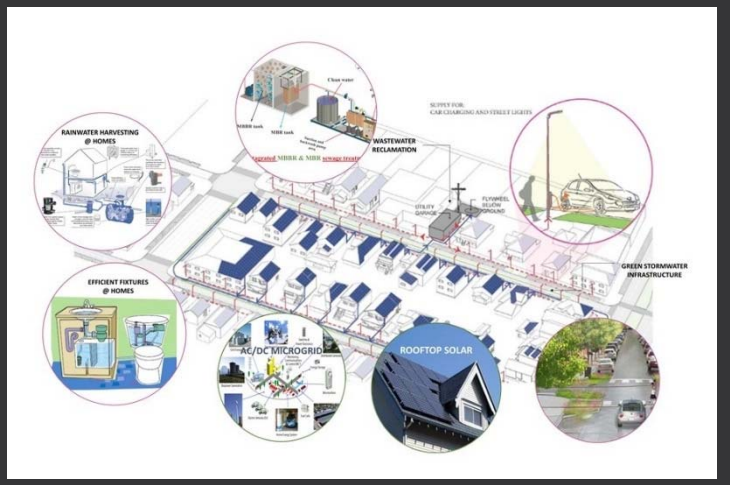
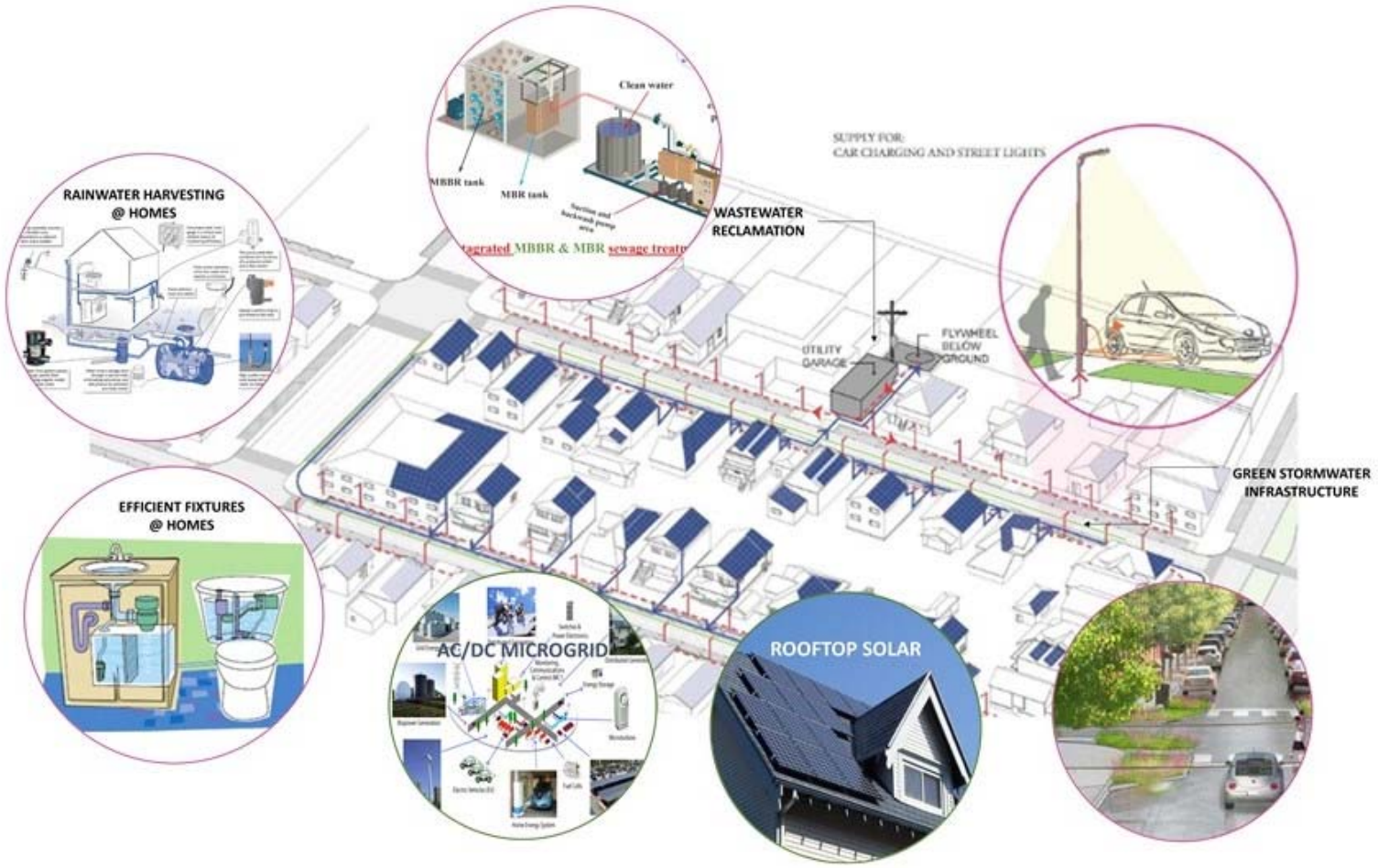
Oakland EcoBlock

Residential Solar + Storage Microgrid Paired with Energy Efficiency and Fuel Switching



March 27, 2018

Oakland EcoBlock Schematic



Existing Conditions – Grid Infrastructure

Electrical power at the site is currently distributed at 12.47 kilovolts (kV) across 17 telephone poles, and then through 7 PG&E pole-mounted transformers into the 28 properties at 240 V/120 V split-phase AC power.

