Jacob Turner
Engr 115
12/2/2016

Input Parameters	
Temperature (k)	295.55
Pressure (atm)	1.01
Gas Constant R	0.0821
Energy of H2 (KJ/mol)	237

Final Efficiencies:	
Run 1	10.86%
Run 2	9.29%
Run 3	9.98%
Average	10.04%

Run 1 Data:

Time (seconds)	H2 (mL)	Voltage (V)	Current (A)
0	0	12	0.5
30	4	12	0.5
60	6	11.99	0.52
90	8	11.99	0.54
120	10	11.99	0.56
150	12	11.98	0.57
180	14	11.98	0.59
210	16	11.98	0.6
240	18	11.97	0.62
270	20	11.97	0.63
300	23	11.97	0.64
330	25	11.97	0.65

Run 2 Data:

Time (seconds)	H2 (mL)	Voltage (V)	Current (A)
0	27	11.98	0.6
30	29	11.98	0.62
60	32	11.97	0.64
90	34	11.97	0.65
120	36	11.96	0.67
150	39	11.96	0.68
180	41	11.96	0.69
210	44	11.95	0.71
240	47	11.95	0.72
270	48	11.95	0.73
300	50	11.95	0.73

Run 3 Data:

Time (seconds)	H2 (mL)	Voltage (V)	Current (A)
0	50	11.96	0.73
30	52	11.96	0.71
60	55	11.95	0.73
90	58	11.95	0.74
120	60	11.95	0.75
150	63	11.94	0.77
180	66	11.94	0.78
210	69	11.94	0.79
240	72	11.94	0.8
270	75	11.93	0.81

Run 1 Calculations

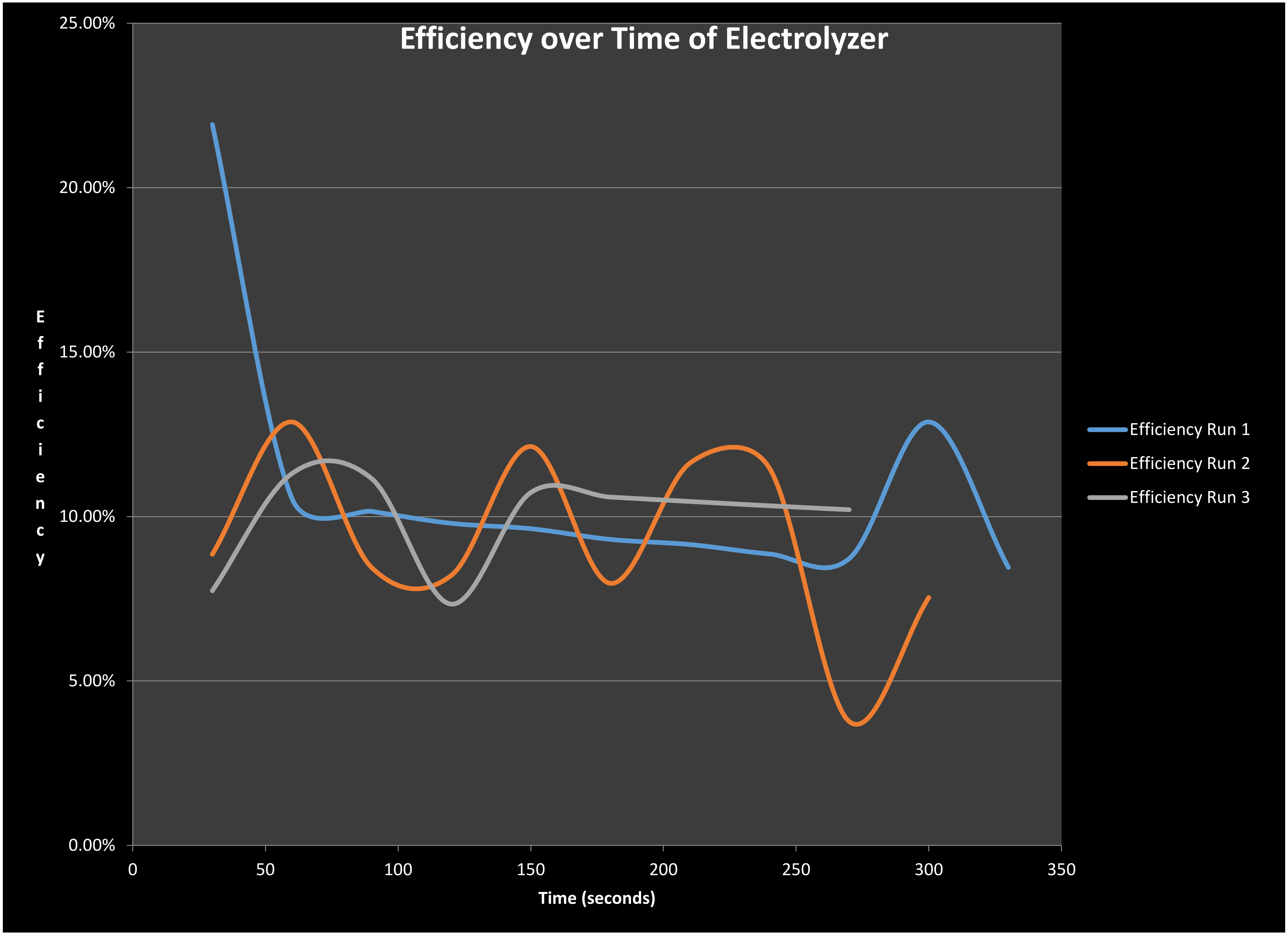
Power (w)	Electrical Energy (J) In	Mols H2 (mols)	Chemical Energy (J) Out	Efficiency (%)
6.00	0.00	0.0000E+00	0.0000	N/A
6.00	180.00	1.6650E-04	39.4599	21.92%
6.23	187.04	8.3249E-05	19.7299	10.55%
6.47	194.24	8.3249E-05	19.7299	10.16%
6.71	201.43	8.3249E-05	19.7299	9.79%
6.83	204.86	8.3249E-05	19.7299	9.63%
7.07	212.05	8.3249E-05	19.7299	9.30%
7.19	215.64	8.3249E-05	19.7299	9.15%
7.42	222.64	8.3249E-05	19.7299	8.86%
7.54	226.23	8.3249E-05	19.7299	8.72%
7.66	229.82	1.2487E-04	29.5949	12.88%
7.78	233.42	8.3249E-05	19.7299	8.45%

