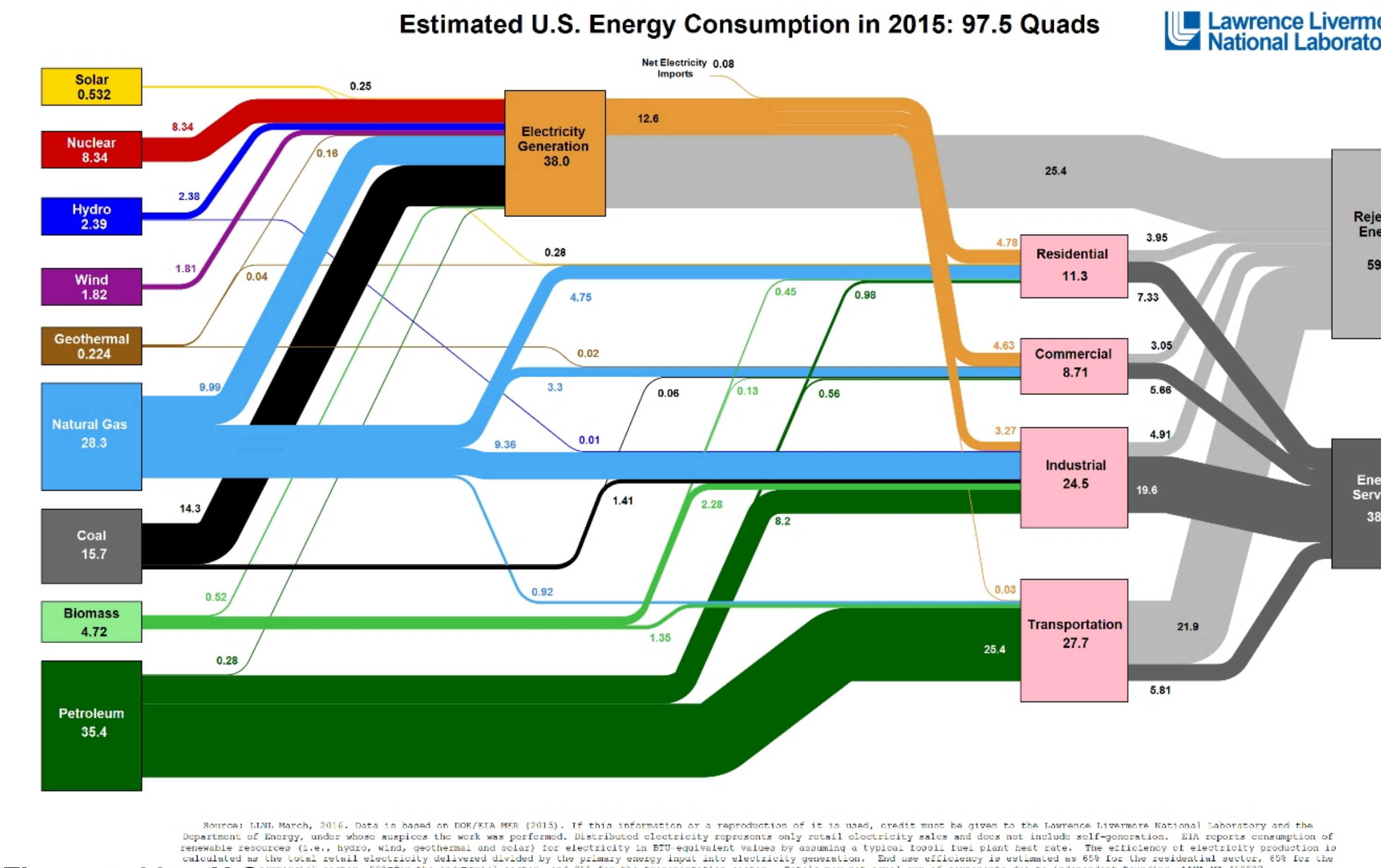
Introduction

The amount of solar energy falling to the Earth far exceeds current human consumption. Assuming 300 W/m2 irradiation for 12 hours a day, which is average for the Southwest United States, about 100 quadrillions BTU (~10^20 J) – the amount of energy consumed annually in the U.S. - can be collected from an approximately 100 x 100 mile square. The problem with utilizing renewable energy, however, is its highly dispersed nature. Solar and wind energy is distributed over large areas at a relatively low density. With the above irradiation assumptions, collecting 30 kW power to move a small car would require an area of 10x10 meters. Unlike oil and gas where only a small wellhead installation on the surface enables extraction of large amounts of energy, wind and solar necessarily have to be collected over large swaths of land. To be economically viable this should be low utilization land such as deserts or mountains, generally far removed from populated areas where the energy is ultimately consumed. The clean energy challenge, therefore, is not in finding energy - wind and solar alone far exceed human needs - the challenge is in converting the energy into a form suitable for consumption, accumulating it and delivering it to the consumer on demand and at competitive cost.

