UCDAVIS Energy and Efficiency Institute

Pathways to Zero-Net Energy

A Road Map to Low-carbon Residence in Davis

June 2020

UCDAVIS Program for International Energy Technologies

D-Lab

COOL DAVIS

UCDAVIS Facilities Management

ECO energy conservation office

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Introduction

A zero net energy (ZNE) house tries to produce enough renewable energy to meet its own annual energy consumption requirements and thus tries to reduce the use of non-renewable energy and make the building environmentally friendly. ZNE houses use all the necessary, cost-effective measures that can be implemented to reduce the energy usage of the house through energy efficiency (Wiberge et al., 2014). It aims to achieve this by introducing renewable energy systems in the house that produce enough energy to meet the house's remaining energy requirements. Another way to convert the existing home into a ZNE home is by adopting behavioral changes that can lead to energy savings in the house. These changes can be in the form of changes in the settings of the different systems present in the house to change/replace the appliances with new energy-efficient ones.

There are several long-term advantages of moving toward ZNE homes, including a reduction in the environmental impacts due to a building's decline in operation and maintenance costs. Other benefits include better resiliency to power outages and improved energy security (Allouhi et al., 2015). In the case of new home construction, reduction in the can be accomplished through means like the integrated design of the house to use the maximum natural environment as possible, use of energy efficiency retrofits, use of reduced plug loads, and adapting to various energy conservation programs.

The “Project"

A roadmap to low carbon residence is an initiative for a sustainable living solution, initiated by Cool Davis. Cool Davis is a non-profit organization. As a community organization, it does care for carbon neutrality and execute projects to meet its objective for cooling down the city of Davis and measure the climate change impacts.

This project is developed as part of the Cool Davis’s “Low-Carbon Residence Roadmap” that aims to educate interested residents and connect these residents with others that already have a ZNE or low-emissions home.

Problem Statement

At first, there is a need to define What do we consider as a ZNE building in this study due to client need?

"Zero Net Energy Building: An energy-efficient building where, on a source energy basis, the actual annual consumed energy is less than or equal to the on-site renewable generated energy."

Many homeowners in Davis, California, are interested in reducing their natural gas consumption and carbon emissions from their residence. As a result, they are interested in taking steps to become either carbon neutral or to electrify their homes. However, many eager homeowners have experienced challenges moving a project forward or have been deterred by uncertainty surrounding the electrification process. These challenges often are associated with permitting, prioritizing work, selecting equipment, or understanding the potential financial risks and benefits.

Project Questions

Project objectives can be formulated as soon as the project has a particular question to ask. The project questions below are outlined based on interactive meeting sessions with the client and project description. Basically, Cool Davis is seeking to find an answer to the following questions:

- What policy frameworks support Cool Davis for zero-net energy pathways projects?
- What technology or practices help with transforming a house to the ZNE house?
- Who are the audiences for zero net energy homes?
- What are the barriers or constraints that cause limitations for ZNE residential development?

Project Objectives

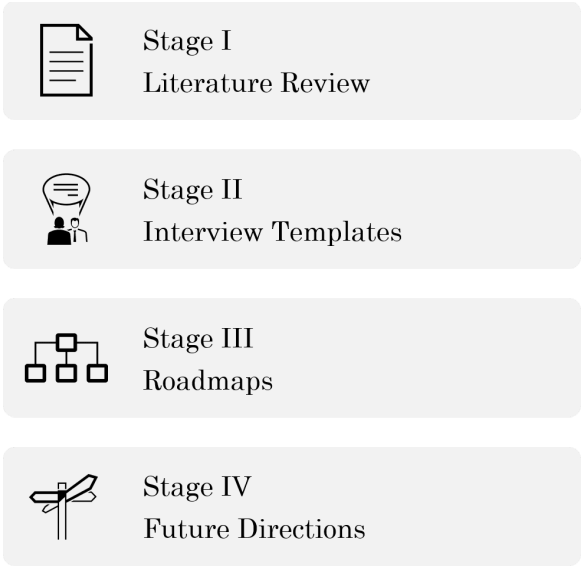
The primary goal of the project is to design an **efficient, convenient, and cost-effective** tool for supporting households through ZNE transformation. The following objectives are identified throughout the project carry out based on observations and experiments:

- Conduct a method to design a practical tool for homeowners
- Outline the strategies to connect and shape network communities for ZNE implementation