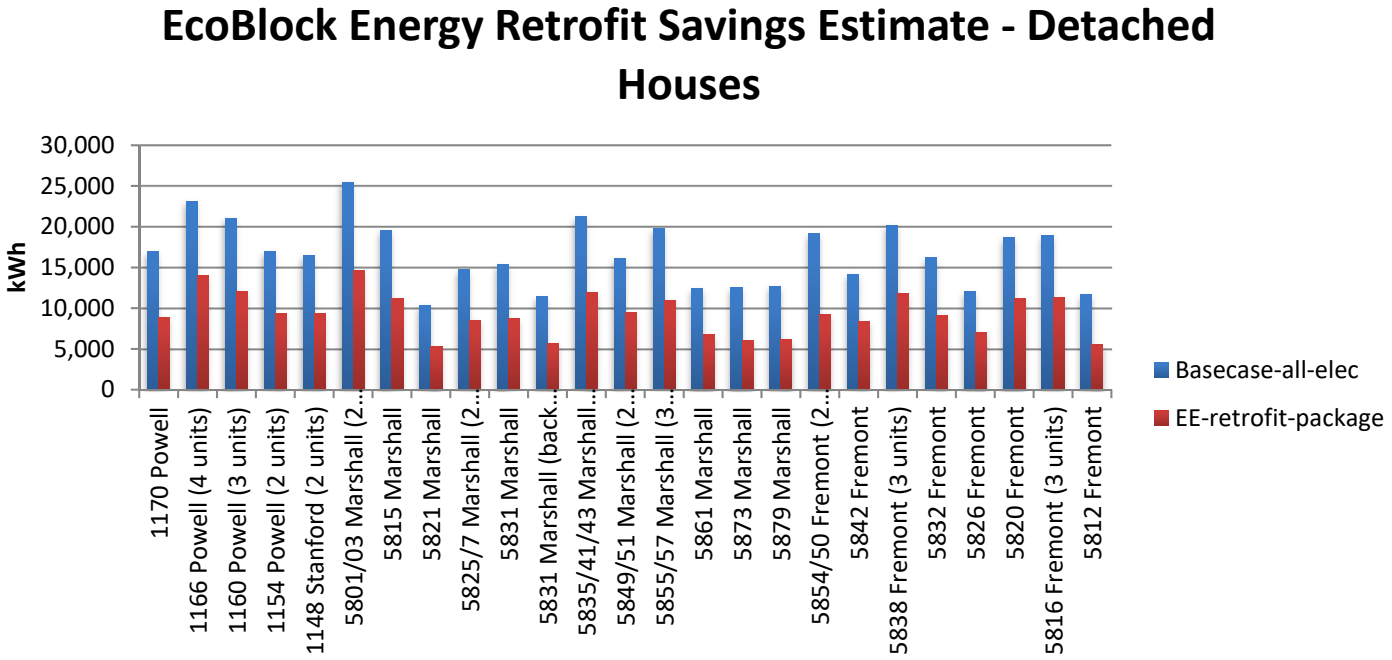
Solar PV Rooftop Generation Capacity

Building	Address	Roof Total Area (SF)	Roof Area Available for PV(SF)	$Watt_{DC}$_STC / SF	KW_{DC}_STC	KWH_{AC} / YR-KW_{DC}_STC	KWH_{AC} / YEAR	Exisitng PV Installed
1	1175 59th St	8,946	6,710	17.3	116	1,400	162,502	
2	5879 Marshall St	709	532	17.3	9	1,400	12,879	
3	5873 Marshall St	590	443	17.3	8	1,400	10,717	
4	5865 Marshall St	1,338	1,004	17.3	17	1,400	24,305	
5	5850/4 Fremont St	503	377	17.3	7	1,400	9,137	
6	5861 Marshall St	793	595	17.3	10	1,400	14,405	
7	5857 Marshall St	404	303	17.3	5	1,400	7,339	
8	5842 Fremont St	677	508	17.3	9	1,400	12,298	
9	5849/51 Marshall St	528	396	17.3	7	1,400	9,591	YES
10	5838 Fremont St	698	524	17.3	9	1,400	12,679	
11	5841/43 5835 Marshall St	1,351	1,013	17.3	18	1,400	24,541	
12	5832 Fremont St	443	332	17.3	6	1,400	8,047	
13	5831 Marshall St	354	266	17.3	5	1,400	6,430	
14	5826 Fremont St	645	484	17.3	8	1,400	11,716	
15	5827 Marshall St	368	276	17.3	5	1,400	6,685	
16	5820 Fremont St	521	391	17.3	7	1,400	9,464	
17	5821 Marshall St	235	176	17.3	3	1,400	4,269	
18	5816 Fremont St	493	370	17.3	6	1,400	8,955	
19	5815 Marshall St	661	496	17.3	9	1,400	12,007	
20	5812 Fremont St	427	320	17.3	6	1,400	7,756	
21	1170 Powell St	515	386	17.3	7	1,400	9,355	
22	1166 Powell St	1,299	974	17.3	17	1,400	23,596	
23	1160 Powell St	1,348	1,011	17.3	17	1,400	24,486	
24	1154 Powell St	988	741	17.3	13	1,400	17,947	
25	1148 Powell St	1,794	1,346	17.3	23	1,400	32,588	YES
26	5801/5803 Marshall St	1,422	1,067	17.3	18	1,400	25,830	
	TOTAL	**28,050**	**21,038**		**364**		**509,523**	