Present day energy carriers

Figure 1 shows the energy flow diagram for the United States. Currently, solar and wind energy are utilized almost exclusively as electricity, and other than via electrified transportation do not make inroads into the transportation fuel market. Yet electricity accounts for only about 18% of energy delivered to consumers (12.71 out of total of 72.86 quads consumed by all sectors combined). While large investments directed in increasing the use of electricity in the industrial and transportation sectors have been made, complete replacement of natural gas and petroleum carriers by electricity (even if technologically feasible) would require nearly 5-fold increase in the electrical grid capacity, an extremely large and costly undertaking.


Estimated U.S. Energy Consumption in 2015: 97.5 Quads
Solar 0.532
Nuclear 8.34
Hydro 2.39
Wind 1.82
Geothermal 0.224
Natural Gas 28.3
Coal 15.7
Biomass 4.72
Petroleum 35.4
Net Electricity Imports 0.08
Electricity Generation 38.0
12.6
25.4
Residential 11.3
Commercial 8.71
Industrial 24.5
Transportation 27.7
3.95
7.33
3.05
5.66
4.91
19.6
21.9
5.81
0.25
8.34
2.38
1.81
0.16
0.04
9.99
14.3
0.52
0.28
0.28
4.75
0.02
3.3
9.36
0.01
0.06
0.13
0.56
0.45
0.98
1.41
2.28
8.2
0.92
1.35
25.4
4.78
4.63
3.27
0.03
Source: LLNL March, 2016. Data is based on DOE/EIA MER (2015). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the
Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of
renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is
calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the

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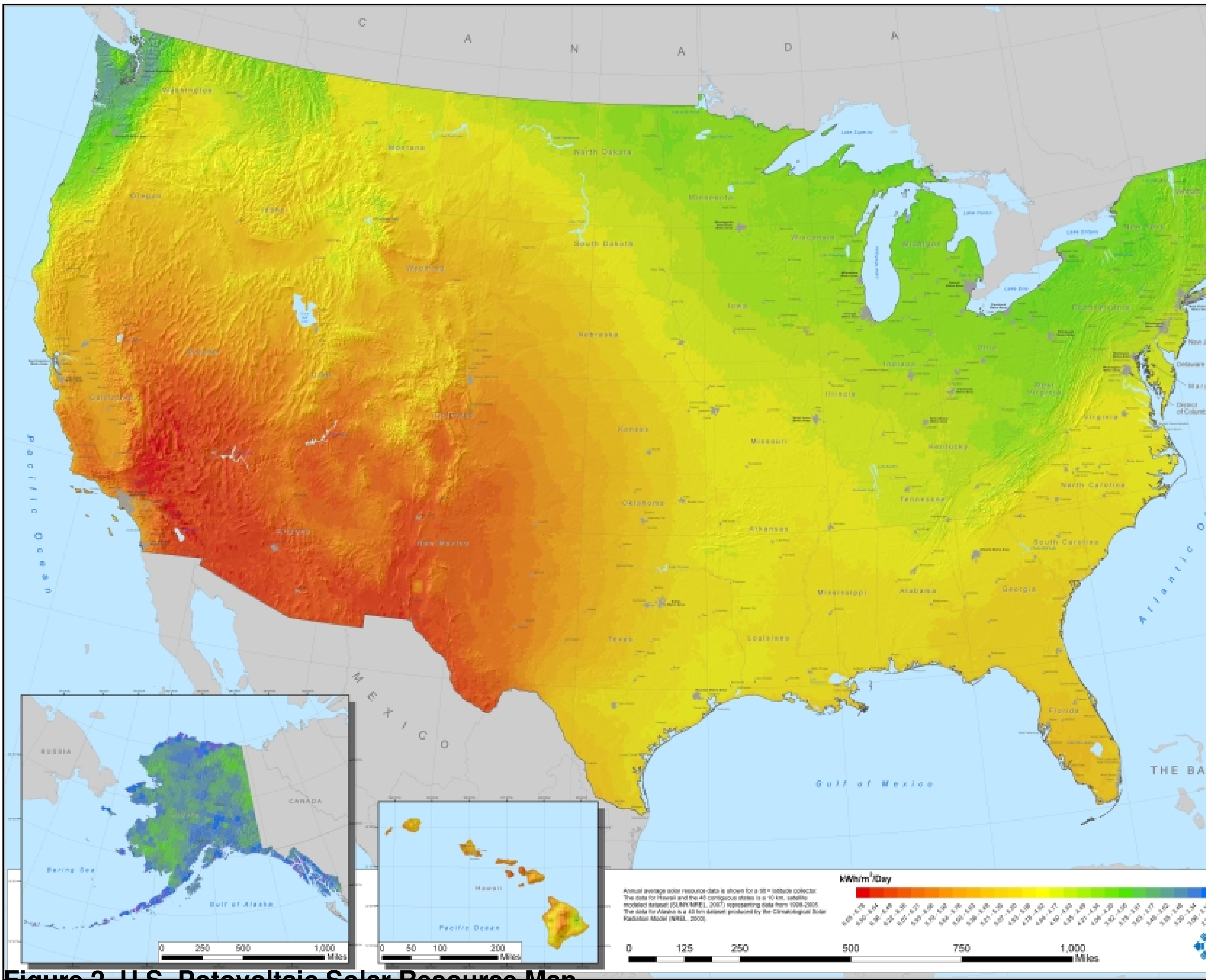