Run 2 Calculations

Power (w)	ectrical Energy (J)	Mols H2 (mols)	hemical Energy (J) O	Efficiency (%)
7.188	0.00	0.0000E+00	0.0000	N/A
7.4276	222.83	8.3249E-05	19.7299	8.85%
7.6608	229.82	1.2487E-04	29.5949	12.88%
7.7805	233.42	8.3249E-05	19.7299	8.45%
8.0132	240.40	8.3249E-05	19.7299	8.21%
8.1328	243.98	1.2487E-04	29.5949	12.13%
8.2524	247.57	8.3249E-05	19.7299	7.97%
8.4845	254.54	1.2487E-04	29.5949	11.63%
8.604	258.12	1.2487E-04	29.5949	11.47%
8.7235	261.71	4.1624E-05	9.8650	3.77%
8.7235	261.71	8.3249E-05	19.7299	7.54%

Run 3 Calculations

Power (w)	ectrical Energy (J)	Mols H2 (mols)	hemical Energy (J) O	Efficiency (%)
8.7308	0.00	0.0000E+00	0.0000	N/A
8.4916	254.75	8.3249E-05	19.7299	7.74%
8.7235	261.71	1.2487E-04	29.5949	11.31%
8.843	265.29	1.2487E-04	29.5949	11.16%
8.9625	268.88	8.3249E-05	19.7299	7.34%
9.1938	275.81	1.2487E-04	29.5949	10.73%
9.3132	279.40	1.2487E-04	29.5949	10.59%
9.4326	282.98	1.2487E-04	29.5949	10.46%
9.552	286.56	1.2487E-04	29.5949	10.33%
9.6633	289.90	1.2487E-04	29.5949	10.21%