Energy Load Summary

- Projected Energy Demands Following Improvements
  - Base Case: 587,651 kWh equivalent (electricity plus natural gas conversion)
  - Post-Retrofit Demand: 357,544 – 407,378 kWh (all electric)

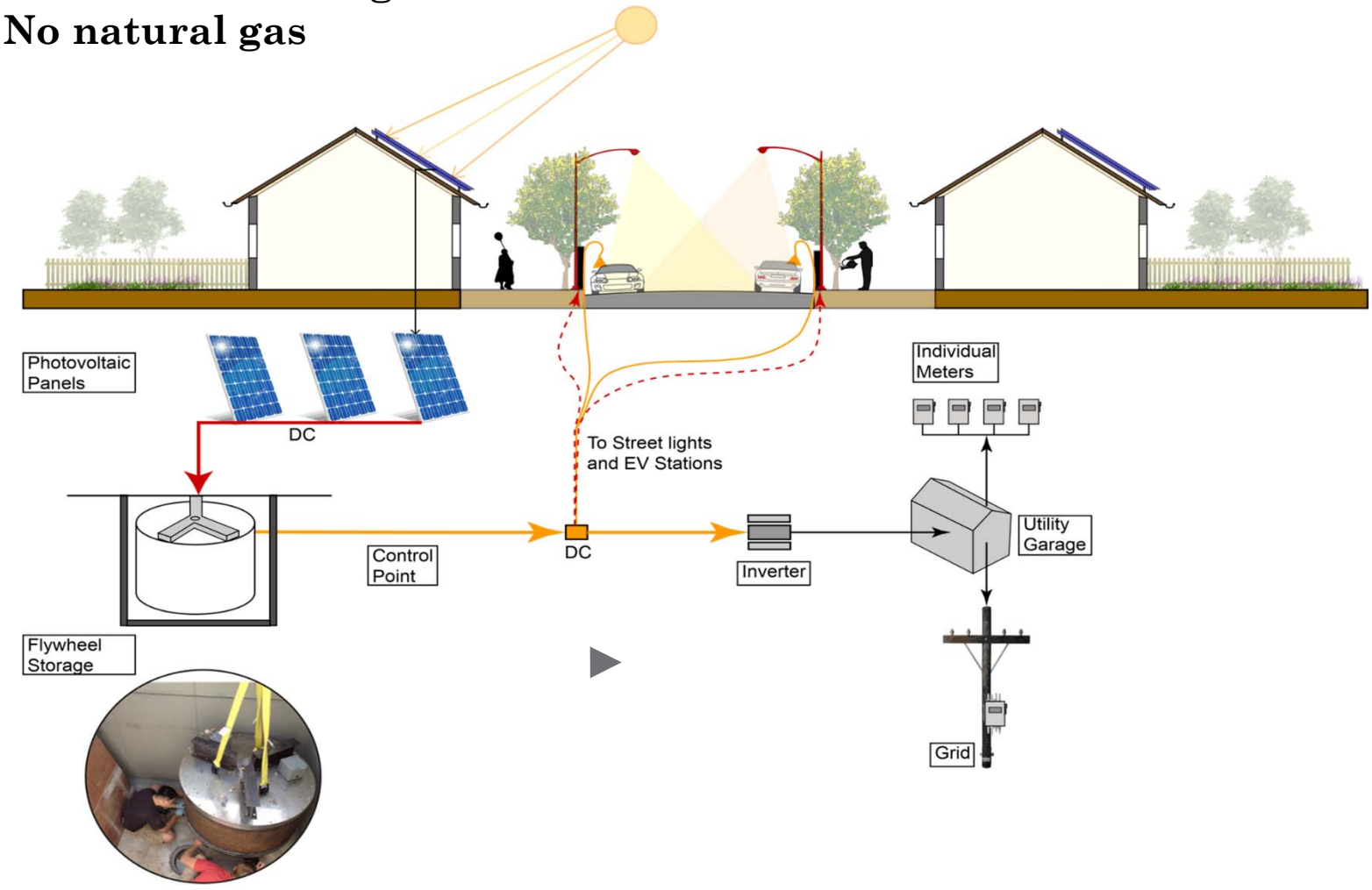
- Energy Retrofits:
  - Upgrades to Building Envelope, Lighting, and Appliances (all electric replacements)
  - Conversion of DHW and furnaces to a large capacity Heat Pump Water Heater combined system