Project Staging

In the first stage, the team studied articles, guides, the client's pre-existing material for the project along with Davis plans to familiarize with Zero Net Energy homes. The purpose of this literature review stage was to find potential content to generate the roadmaps and to obtain an understanding of the special status of the City of Davis. Secondly, in the interview stage, a paper on how to conduct compelling interviews was used in conjunction with the client's pre-existing home energy audit questionnaire to design a final interview template for Davis homeowners that would provide valuable insight on the design of the roadmap. The next step, Using the knowledge obtained from the previous stages in conjunction with the client's pre-existing home energy checklist, the design of the roadmap to ZNE started. Finally, the team evaluated the progress and achievements towards the project to determine the next steps to be worked on to reach the ultimate goal of the client: an online version tool of the roadmap to ZNE.

Fig1, Project staging for roadmap residence



ZNE Context & Background

Energy, and environmental economics Inc. in a joint cities study report, for building electrification in California, states that the share of Greenhouse gas emissions from buildings is around 25% of total emissions in California. It is also projected that to meet the goal of California carbon neutrality in 2045, emissions from buildings need to be cut by 40% over the next ten years. (E3 Inc.,2019).

Relevant Literature

The Zero Energy Building (ZEB) concept is no longer considered as a concept of a future. It is a realistic solution for the mitigation of CO2 emissions and the reduction of energy use in the residential building sector. A study by Marszal et al. 2015 focused on reviewing most of the ZEB related definitions and the various approaches towards possible ZEB calculation methodologies by doing a literature review. The study gave us an overview of the existing ZEB similar definitions with highlighting the most important aspects that should be included before developing new ZEB definitions which include metric of the balance, the balancing period, the type of energy use included in the balance, the kind of energy balance, the accepted renewable energy supply options, the connection to the energy infrastructure and the requirements for the energy efficiency, the indoor climate and in case of grid-connected ZEB for the building–grid interaction. The study also discussed various approaches to possible ZEB calculation methodologies.

Similarly, a study by Nejat et al., 2015 helped us review the status and current trends of energy consumption, CO2 emissions, and energy policies in the residential sector – both globally and in different countries. Since residential buildings account for approximately 40% of global energy consumption and are responsible for one-third of the worldwide energy CO2 emissions, it was necessary to understand the relation between energy consumption and CO2 emissions.

A paper about the design, construction, and characteristics of a ZNE home for Davis, California, was found and used as a critical reference after research. This paper, titled Energy efficiency measures in affordable zero net energy housing (Alemi et al., 2017), conducted by UC Davis students.

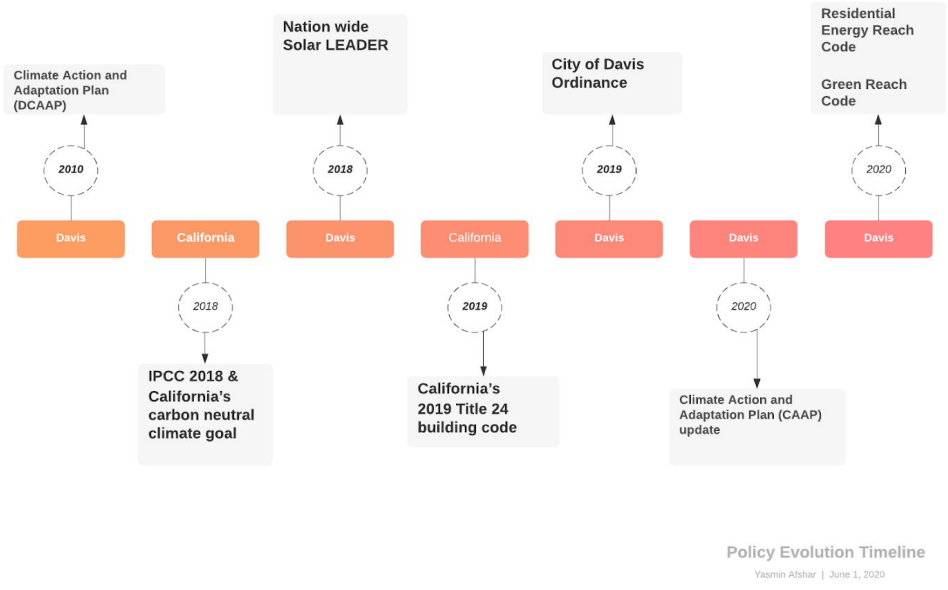
The next valuable literature used was obtained from the U.S. Department of Energy, the resource is titled A Guide to Energy Audits (Baechler et al., 2011), and in conjunction with the energy audit excel class by the course professor Joshua Morejohn, provided an understanding of the critical energy loss sources and areas of energetic improvement of a home.

