Electrolyzer/Grid Carbon Analysis

14.11.22

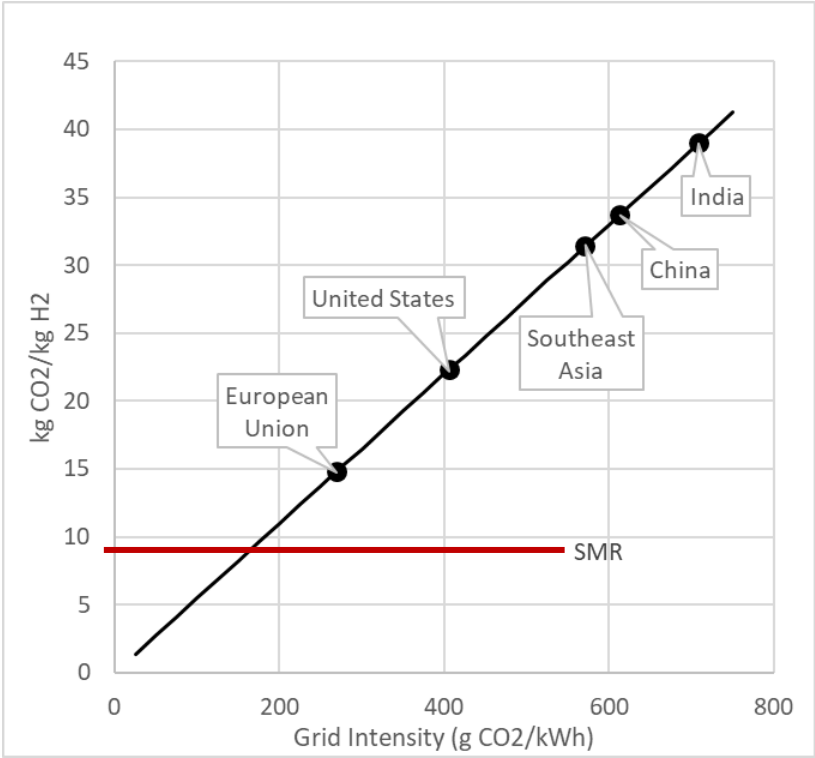
Table of Contents

- **Electrolyzer based hydrogen is not de-facto green**
- **Lowest Cost = Lowest Carbon = Renewable energy**
- **Renewable energy → Intermittency**

Grid Connected Electrolyzers- NOT GREEN

An electrolyzer running close to 100% capacity factor will **run at the average carbon intensity of the grid.**

Today, hydrogen produced by electrolyzers on the grid is actually **MORE carbon intensive than steam methane reforming**.



Grid intensity from IEA
Assumptions: 55 kWh/kg H2

ELECTRIC HYDROGEN

Average Carbon Intensity over the year

2020 CAISO carbon intensity—

- very few hours with less than 200 g/kW
- none at night!

Row	12 AM	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM
Jan	319	318	318	317	314	311	309	302	259	227	218	209	208	208	215	243	289	310	314	314	315	316	319	320
Feb	328	327	326	325	324	323	323	297	234	197	184	177	176	176	182	206	264	318	331	331	330	332	331	328
Mar	323	319	305	309	304	299	311	301	252	211	190	181	177	177	178	187	208	245	285	316	328	335	334	327
Apr	294	288	281	275	268	271	281	242	178	149	132	123	119	118	119	125	139	171	233	287	308	309	306	296
May	299	295	292	287	282	286	274	212	163	140	125	118	114	118	122	130	143	173	230	286	310	315	311	303
Jun	307	305	303	299	293	297	278	224	185	164	152	148	148	150	155	163	174	193	232	283	309	320	320	313
Jul	326	321	317	313	307	307	292	239	195	177	172	172	173	178	184	195	204	222	265	317	335	341	340	331
Aug	340	336	332	329	322	320	315	281	239	214	203	203	206	214	224	237	246	269	311	337	348	352	354	345
Sep	351	349	343	336	329	323	328	309	267	234	218	214	215	220	230	248	270	311	348	365	364	368	368	359
Oct	372	368	363	357	346	336	342	340	293	250	231	223	224	226	234	252	280	341	379	389	383	390	391	382
Nov	344	345	345	345	344	343	343	302	230	201	189	186	185	190	211	266	342	363	363	357	352	351	348	345
Dec	350	349	350	350	348	345	345	332	279	241	225	217	215	215	229	282	342	360	362	360	357	357	355	353

Units: g CO2/kWh

Carbon Intensity over the year

2020 CAISO carbon intensity

- "What if we ran an electrolyzer on the grid last year?"