All solar electricity: integrated overview

ENERGY EFFICIENT HOMES

- **38% reduction target**
- **No natural gas**



Communal, rooftop-PV, DC + AC microgrid

- System architecture:
  - ~360 kW PV, DC microgrid
  - 30% non-premium rooftop space --> 20% extra energy
  - operates via a utility loop under the sidewalk (blue) with a single inverter connection to the grid & a utility garage housing the power electronics.
- Estimated PV system output: 500 MWh/year
  - drives down electricity costs
  - removes natural gas in homes
  - Increases reliability & resilience

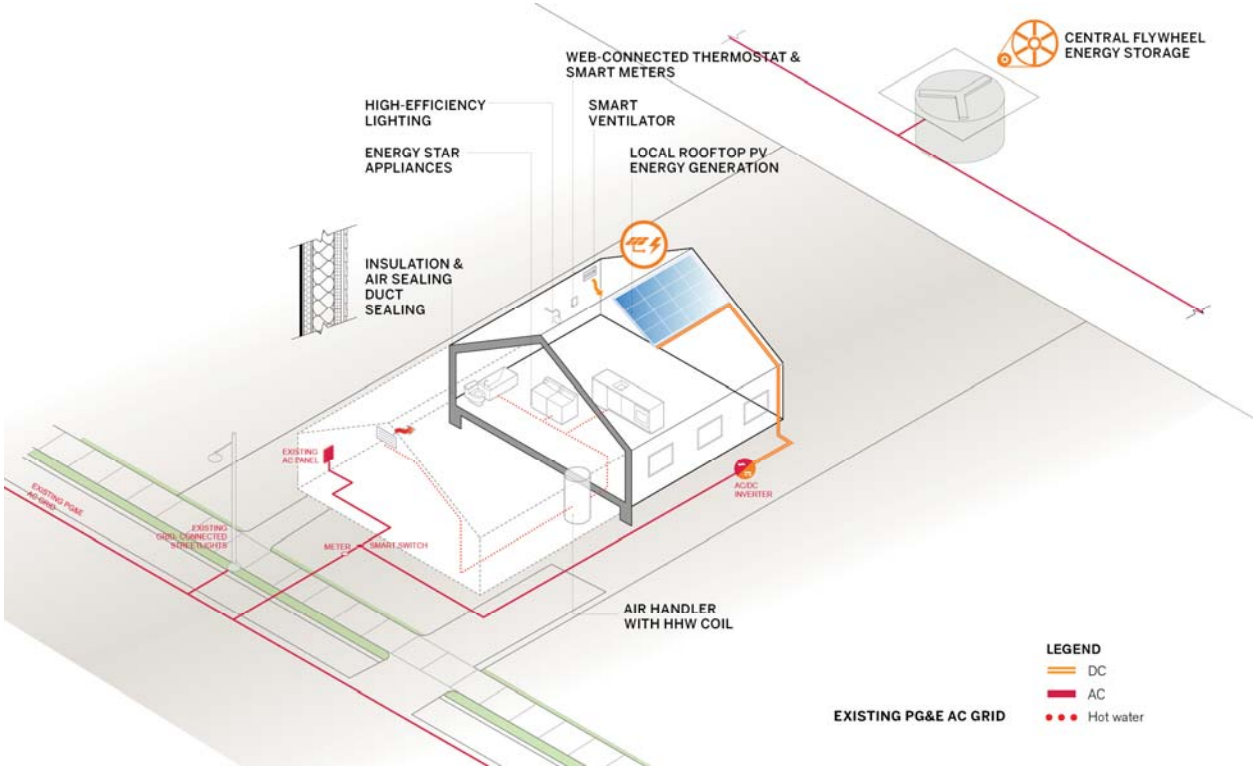
Flywheel Storage at Utility Plant

- system architecture
  - 120kW distributed by 3 units
  - capacity = 40kW x 4.0 hrs = 160 kWh/unit
  - net energy rating = 480 kWh
- flywheel technology
  - 30-year design life
  - zero CO_2 emissions
  - no capacity degradation
  - no hazardous materials
  - low cost manufacturing process
  - high end-of-life value material
  - 100% recyclable