Finally, since the original project description involved communication with Davis residents to investigate their situation regarding ZNE homes and their current experiences, a study on how to design an interview was agreed to be necessary by the team. As a result, the paper titled Strategies for Qualitative Interviews (Unknown Author, 2017) by the Depart of Sociology of Harvard University used in the design of the interview templates.

Local Climate Action Plan and Policies[1] (LCAP)

With specific policies in place, the City of Davis has the advantage of promoting energy efficiency measures for the built environment through various programs. There are several local action plans and policies (LCAP) that help a city to achieve goals smarter and quicker. Figure 2 represents an overview of the City of Davis's sustainability and energy policy evolution with highlights from California's state in the past two years. Each box shows the related LCAP as current measures in place.

Fig2- Policy Evolution timeline of City of Davis complying the State of California



[1] This would annotate as LCAP in the description. To follow the project scope, LCAP assessment would be kept for the residential zne buildings.

Fig3- Major California green policies for carbon neutrality statewide

Figure 4

Major Policies to Meet Statewide Greenhouse Gas Limits

- ✓ ***Cap-and-Trade.*** Regulation that establishes a "cap" on overall emissions from large emitters by issuing a limited number of permits (also known as allowances). Allowances can be bought and sold (traded), which creates a market price for allowances and an incentive for lowest cost reductions.
- ✓ ***Short-Lived Climate Pollutants.*** Regulations and incentives intended to reduce certain types of emissions from dairies, landfills, and refrigeration equipment.
- ✓ ***Renewable Portfolio Standard.*** Regulations that require utilities to provide a certain percentage of electricity from qualifying renewable sources, such as wind and solar.
- ✓ ***Energy Efficiency.*** Regulations and financial incentives to encourage more efficient energy use in commercial buildings, homes, and manufacturing facilities.
- ✓ ***Low Carbon Fuel Standard.*** Regulation that requires transportation fuel suppliers to reduce the amount of greenhouse gases per unit of fuel used in California—also known as carbon intensity of fuels.
- ✓ ***Vehicle-Related Programs.*** Regulations and incentives to encourage more efficient light- and heavy-duty vehicles, as well as promote certain types of technologies such as electric vehicles.
- ✓ ***Vehicle Miles Traveled.*** Planning strategies and financial incentives intended to reduce the amount of light-duty vehicle use through such things as increased transit and changes to land use.

City Profile

Located in Yolo county, California, the City of Davis lies within a distance of 15 miles from Sacramento, the capital city of the Republic of California. The city boundary covers the total area of 9.92 square miles and houses almost 69413 people as of July 2019. Davis is a primary home of the University of California with half of its population, and most city residents are educated and have higher education degrees (Census Bureau, 2018). Figure 4 represents Davis regional location.