- Answer: Most of the time electrolyzers would emit **more carbon than steam methane reforming.**

Row	12 AM	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM
Jan	319	318	318	317	314	311	309	302	259	227	218	209	208	208	215	243	289	310	314	314	315	316	319	320
Feb	328	327	326	325	324	323	323	297	234	197	184	177	176	176	182	206	264	318	331	331	330	332	331	328
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Apr	294	288	281	275	268	271	281	242	178	149	132	123	119	118	119	125	139	171	233	287	308	309	306	296
May	299	295	292	287	282	286	274	212	163	140	125	118	114	118	122	130	143	173	230	286	310	315	311	303
Jun	307	305	303	299	293	297	278	224	185	164	152	148	148	150	155	163	174	193	232	283	309	320	320	313
Jul	326	321	317	313	307	307	292	239	195	177	172	172	173	178	184	195	204	222	265	317	335	341	340	331
Aug	340	336	332	329	322	320	315	281	239	214	203	203	206	214	224	237	246	269	311	337	348	352	354	345
Sep	351	349	343	336	329	323	328	309	267	234	218	214	215	220	230	248	270	311	348	365	364	368	368	359
Oct	372	368	363	357	346	336	342	340	293	250	231	223	224	226	234	252	280	341	379	389	383	390	391	382
Nov	344	345	345	345	344	343	343	302	230	201	189	186	185	190	211	266	342	363	363	357	352	351	348	345
Dec	350	349	350	350	348	345	345	332	279	241	225	217	215	215	229	282	342	360	362	360	357	357	355	353

Units: g CO2/kWh

Marginal Carbon

CARB Analysis of Marginal Carbon is basically the same story

- Marginal Carbon intensity answers the question “What if we added load to the grid?”
- Answer: Same answer!

	12 AM	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM
Q1	313.4	313.4	313.4	313.4	315.5	340.1	399.5	380.8	310.9	211.2	208.1	203.5	201.5	203.4	203.5	208.1	332.8	453.1	521.6	459.4	412.2	344.0	317.7	313.5
Q2	312.9	309.3	313.9	313.3	329.2	380.7	339.4	8.9	7.1	10.5	180.9	191.9	198.4	211.2	228.9	95.2	174.9	434.8	545.0	543.5	441.5	337.0	317.2	313.6
Q3	312.7	312.5	312.4	312.2	313.8	344.8	331.5	318.2	321.8	327.9	335.6	352.3	375.2	396.5	416.7	446.1	473.5	527.5	560.5	505.0	426.1	361.6	328.4	318.9
Q4	324.9	318.8	316.1	316.5	327.5	378.3	440.6	393.2	339.4	324.9	323.4	328.2	331.3	336.1	342.9	375.5	493.1	563.0	550.8	508.9	470.8	414.8	367.3	336.0

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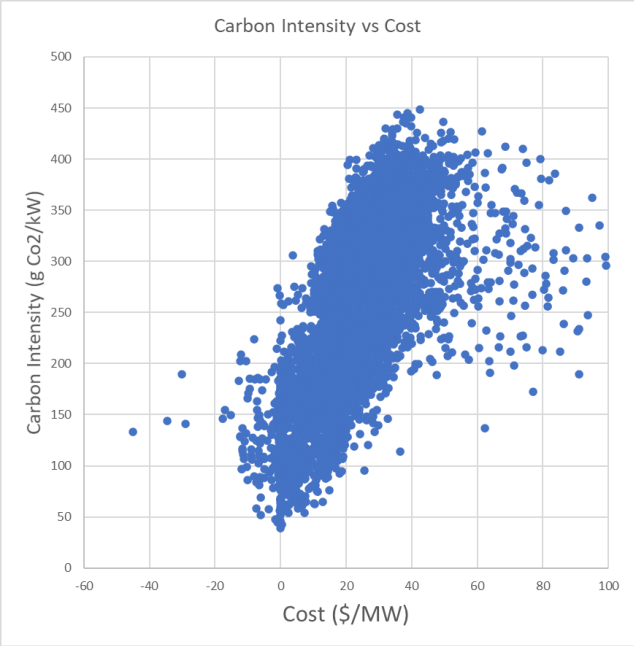
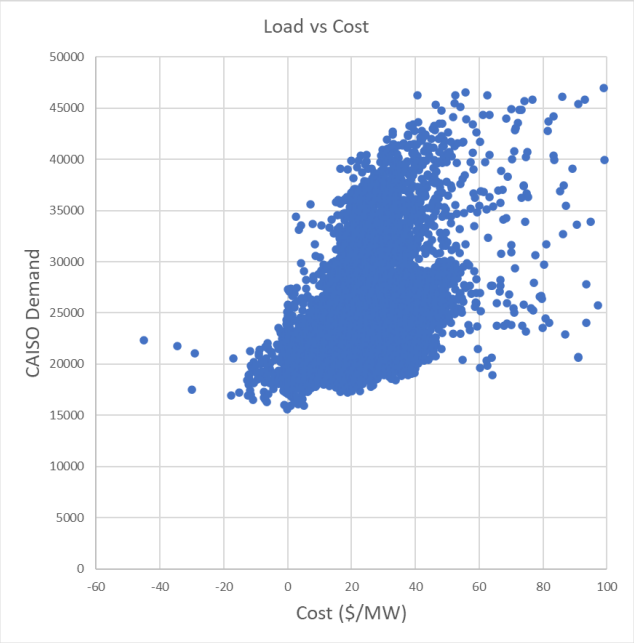
Units: g CO2/kWh

Lowest Cost = Lowest Carbon

Within CAISO, the Lowest Cost times are coincident with the lowest hourly carbon generation for the network.

