Report for the Green Ribbon Environmental Committee

Physical and Financial Potential of a Solar-Powered Irvine

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Executive Summary

I summarize an analysis of the energy requirements of the residential community in the City of Irvine, as well as how it can be met by solar power available on residential rooftops themselves. The solar resource is also cost-effective, with recent costs far below that of retail residential electricity. A revolving fund for up-front costs for residents can facilitate rapid adoption of this renewable resource in order to help meet our City's climate action obligations.

1. Introduction

In 2018, the Intergovernmental Panel on Climate Change (IPCC) reported that the remaining carbon budget into the atmosphere is 420 gigatonnes of CO_2 in order to have a 67% chance of staying below the 1.5°C increase in global temperature goal of the Paris Climate Agreement in order to avoid the worst effects of global climate change [1]. Now, three years later, global CO_2 emissions have not decreased, and we now have less than seven years of time left in this carbon budget at current rates of global emissions [2]. The need for immediate action from local to global scales cannot be over-emphasized. The City of Irvine has committed to the Paris Climate Agreement, and has its own obligations to reduce its carbon emissions as soon as possible, and it has several pathways to do so.

Since the founding of the City of Irvine shortly after the founding of the University of California, Irvine (UCI), campus scientists and engineers have teamed up with city staff and elected officials to address the environmental challenges the city and world had faced. The most notable of the actions was the development of a city ordinance banning the use of chlorofluorocarbons, or CFCs, as a collaboration of UCI scientists and engineers with business leaders. CFCs were discovered to be destroying the Earth's critically protective ozone layer at UCI, led by Dr. Mario Molina and Prof. Sherwood Rowland. This ordinance was described as "the most far-reaching measure" to protect the ozone in national coverage [3], and the Los Angeles Times declared it "the most comprehensive law in the nation" [4]. The City of Irvine ordinance is credited with kick-starting the ozone's recovery, with other municipalities, states and national governments following suit [5]. Current City Councilmember Larry Agran helped lead that effort in 1989 when he served as Irvine's mayor.

In writing this report for the Green Ribbon Environmental Committee, I hope to identify the strong potential that Irvine's solar resource has in fulfilling the energy requirements of it residents along with the strong potential available in financing solar power due to its highly competitive pricing with respect to fossil-fuel-based electricity sources more broadly, and local consumer electricity prices specifically. I summarize detailed estimates of the energy needs in residential usage in electricity, in transportation, and in household heating via natural gas. I also detail how the solar resource available to residential households through rooftop solar, and how it may accommodate the full residential energy needs. I point out

some shortcomings in solar capabilities, namely, in multi-family developments like condominiums and apartments. I also summarize the financial potential in municipal financing through structures such as revolving funds in facilitating rapid solar energy adoption by current residents, and the need for halting the installation of new fossil-fuel infrastructure.

2. Residential Energy Usage

There are three large bins in which a typical Irvine household uses their energy. The most obvious that people think of us electricity. Another that people often immediately think of is fueling their vehicles in which to get around. The last, and it turns out not the least, usage of energy is natural gas, and it often gets unnoticed as a major source of carbon-based energy in a household. I go through detailed estimates of accounting of these usages. I use public reports from state and federal agencies as they are most recently available. These are of course estimates, but can be guiding principles for our ability as a community and as a City to move to cheap, renewable energy to power our lives, and to do it within the short time available. The total energy need to all sectors is shown in Fig. 1.

2.1 Electricity

The first thing many think about in energy usage is electrical energy. When one is at home, and needs to power something, the first thing that usually comes to mind is "where is the nearest plug?" So, first, let's tackle electrical energy. I based the calculation using Irvine's population as reported by census data to be 287,401 as of 2019 [6]. Orange County has a total annual electrical energy usage of 6,661 GWh [7]. Given OC's population of 3.17 million people [8], this works out to 2,103 kWh per year per person.

Taking the kWh per person rate for the County, and multiplying by the City of Irvine population gives us the City's electrical energy need, in kWh. Converting to SI units of joules (J), and in this case petajoules (PJ), the total electrical energy need for one year is approximately 2.18 PJ for all residents in the City of Irvine.

2.2 Transportation

Likely the next most common thought of an energy need in powering our lives is fueling and powering our motor vehicles. Personal vehicle transportation usage of residents is another major use of energy. The Federal Highway Administration reports 8572 miles/year/person for California [9], and I take Irvine to be typically Californian, given the mix of urban-style commuting (bus, shuttle, bikes and pedestrian-mode) associated with our largest campus, UC Irvine, and the suburban commuting typical for much of our community. Also needed to know is how much energy a typical car uses to get around. A typical electric car requires 28 kWh per 100 miles [10].

Now, the total energy used by residents is the miles per person per year multiplied by the population of Irvine, then multiplied by the given kWh per 100 miles. Converting to petajoules, the total is 2.48 PJ per year for all of Irvine's residential vehicle usage.

