWT of the ship	0.244
Combination carrier	1219.00	DWT of the ship	0.488

Figure 1. Attained and reference EEDI values subject to capacity (- - - line: Attained EEDI; — Line: Reference EEDI)

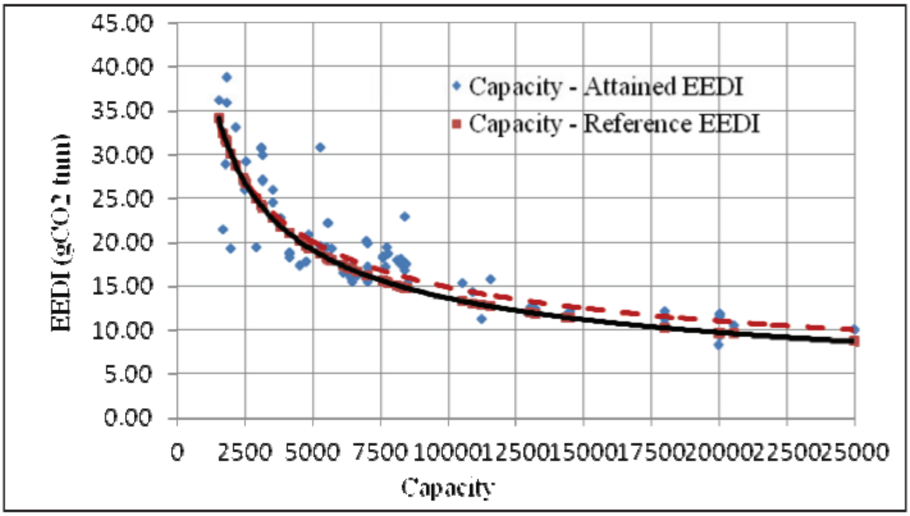


Figure 2. Attained and reference EEDI values subject to speed
(- - - line: Attained EEDI; — Line: Reference EEDI)

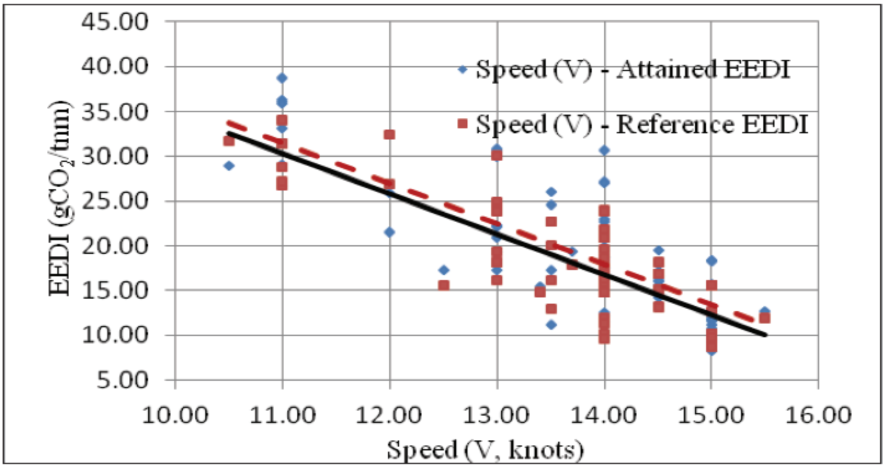


Figure 3. Attained and reference EEDI values subject to main engine power
(- - - line: Attained EEDI; — Line: Reference EEDI)

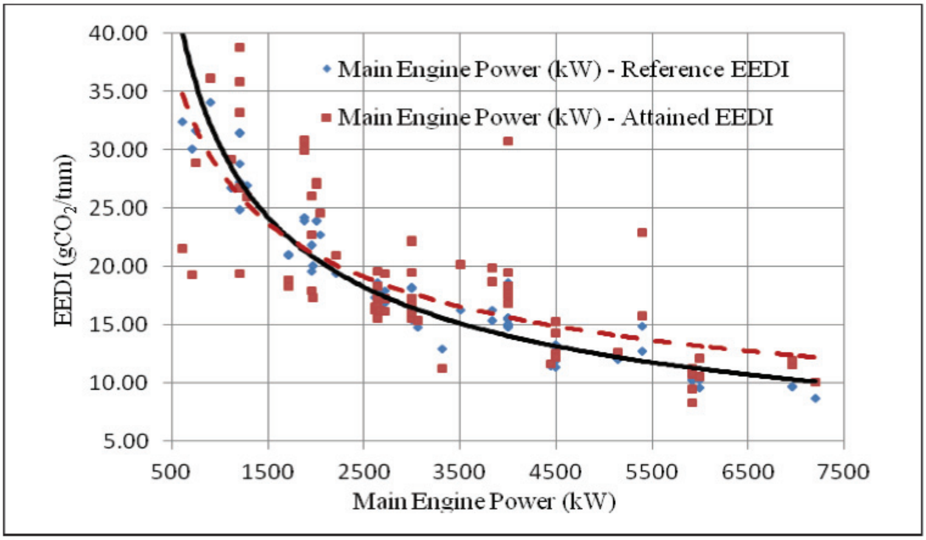
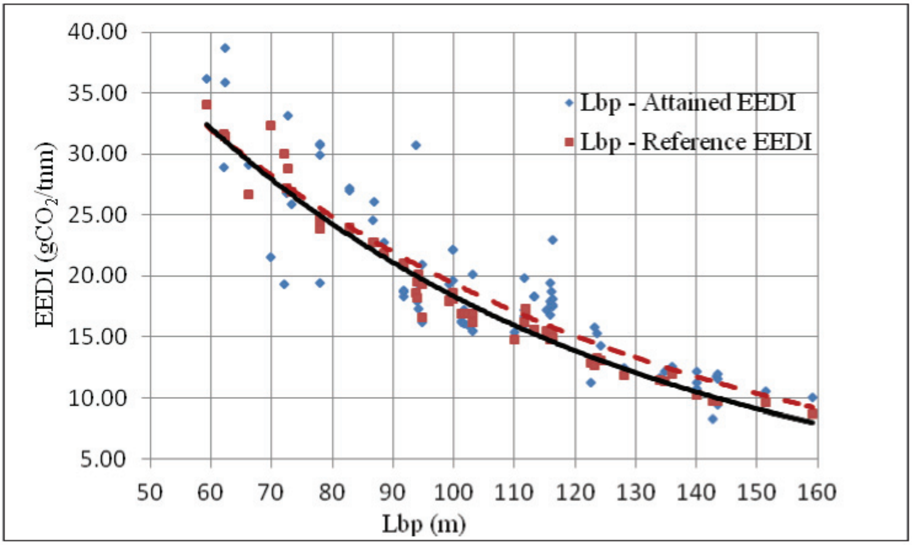


Figure 4. Attained and reference EEDI values subject to length between perpendicular (- - - line: Attained EEDI; — Line: Reference EEDI)



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