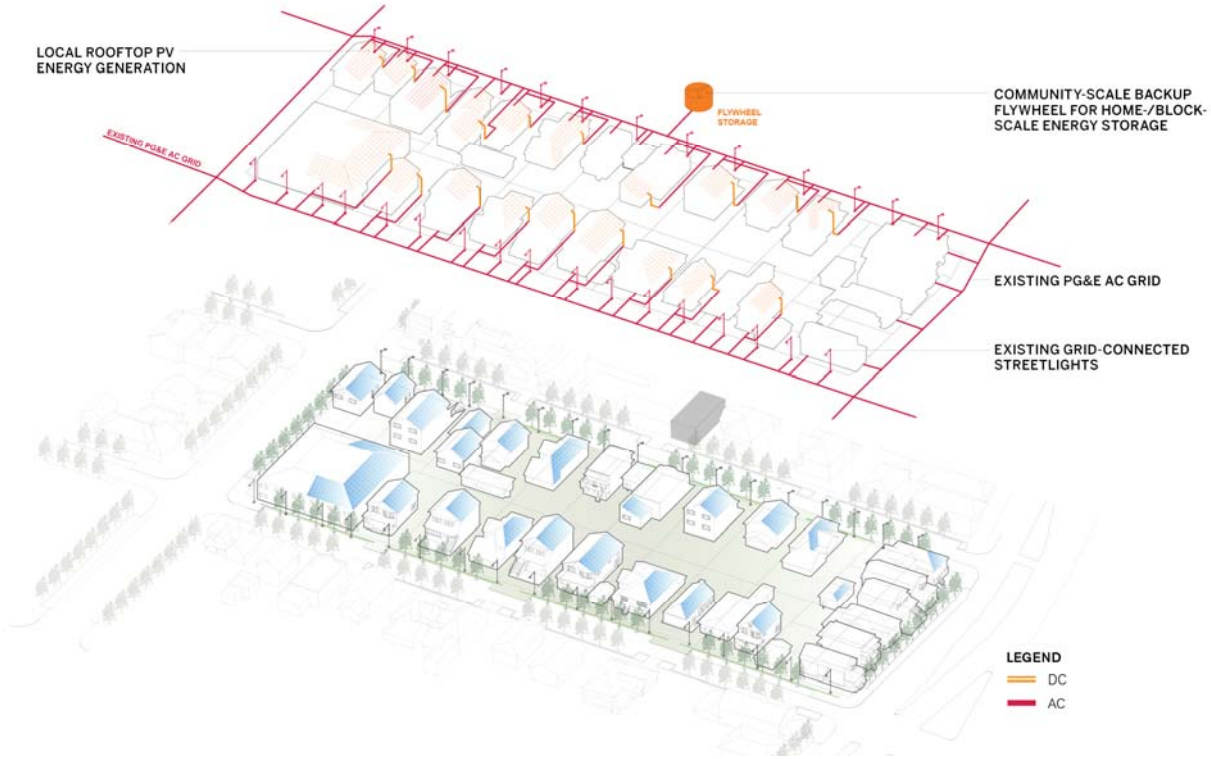
Potential – Scaling Up to Oakland

- Average Oakland block = 40 homes
- 40 homes can produce = 400MWh/year
- Oakland has 3,500 potential ecoblocks
- 400MWh/block/year x 3,500 blocks = 1,400 GWh/year
- > Topaz Solar Farm in San Luis Obispo = 1,100 GWh/year
- More than 60% of total Oakland electricity demand in a given year

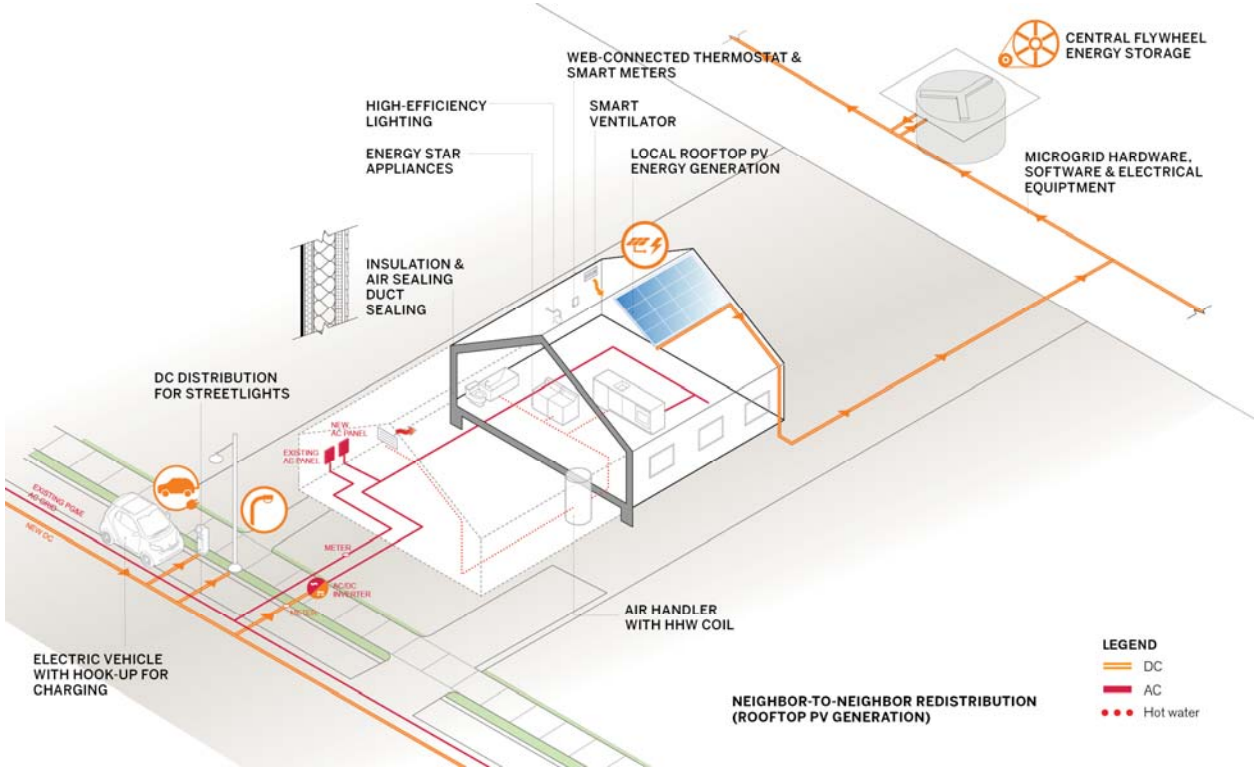
AC Solar + Storage Microgrid: House Diagram