Figure 2. U.S. Potovoltaic Solar Resource Map.

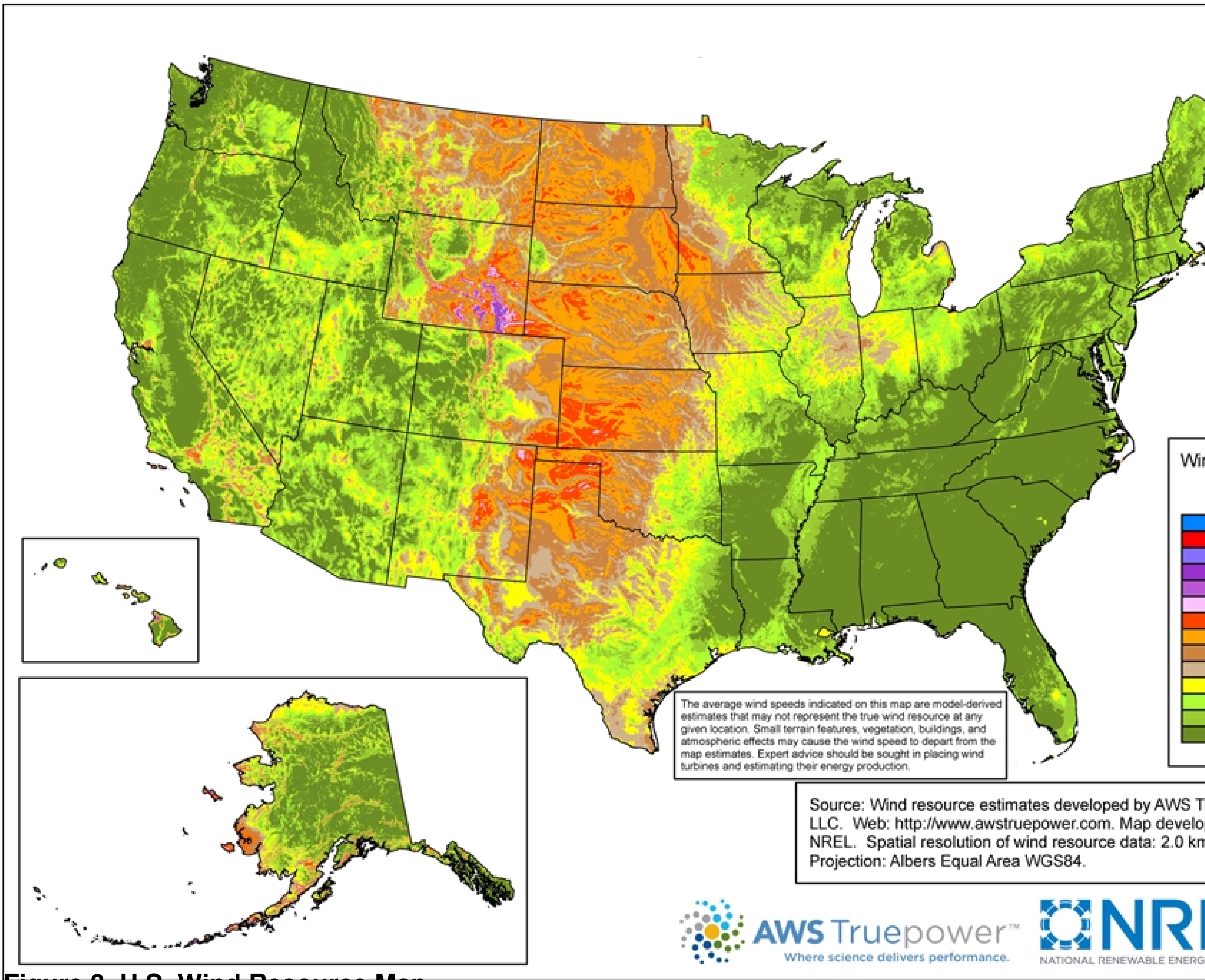

Figure 3. U.S. Wind Resource Map.