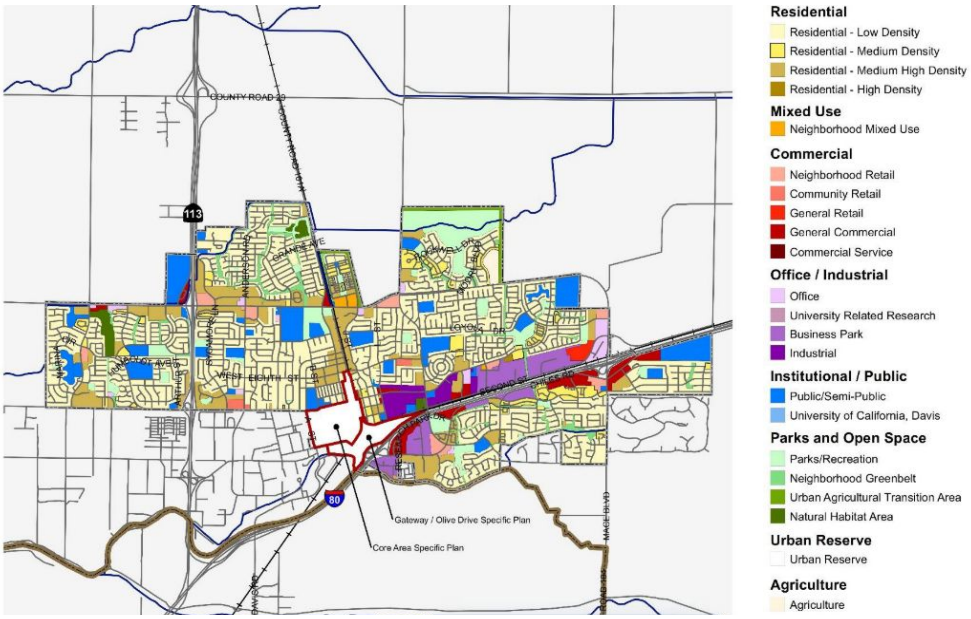
Sources: City of Davis, 2017

The City of Davis has arid and warm summer months, and cool to freezing winter months with variable rainfalls during spring and fall. The City is located in the center of Sacramento Valley. Therefore, it is ranked among poor air quality regions that suffer from inversion events in winter months because of local topography, EPA reports.

The City of Davis is a pioneer for the incorporation of sustainability initiatives and the use of technology

to achieve existing CAPP's climate goals in 2020. The City aims to implement reducing greenhouse gas emissions, increasing energy efficiency (Retrofitting and PV installation), utilizing sustainable transportation with EVs, and waste-free consumption strategies. The City monitors the progress toward municipal policies and objectives with engaging communities through community organizations (City of Davis, 2019). The state of City in 2017, reports that land use designation in the existing Davis general plan shows that 62.5 percent of land uses are residential in which the share of low-density residence is 48 percent (Fig 5).