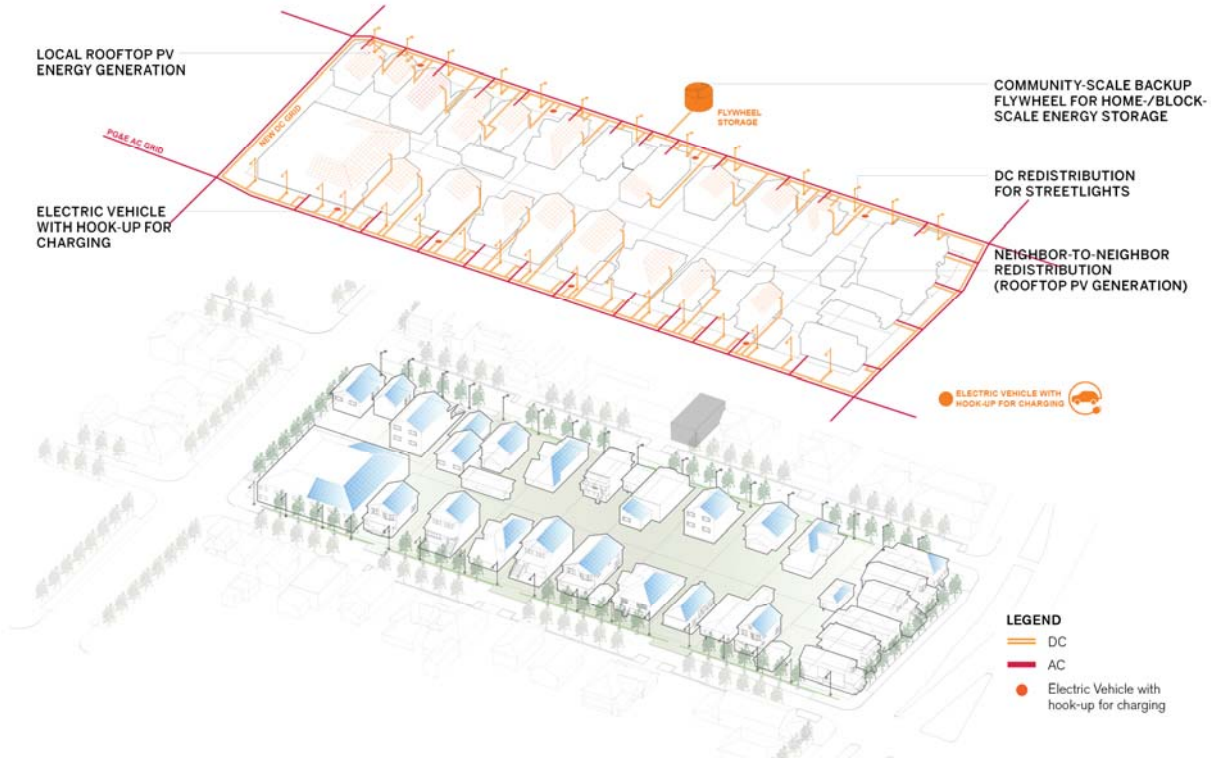
AC Solar + Storage Microgrid: Block Diagram



DC Solar + Storage/EV Microgrid – House Diagram



DC Solar + Storage/EV Microgrid – Block Diagram



Project Specifications and Details

Photovoltaic retrofits and associated home upgrades

Each available home will be outfitted with an array of 78" x 40", 365 W solar panels; the number of solar panels on each home will depend on the size and design of each roof. Based on an approximate estimate of each building's roof area, the EcoBlock has a combined useable roof area of 37,000 square feet (ft^2). Assuming that 75 percent of the useable area can be utilized, we will be able to fit 1,309 panels on the block, with a peak output of 509 kilowatts (kW) of solar power.