Efficiency over Time of Electrolyzer
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Efficiency
0
50
100
150
200
250
300
350
Time (seconds)
Efficiency Run 1
Efficiency Run 2
Efficiency Run 3

Jacob Turner
Engr 115
12/2/2016

Input Parameters	
Temperature (k)	295.55
Pressure (atm)	1.01
Gas Constant R	0.0821
Energy of H2 (KJ/mol)	237

Final Efficiencies:	
Run 1	18.43%
Run 2	19.75%
Run 3	19.27%
Average	19.15%
Total System	3.67%

Run 1 Data:

Time (seconds)	H2 (mL)	Voltage (V)	Current (A)
0	75	0.412	0.21
30	70	0.392	0.2
60	68	0.242	0.14
90	64	0.677	0.2
120	63	0.598	0.22
150	62	0.507	0.25
180	61	0.27	0.25
210	56	0.533	0.27
240	54	0.485	0.25
270	53	0.367	0.2
300	50	0.565	0.27

Run 2 Data:

Time (seconds)	H2 (mL)	Voltage (V)	Current (A)
0	50	0.538	0.27
30	48	0.53	0.19
60	46	0.418	0.2
90	41	0.45	0.26
120	40	0.581	0.24
150	39	0.523	0.2
180	36	0.446	0.26
210	35	0.544	0.27
240	33	0.408	0.2
270	31	0.29	0.24
300	28	0.544	0.25
330	25	0.579	0.25

Run 3 Data:

Time (seconds)	H2 (mL)	Voltage (V)	Current (A)
0	25	0.656	0.14
30	23	0.652	0.14
60	22	0.652	0.14
90	21	0.638	0.14
120	20	0.611	0.14
150	18	0.571	0.14
180	18	0.643	0.14
210	17	0.6	0.12
240	15	0.403	0.14
270	14	0.636	0.14
300	14	0.6	0.14
330	14	0.55	0.15
360	13	0.62	0.14
390	12	0.577	0.13
420	10	0.595	0.14
450	10	0.57	0.14
480	8	0.565	0.14
510	7	0.513	0.14
540	6	0.53	0.14
570	5	0.576	0.14
600	4	0.437	0.14
630	3	0.468	0.14
660	0	0.481	0.13