Fig 5: City of Davis major land uses from General Plan, 2017

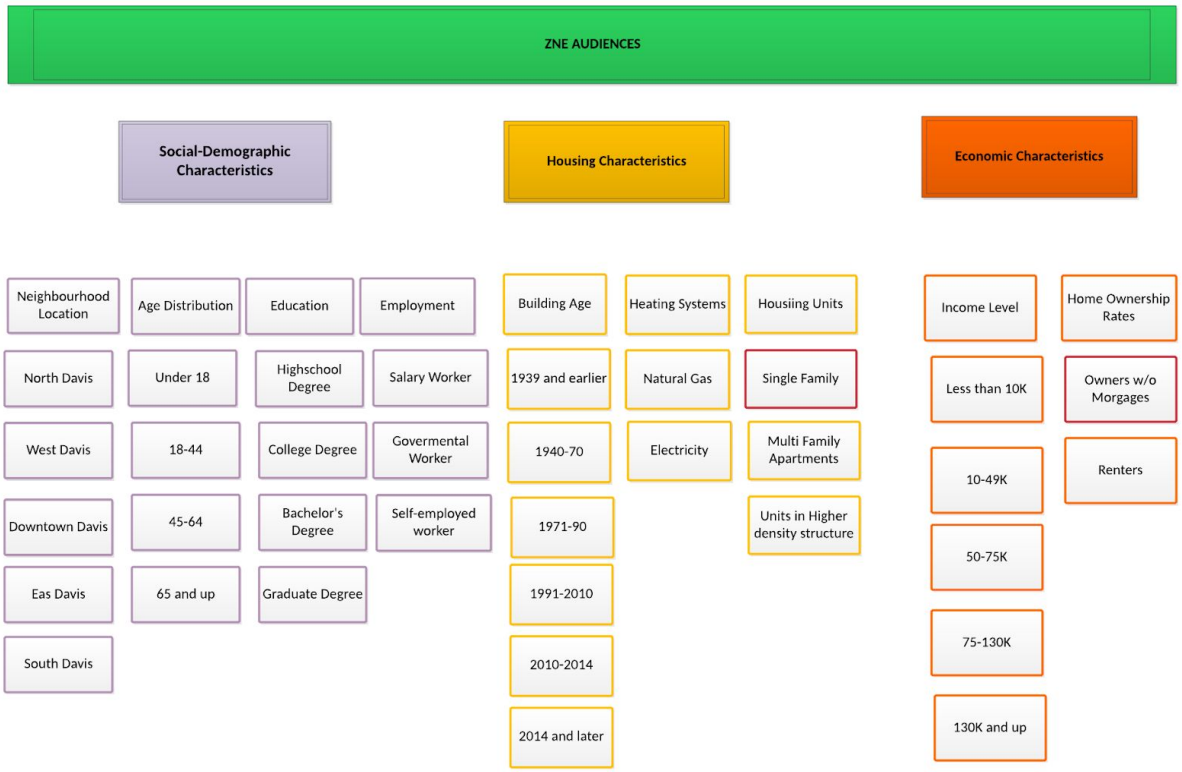


Audience Analysis

The audience scope for this research project would be the residents of the city of Davis who live in low-density housing in residential areas in particular. This includes single-family homes and low rise multi-family homes. The analysis of the population dynamic can be viewed from social characteristics such as education, profession, and income or demographics, including race, age, and housing units. Per the University of California's most recent survey, the total number of students is 39629 as of the academic year of 2019-20 (student profile report,2020). This is why it is necessary to identify the residential groups that may need to implement the building energy conservation and efficiency measures in their communities for decarbonization.

The strength of audience analysis is that it will give the flexibility to adjust various focus groups or critical stakeholders depending on project objectives. Three significant areas that potential audiences can be identified are analyzed below. Focus groups can be defined by their social and demographic characteristics such as educational degrees, employment status, or age distributions. Audiences also can get viewed from a housing characteristics standpoint. This means that focus groups are identifiable based on their home characteristics like indoor heating systems, the year that a house was built, or the residence type (Property owner, Student housing, or rental). Last but not least, income levels and ownership rates would help identify focus groups under economic characteristics (Fig 6).

Fig 6: Audience Analysis and potential focus groups for ZNE implementation in City of Davis[2]



[2] Categories, and Data adapted from U.S Census and American Community Survey (ACS) for City of Davis

Methodology

Roadmap design is a bottom-up approach that starts from a single housing unit spreading gradually to community, city, county up to another larger geographical scale. It is also human-based research that requires time-sensitive and large behavioral datasets for tracking the change over time. Therefore, observational data such as Survey research, sampling, interviewing, and other evolving methods are among the tools that allow insights from data patterns that could shape the practices and research directions over time. The roadmap design in this project is survey research in nature. It is based on random sampling, and semi-structured interviews to capture data on the ground.

Data Collection

Various data sources can implement before and during the project execution for multiple reasons. On the first hand, the roadmap design would need a geographical database for baseline analysis. Also, the building profiles are another valuable data source for understanding the current dynamic of ZNE in the City of Davis.

American community surveys (ACS) would also give a yearly interpretation of socioeconomic, financial, and housing data in each community, making monitoring changes easier.

Interview Templates

The purpose of generating interview templates for non-ZNE and ZNE homeowners in Davis is to provide the team and the client valuable information which would feedback into the design of the roadmap to ZNE. In this stage, the strategies detailed in the paper Strategies for Qualitative Interviews by the Department of Sociology of Harvard University implemented so the interviewee could be indirectly encouraged to speak about the details of the home in regards to ZNE plus the perceived challenges of non-ZNE homeowners and the expertise of ZNE homeowners. Additionally, input by the client led the team to include home characterization-type questions to gain insight on the status of non-ZNE and ZNE homes, and to serve as a pre-audit of the energy consumption of their homes. The resulting interview templates can be found in Annex 5 and 6 of this paper. Both types of interview templates have questions related to house characterization, house appliances, HVAC systems, and lighting in common areas.

Road Map Design

The structure of the roadmap must be able to address the basic home implementations the user is suggested to adopt, keeping the prioritization of energy reduction first, then energy efficiency and energy generation last. The roadmap must cover all the different answers that might arise from each question and point the user in the right direction. As a result, and taking a previously created energy home energy checklist provided by Cool Davis as a reference, the roadmap's framework was divided into four main categories:

1. Habitual Changes
2. Changes in Settings
3. Product replacement and upgrades
4. Systems Upgrades

For each question, the roadmap's structure was designed to redirect the user until the provided answers lead to a satisfactory energy implementation suggestion, or for the contrary case, when the solutions could not meet the proposal, the roadmap would redirect the user to the next category level (e.g., when the change in habits do not work for the user, the roadmap redirects to change in settings suggestions).

Prospective Research

Representative sample of Davis homeowners

The first step for the future of this project is to define and identify a representative sample of non-ZNE and ZNE homeowners in Davis to first use the interview templates on them, and next to put a full pilot version of the roadmap to the test with them as well.