Energy Storage

In each scenario, the microgrid will be supported by three 40 kW flywheels, located in the Central Utility Plant. Total storage capacity of 480 kilowatt hours.

AC Microgrid

In Scenario 1e, existing high-voltage cables from PG&E will be used to distribute power from the Central Utility Plant to the existing PG&E pole-top transformers for distribution to the homes. A new AC microgrid (parallel to the PG&E power lines) will be created with a 1000 amp (A), 240 V busway, to collect power from the solar arrays and transmit it to the central utility plant and flywheel.

DC Microgrid

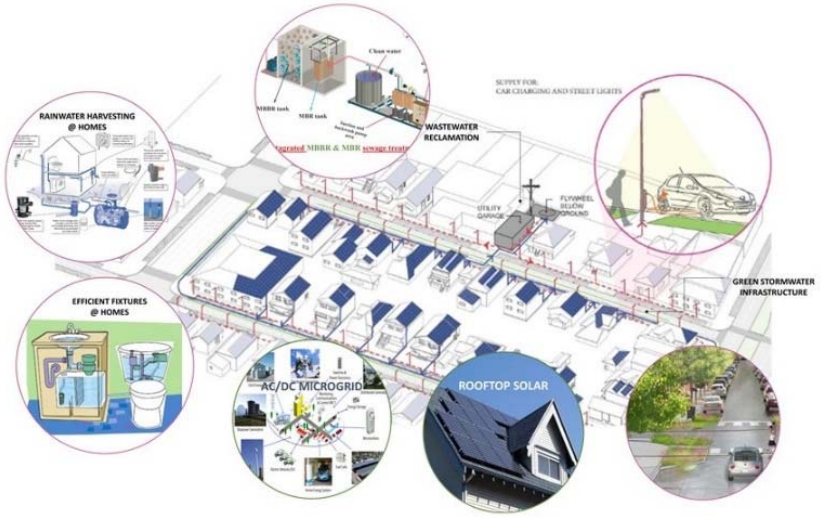
In scenarios 2e and 3e, two DC busways will be installed in new underground conduit using directional drilling (thus avoiding the expense of full trenching). One busway, at 760 VDC, will be used to collect and transmit the solar power from the rooftop arrays to the Central Utility Plant. The other busway, at 380 VDC, will transmit power from the Central Utility Plant to the load panels in each home. These voltages were chosen to minimize line losses while also minimizing conversion losses to the lower voltage loads in the homes.

Electric Vehicle Charging

Scenarios include the installation of curbside electric vehicle chargers (also known as *electric vehicle supply equipment,* or EVSE) to allow EV charging from the solar-powered microgrid. As explained below, the optimal number of chargers is 24, assuming that all houses participate in the microgrid, although that number can be scaled with the amount of PV generation available. The chargers will be fed from the DC microgrid and supply DC power to the EVs using a DC fast charging standard.

Conclusion

- **With the Project As Designed**:
  - ZNE readily achievable
  - All electric homes
  - Mostly electric transportation
  - Up to 80% water reduction