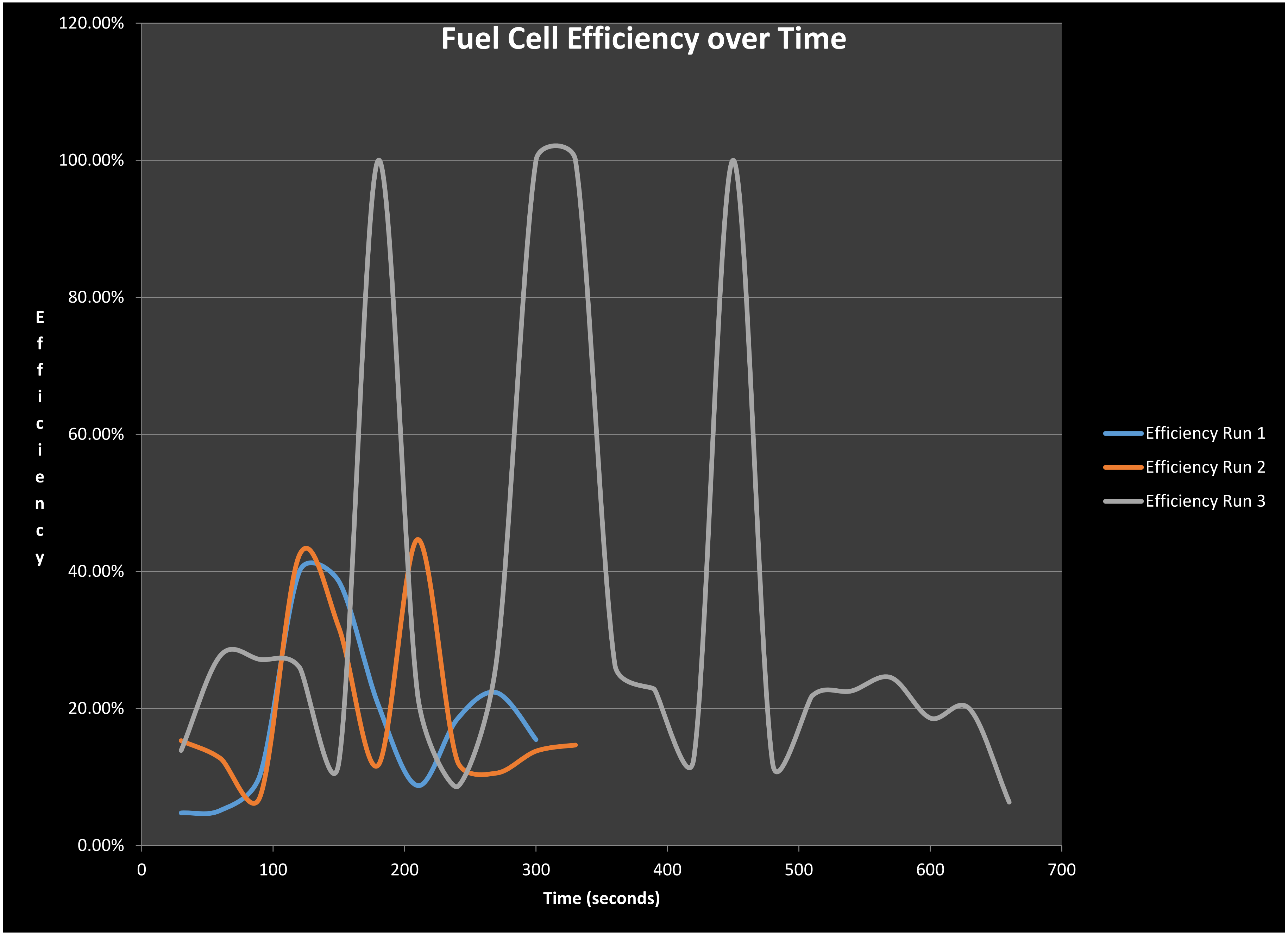
Run 1 Calculations

Power (w)	Chemical Energy Input (J)	Mols H2 (mols)	Electrical Energy Out (J)	Efficiency (%)
0.0865	0.0000	0.0000E+00	0.00	N/A
0.0784	49.3248	2.0812E-04	2.35	4.77%
0.0339	19.7299	8.3249E-05	1.02	5.15%
0.1354	39.4599	1.6650E-04	4.06	10.29%
0.1316	9.8650	4.1624E-05	3.95	40.01%
0.1268	9.8650	4.1624E-05	3.80	38.55%
0.0675	9.8650	4.1624E-05	2.03	20.53%
0.1439	49.3248	2.0812E-04	4.32	8.75%
0.1213	19.7299	8.3249E-05	3.64	18.44%
0.0734	9.8650	4.1624E-05	2.20	22.32%
0.1526	29.5949	1.2487E-04	4.58	15.46%

Run 2 Calculations

Power (w)	Chemical Energy Input (J)	Mols H2 (mols)	Electrical Energy Out (J)	Efficiency (%)
0.1453	0.0000	0.0000E+00	0.00	N/A
0.1007	19.7299	8.3249E-05	3.02	15.31%
0.0836	19.7299	8.3249E-05	2.51	12.71%
0.1170	49.3248	2.0812E-04	3.51	7.12%
0.1394	9.8650	4.1624E-05	4.18	42.40%
0.1046	9.8650	4.1624E-05	3.14	31.81%
0.1160	29.5949	1.2487E-04	3.48	11.75%
0.1469	9.8650	4.1624E-05	4.41	44.67%
0.0816	19.7299	8.3249E-05	2.45	12.41%
0.0696	19.7299	8.3249E-05	2.09	10.58%
0.1360	29.5949	1.2487E-04	4.08	13.79%
0.1448	29.5949	1.2487E-04	4.34	14.67%