Conduct interviews

The second step, as mentioned above, is to conduct the interviews to non-ZNE and ZNE homeowners in Davis to gain insight on real data regarding home characteristics, concerns and perceived challenges by non-ZNE homeowners, and the expertise and advice successful ZNE

homeowners can share along with their success story. Since this step involves the team to gather research information of human subjects, It is important to point out that it requires compliance with the Institutional Review Board (IRB) Administration of UC Davis. To this moment, the team has found that the survey-like structure of the interview templates may exempt the project for IRB review. However, even if this is the case, the team would still be required to file an IRB review exemption application.

Roadmap Calibration and validation

In this step, the valuable insights and success stories gathered in the step above will serve as feedback to make any necessary adjustments to the current design of the ZNE roadmaps. Some of the potential inputs include adding, removing or adjusting the thermal comfort suggestions in the Change in Habits category, the appliances that have the potential of operating at lower energy consumption in the Change of Settings category, the devices to the Change the in Products category, and the suggested technician hiring and external resources of the Change in Systems category.

After applying the necessary changes, the ZNE roadmap should be put to the test to the same non-ZNE homeowners determined in the representative sample of Davis, who was interviewed. This exercise will serve as a secondary stage of feedback to the roadmap's enhancement, so an active detection of improvement opportunities should be done by the next team working on this project.

Digitization of roadmaps to a web based platform

Finally, the team's criteria suggest that after the first three steps are completed, it is time to start the conversion of the roadmap towards an online tool. This step requires a team member with web page development skills, and detailed coordination with the client since modification to their website will be involved.

Conclusion

To wrap up, the ultimate goal of our Client, Cool Davis, to create an online tool serving as a roadmap to ZNE for interested non-ZNE homeowners in Davis is achievable, and the work done

by this project has provided initial activities to do so. The team considers that a continuous-improvement approach (feedback input to the roadmap), as detailed in the future direction steps above, will prove successful for the development and completion of the project. Regarding the far future of the project, the team also suggests considering a broader scope of the audience of the roadmap. Currently, it focuses on single-family households, but the City of Davis has a high population of students living in shared spaces. As a result, generating additional roadmaps but for student-housing buildings may have a significant impact on the Davis community and its progress towards Zero Net Energy, electrification, and greenhouse gas reduction.

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Annex 1: Cool Davis Project Description & Home Checklist

Low-Carbon Residence Roadmap – Davis Resident ZNE Network

Many homeowners in Davis, CA are interested in reducing the carbon emissions associated with their home. As a result, they are interested in taking steps to become either carbon neutral or to electrify their homes. However, many eager homeowners have experienced challenges moving a project forward or have been deterred by uncertainty surrounding the electrification process. These challenges often are associated with permitting, prioritizing work, selecting equipment, or understanding the potential financial risks and benefits. Students in this year's Pathways to Zero Net Energy course will work to help Cool Davis break down some of these barriers.

This project will develop part of the Cool Davis "Low-Carbon Residence Roadmap" that aims to educate interested residents and connect these residents with others that already have a ZNE or low-emissions home.

As part of this project students will do the following:

1. Meet with the client to further define the scope and deliverables that are expected from this project.
2. Research and identify other community networks focused on residential low carbon solutions
3. Interview three Davis Residents that are motivated to electrify or own a ZNE home
4. Document their challenges and concerns
5. Interview three Davis Residents that have already achieved a ZNE home.

ing, design, and construction
talled that crucial to the ZNE goal.
allows Davis residents to share
he website may also include
s, and available local incentives.
hat the student consultants have

recommendations

COOL HOME CHECKLISTS

TRANSPORTATION CHECKLIST

Cool solutions for sustainable living

DONE	Change Commute	TO DO
	Telecommute___days/wk	
	Carpool___days/wk	
	Ride bus/train___miles/wk	
	Ride bike___miles/wk	
	Teleconference___/year	
	Reduce air travel by___%	
DONE	**Change Mode in Town**	**TO DO**
	Walk to restaurants	
	Bike/skate for errands	
	Ride bus to Sac or campus	
DONE	**Change Habits**	**TO DO**
	Accelerate and brake slowly	
	Maintain vehicles regularly	
	Reduce speed by 15mph	
	Consolidate trips	
	Take "staycations"	
	Bike with friends & family	
DONE	**Change Vehicle**	**TO DO**
	Drive more efficient vehicle	
	Drive an electric vehicle	
	Drive a hybrid vehicle	
	Drive a micro vehicle	
	Reduce # of cars owned	
DONE	**Share**	**TO DO**
	Share rides or carpool	
	Carshare with a friend	
	Use ride services	
	Rent instead of owning	