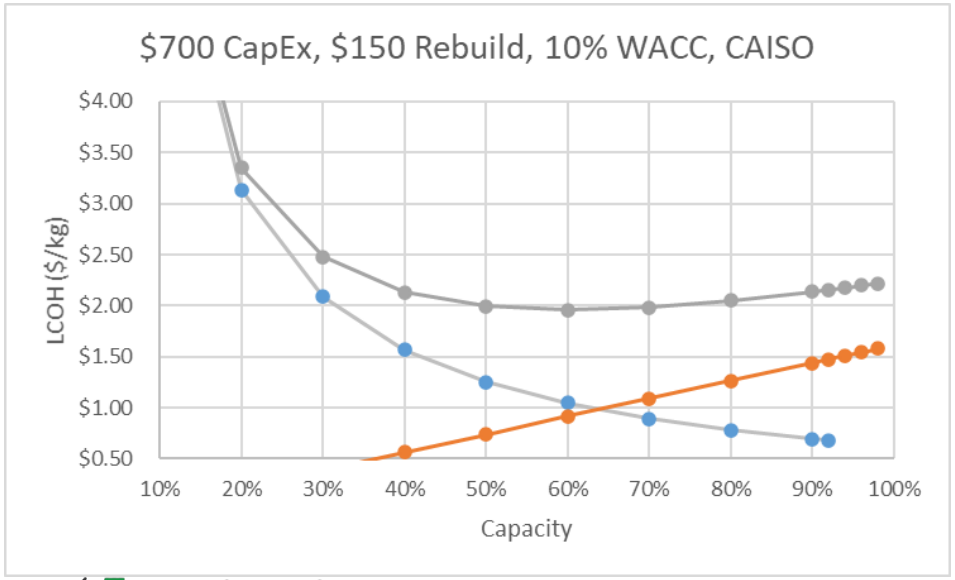
AND Lowest demand is lowest cost

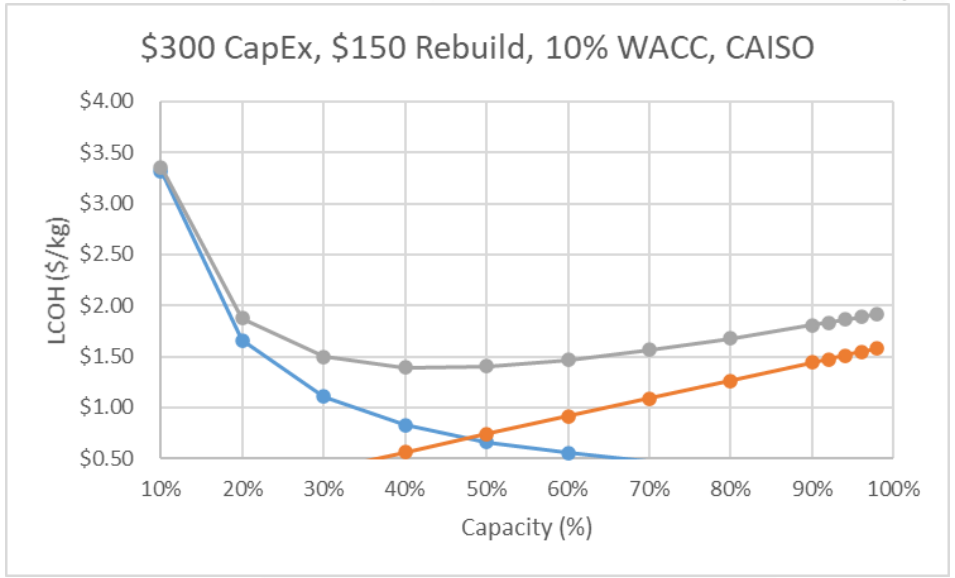




Energy Drives LCOH

- Lowest levelized cost of hydrogen (LCOH) is not at 100% capacity because the lowest cost energy isn't available all the time.





ELECTRIC HYDROGEN

CapEx OpEx Sum of CapEx and OpEx

What this tells us

1. New renewable generation is the lowest cost energy source
2. Energy Cost beats Capacity factor
3. Lowest cost = lowest carbon = win-win

CAISO Data sources

Pricing, Carbon and Demand

- Pricing

http://www.energyonline.com/Data/GenericData.aspx?DataId=20&CAISO___Average_Price

Downloaded all of 2020, 5m interval

- Carbon

http://www.caiso.com/todaysoutlook/pages/emissions.html

Scraped website for all CO2/hr estimates for 2020, 5m interval

- Demand

http://www.caiso.com/planning/Pages/ReliabilityRequirements/Default.aspx#Historical

Downloaded all hourly data

Averaged Price, and Carbon into hourly intervals, and joined with Demand.