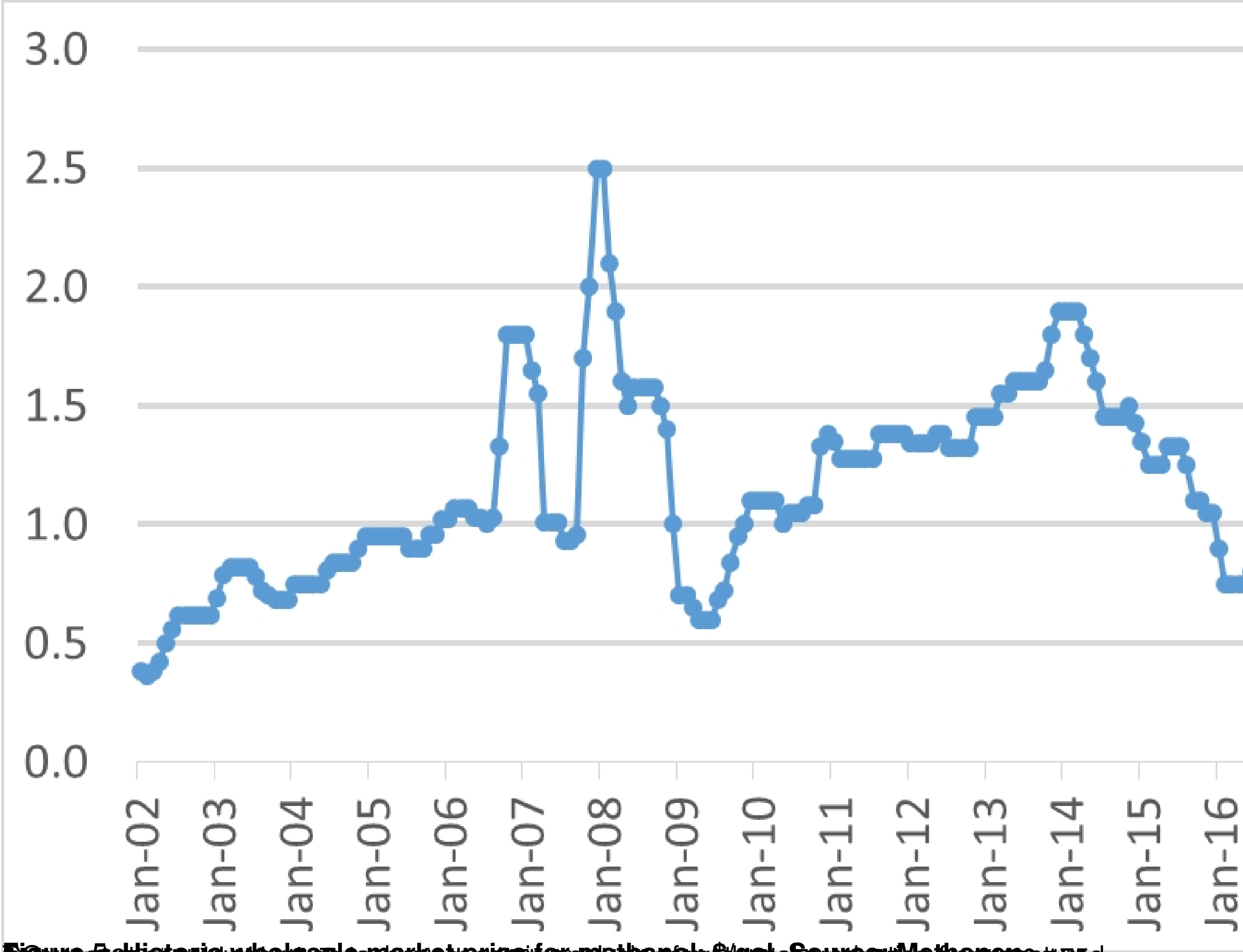

Figure 5. Historic wholesale market price for methanol, $/gal. Source: Methanex