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CONSUMPTION CHECKLIST

Cool solutions for sustainable living

DONE	Water	TO DO
	Install low flow fixtures, aerators	
	Take shorter showers	
	Filter water instead of bottled	
	Install smart/drip irrigation	
	Replace turf w/drought tolerant	
	Catch greywater or rainwater	
DONE	**Food**	**TO DO**
	Eat plant-based meal ___days/wk	
	Eat a vegetarian or vegan diet	
	Eat whole foods not processed	
	Raise chickens	
	Buy fruits/veggies in season	
	Buy organic	
DONE	**Waste**	**TO DO**
	BYO bottle, dish, bag, jar	
	Compost/vermiculture	
	Recycle glass, plastic, metal	
	Repair, repurpose, or donate	
	Use rechargeable batteries	
	Buy in bulk/avoid packaging	
	Use cloth bags instead of paper	
DONE	**Shopping**	**TO DO**
	Invest in higher quality stuff	
	Buy local & at farmers markets	
	Research with web, phone	
	Buy recycled products	
	Reduce unnecessary shopping	
DONE	**Share or Rent**	**TO DO**
	Share tools, equipment w/others	
	Trade services or expertise	

Visit our Plant-Based Eating page
cooldavis.org/eat-plants

HOME ENERGY SYSTEMS CHECKLIST

Cool solutions for sustainable living

DONE	Change Systems	TO DO
	Install photovoltaic panels (rooftop solar)	
	Get HVAC tune up	
	Replace HVAC filters 3-4x/year	
	Get a home energy audit	
	Install/program smart thermostat	
	Install weather stripping	
	Seal leaky windows and doors	
	Upgrade to dual pane HE windows	
	Install a whole house fan	
	Install ceiling and attic fans	
	Install swamp or window fan units	
	Seal attic penetrations	
	Insulate and seal HVAC ducts	
	Insulate attic space to R39	
	Insulate walls	
	Install solar thermal water heater	
	Install efficient HVAC system	
	Install heat exchange radiant panel	
	Remove, disable, or seal off wood-burning fireplaces	
	Plant/build south & west side trees, shades, awnings, soffits	

Visit our Home Heating & Cooling page
cooldavis.org/home-heat-cool

HOME ENERGY CHECKLIST

Cool solutions for sustainable living

DONE	Change Habits	TO DO
	Keep windows and doors closed when AC or heat on	
	Open windows on cool summer nights, let in winter sunshine	
	Dry laundry on racks or lines	
	Turn off lights not in use	
	Close chimney flue seasonally	
DONE	**Change Settings**	**TO DO**
	Lower hot water heater temp	
	Lower thermostat in winter (68°F or lower)	
	Raise thermostat in summer (78°F or higher)	
DONE	**Change Products**	**TO DO**
	Buy Energy Star appliances and electronics	
	Use smart strips with timers for lights and electronics	
	Use light dimmers	
	Buy solar powered devices	
	Down size refrigerators/freezers	
	Use a solar cooker or microwave	
	Install LED bulbs (low Kelvin)	
	Install motion detector lights	
	Install skylights/solartubes	