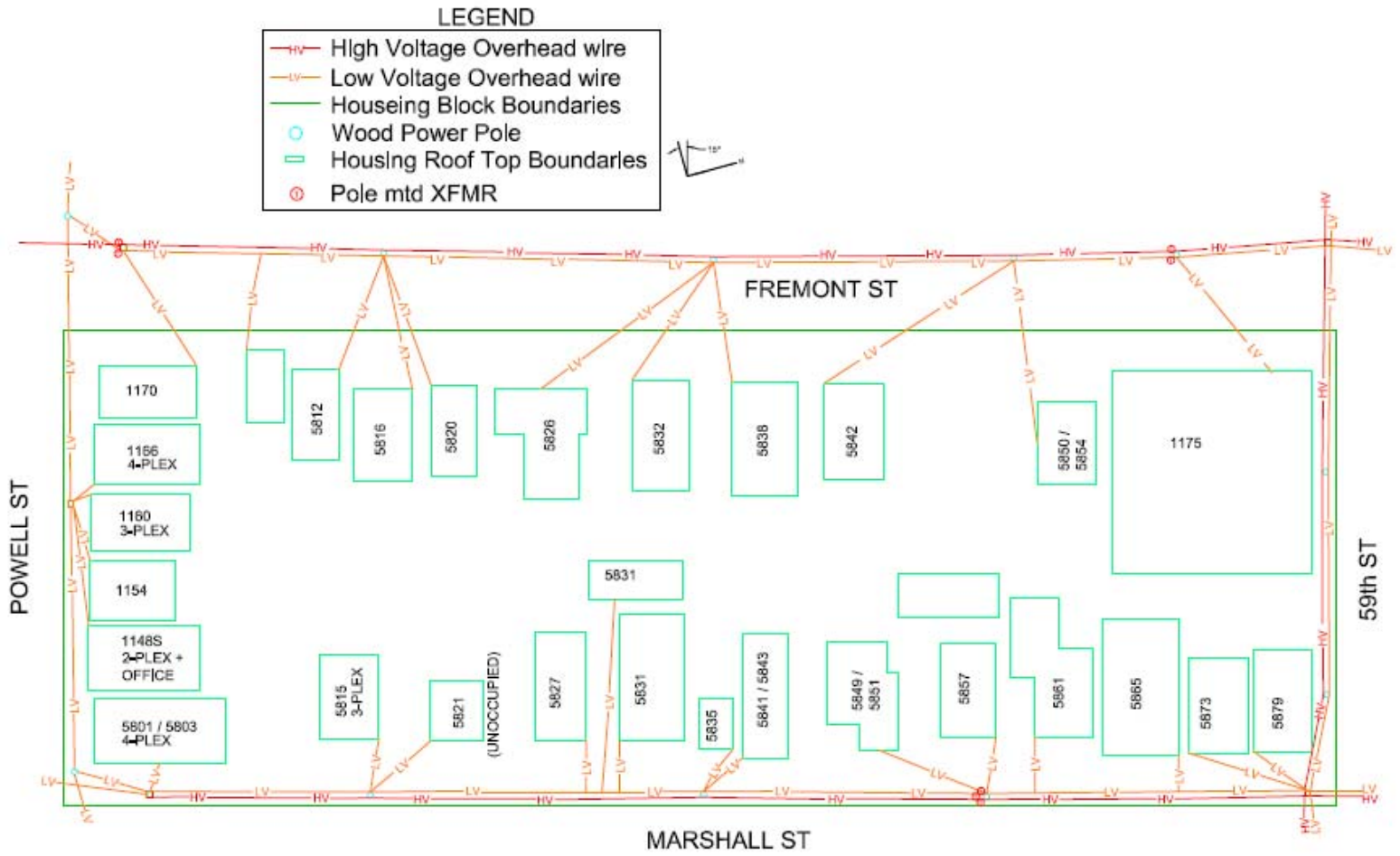


The Result:

The Oakland EcoBlock set out to test how we can adapt existing urban environments to meet the long term (2050) climate and sustainability goals set by the State. It appears to be technologically and legally permissible, but requires changes to local codes, expansion of finance tools, and cooperative arrangements at the neighborhood level to accomplish.

ENERGY SYSTEMS									
Component Description	Option 0:		Option 1:		Option 2:		Option 3:		
Renewable Energy:	VIRTUAL		RELIABLE DC (+AC w/ARDA)		RELIABLE AC + DC		RELIABLE AC		
	Core	*Optional*	*Core*	*Optional*	*Core*	*Optional*	*Core*	*Optional*	
Renewable Energy:									
Solar Pane	X		X		X		X		Homeowner
Inverters/Bidirectional Mete	X		X		X		X		Homeowner
Mounting hardware	X		X		X		X		Homeowner
Electrical Distribution	X		X		X		X		Homeowner
Reroofing	X		X		X		X		Homeowner
Miscellaneous	X		X		X		X		Homeowner
Energy Efficiency:									
Insulation	X		X		X		X		Homeowner
New windows	X		X		X		X		Homeowner
Air sealing	X		X		X		X		Homeowner
LED lighting for individual homes	X		X		X		X		Homeowner
LED lighting for exterior and street lighting	X		X		X		X		Homeowner
Lighting controls		X		X		X		X	Homeowner
Exhaust Fans with ECM motors	X		X		X		X		Homeowner
Natural Ventilation + HRV	X		X		X		X		Homeowner
High Efficient HVAC systems	X		X		X		X		Homeowner
Energy Star rated home appliances	X		X		X		X		Homeowner
Induction electrical ranges		X		X		X		X	Homeowner
Electric Vehicle Charging Stations:									
Individual homes		X		X		X		X	Homeowner
Common areas	X		X		X		X		EcoBlock
Microgrid - AC Loop:									
Joint Trenching				X		X		X	EcoBlock
Underground electrical loop				X		X		X	EcoBlock
Point of common coupling connection electric gear				X		X		X	EcoBlock
Automated controls (grid controls and load management)				X		X		X	EcoBlock
Flywheel				X		X		X	EcoBlock
Electrical distribution cable and switching gear				X		X		X	EcoBlock
Individual home electrical switching gear				X		X		X	EcoBlock
submitters				X		X		X	EcoBlock
Transformers				X		X		X	EcoBlock
Replace and extend existing poles			X		X		X		EcoBlock
Microgrid - DC Loop:									
Joint Trenching				X		X		X	EcoBlock
Underground electrical loop				X		X		X	EcoBlock
Electrical common point of connection switching gear				X		X		X	EcoBlock
Automated controls (grid controls and load management)				X		X		X	EcoBlock
Flywheel				X		X		X	EcoBlock
Electrical distribution cable and switching gear				X		X		X	EcoBlock
Individual home electrical switching gear				X		X		X	EcoBlock
Submitters				X		X		X	EcoBlock
Transformers			X		X		X		EcoBlock
Replace and extend existing poles			X		X		X		EcoBlock

Single Line Diagrams – Existing Electric Layout



Single Line Diagrams – Microgrid – Reliable AC & DC