Run 3 Calculations				
Power (w)	Chemical Energy Input (J)	Mols H2 (mols)	Electrical Energy Out (J)	Efficiency (%)
0.0918	0.0000	0.0000E+00	0.00	N/A
0.0913	19.7299	8.3249E-05	2.74	13.88%
0.0913	9.8650	4.1624E-05	2.74	27.76%
0.0893	9.8650	4.1624E-05	2.68	27.16%
0.0855	9.8650	4.1624E-05	2.57	26.01%
0.0799	19.7299	8.3249E-05	2.40	12.16%
0.0900	0.0000	0.0000E+00	2.70	100.00%
0.0720	9.8650	4.1624E-05	2.16	21.90%
0.0564	19.7299	8.3249E-05	1.69	8.58%
0.0890	9.8650	4.1624E-05	2.67	27.08%
0.0840	0.0000	0.0000E+00	2.52	100.00%
0.0825	0.0000	0.0000E+00	2.48	100.00%
0.0868	9.8650	4.1624E-05	2.60	26.40%
0.0750	9.8650	4.1624E-05	2.25	22.81%
0.0833	19.7299	8.3249E-05	2.50	12.67%
0.0798	0.0000	0.0000E+00	2.39	100.00%
0.0791	19.7299	8.3249E-05	2.37	12.03%
0.0718	9.8650	4.1624E-05	2.15	21.84%
0.0742	9.8650	4.1624E-05	2.23	22.56%
0.0806	9.8650	4.1624E-05	2.42	24.52%
0.0612	9.8650	4.1624E-05	1.84	18.61%
0.0655	9.8650	4.1624E-05	1.97	19.93%
0.0625	29.5949	1.2487E-04	1.88	6.34%


Fuel Cell Efficiency over Time
120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
Efficiency
0
100
200
300
400
500
600
700
Time (seconds)
Efficiency Run 1
Efficiency Run 2
Efficiency Run 3

1. What is the average efficiency of your fuel cell? What is the average efficiency of your electrolyzer? What is the “wire to wire” efficiency of this energy storage system, from electricity in to electricity out?

2. Research charge/discharge cycle efficiency for a battery and compare this with the electrolyzer/fuel cell system. With this in mind, what arguments might there be for choosing a fuel cell vehicle over a battery electric vehicle?

3. If you could improve the efficiency of one component of the system (the electrolyzer or the fuel cell), which would you choose? Why?

4. As shown in the Energy Flow Diagram above, the fan motor itself represents another energy conversion process where electrical energy is converted to mechanical energy, with associated energy losses as heat and noise. How could you modify this experiment to measure the efficiency of this step?

5. In scaling this system up to an industrial level, what changes would you expect to see in relative performance and efficiencies of the various components? What opportunities do you see for recovering “waste” energy from the processes?

1. The Average efficiency of the fuel cell I calculated was 19.15% while the average efficiency of my electrolyzer was about 10.04%. The efficiency of the whole system from electricity in to electricity out was only 3.67%, meaning only 3.67% of the energy going in to the system was used in a useful manner.

2. After researching I found that the charge/discharge efficiency of a modern lithium ion battery is about 80-90%. While the efficiency of a battery is significantly higher than that of a fuel cell, the materials used are largely more expensive and are not easily reusable or recyclable and can be more damaging to the environment in the long term. Another drawback of batteries i that they are very heavy and dense which means when used in a vehicle a significant amount of energy may be used in just carrying the weight of the battery with the car.

3. I would choose to improve the efficiency of the electrolyzer as it is about half as efficient as the fuel cell in our experiment. Having a lower efficiency means that there is more potential or room for improving that number and more improvement may be more cost effective.

4. One way you could modify this experiment to measure the efficiency of the fan would be to measure the speed/acceleration of the fan with maybe a radar gun or something that can track speed or rotations over time. One could then find the energy lost from heat and sound from subtracting from the kinetic efficiency of the fan. Efficiency= (energy used from movement/energy in from electricity), 100% - efficiency = % energy lost from heat & sound

5. I would expect to see some sort of automated method to purge the system of any water vapor that would block the hydrogen from being converted to electricity. An opportunity to reduce potiential waste would be to reuse the water that is produced as an exhaust maybe by putting it back into the beginning of the system.