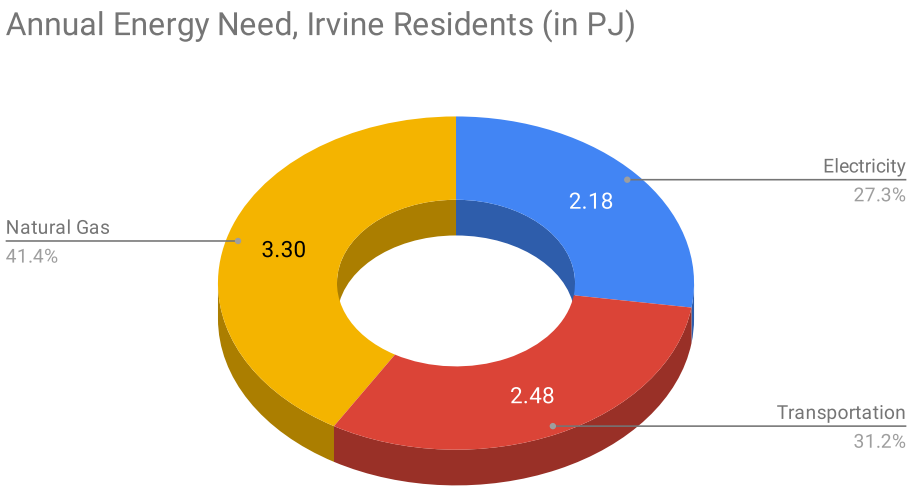

Fig. 1. Shown are the total estimated energy need of Irvine residents in the sectors of electricity, transportation, and natural gas heating. Units are petajoules (PJ).

2.3 Natural Gas

One of the sources of energy in residential lives typically gets significantly less attention: natural gas usage. As I will show, this is the single largest contributor to energy needs, given by the data. Let's move to estimate our City's residential natural gas energy usage. California natural gas utilities report residential per day natural gas usage at 1139 MMcf/d for the entire state (pg. 18, California Gas Report [11]). Using the typical energy content of natural gas, 1033 Btu per cf, one can convert to joules per day. This amounts to about 3,186 kWh/yr per capita. Again, multiplying by the population of Irvine and converting to petajoules, as above, we get 3.30 PJ per year for all of Irvine's natural gas energy usage.

3. Solar Energy Resource

Adding electrical, motor vehicle, and natural gas energies, the total annual energy need for the City of Irvine's residents is then **7.95 PJ** per year. That is the quantity that would need to be fulfilled by renewable or carbon-free energy in order for our residents to satisfy our Paris Agreement requirements.

The rate of solar energy averaged over all year, all weather, and over day and night, in Irvine is 252 Watts per square meter, according to the National Renewable Energy Laboratory of the Department of Energy [12]. The number of homes in Irvine is approximately 114,217 [13]. Average home size built in recent years in the U.S. is reported to be 214 square meters (2301 sq. ft.) [14]. Let us say all homes in Irvine are two stories, a conservative assumption, so that half that area is then covered by a roof. Total residential roof area

in Irvine is then 12.2 square kilometers (3,017 acres!). In the end, this provides **14.5 PJ** of energy per year, using typical photo-voltaic efficiencies of 15%. That is more than enough to power all energy needs, by almost a factor of two more energy available on rooftops than required by residents.

4. Financial Potential

The cost of residential electricity, on average in the State of California is now at about 21.4 cents per kWh (Energy Information Administration of the U.S. Department of Energy [15]). Including all equipment, hardware, and soft costs of permitting, inspection, and interconnection; sales tax; and engineering, procurement, and construction/developer overhead and profit, the National Energy Resource Laboratory places the cost of residential photo-voltaic solar at approximately 15 cents per kWh, without tax credits, to about 8 cents per kWh with tax credits. This places photo-voltaic solar at lower than residential rates [16]. Therefore, there is a tremendous financial benefit to going solar, as well as an environmental benefit.

The main impediment to immediate implementation of solar energy given the cost savings is the up-front costs of installation. Many solar panel power providers have created financial structures through solar panel leases, power purchase agreements and/or monthly billing, to lower consumers' monthly budget costs relative to retail electricity while requiring low to zero up front cost to the consumer.

Helping finance our City's residents with up-front costs and contracting is exactly where the City of Irvine can help bring our City and our residents to the forefront of action on climate. Using City-financed revolving funds, the City can offer zero-cost installation of solar panels from pre-approved contractors, then recovering the loan from property tax billing or another structure. The City's revolving funds are not expended, but are replenished in such a structure, while facilitating the solar transformation of our residential power sector.

5. Limitations of Analysis

A primary limitation is the fact that many residents live in multi-family units, either apartments, condominiums, or town-homes. The total rooftop area used in this analysis is of single-family homes, and could facilitate the power to these homeowners in multi-family units. That would require a different financial structure by which the city purchases power from residents who have excess rooftop capability. This is a complication, but worth exploring. Other solar installation locations may also be able to provide multi-family units with solar power, including City-owned buildings and parking lots.

A secondary limitation is time. Even if half of our City's homes already have solar panels—an optimistic assumption—then the need of solar installations in homes is of order 50,000 homes in 14 years, or about 3,600 homes per year, in order to fulfil our Paris Climate Agreement commitment. This is likely a tall order, but I feel our City may be up to the challenge.

The last limitation is that this current analysis is by design focused only on the residential community's energy needs. Remaining are the energy needs of our commercial and governmental sectors. Some of the same principles can apply regarding the abundance of solar power and its financial benefits. Our City's role in facilitating these sectors to 100% renewable or carbon-free energy should also be a priority.

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