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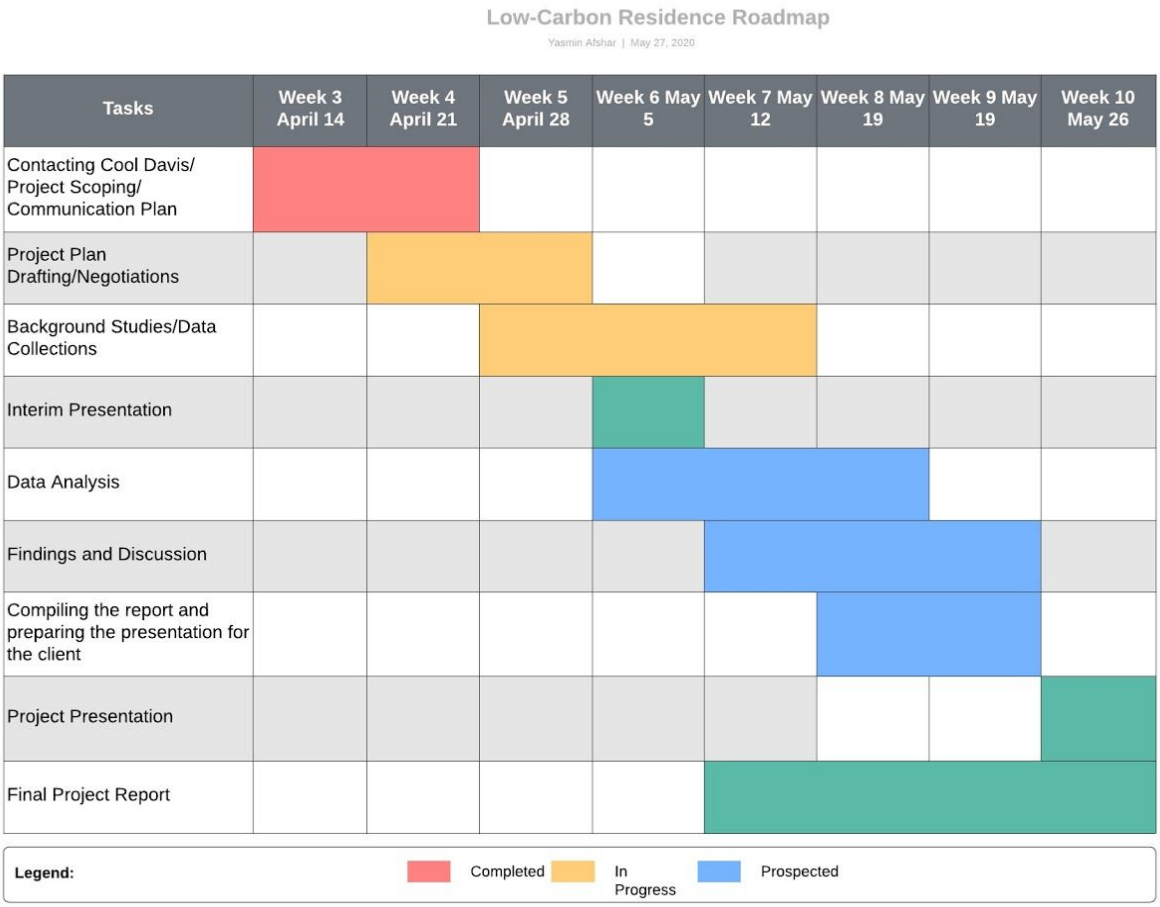
Annex 2: Project Timeline



Project Brief:
Davis Resident Zero net Energy Network

Project Lead Kurt Kornbluth
Project Deliverable Various
Project Scope Davis Single Family Housing
Start Date 14-Apr
End Date 9-Jun

Annex 3: Project & Data Communications

Name	email	Role	Organization
Christine L. Granger	cgranger@cooldavis.org	Executive Director	Cool Davis
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TJ Crowder	tcrowder@cityofdavis.org	GIS System Analyst	City of Davis
Ryan Lockwood	ryan.lockwood@landmarkproperties.com	Resident Manager	West Village
Forest Gouge	Forest.Gouge@solatwestvillage.com	Maintenance Manager	West Village

Annex 4: Building Staff Interview Survey

(Sol at West Village)

Resident Services Manager:

1. What is the square footage of the building?
2. What is the year of construction?
3. Which utilities are metered and where they are located?
4. Where is the location of any mechanical rooms?
5. Is the interior space of the building a comfortable temperature for the occupants? As a building manager, do you receive complaints or feedback related to the room temperatures?
6. What is the shape and height size of the building?

Maintenance Manager:

1. What is the typical building's occupancy schedule? Are there exceptions to the schedule? Do people work late nights? Do people show up on weekends?
2. What is the custodial schedule?
3. Is there any HVAC (Heating, Ventilation, and Air Conditioning control system) equipment on site?
   If yes:
   - how often HVAC units run and if they run 24/7?
   - Are there HVAC zones in the building?
4. How are the HVAC system and lighting maintained? How often is maintenance done? When was maintenance done most recently?
5. How old are the systems in the building? Is there any equipment not running?
6. Have there been any recent retrofits, expansions, changes in the space use, and/or previous energy audits in the building?

Annex 5: ZNE homeowners Interview Questionnaire

1. Tell us a little bit about your home (home characterization)
   Basic information:

   a. Type of home (apartment/house/other):
   - [answer]

   b. No. of rooms in your house:
   - [answer]

   c. Yard/Backyard:
   - [answer]

   d. Basement:
   - [answer]

   e. Garage:
   - [answer]

   f. Construction material:
   - [answer]

   g. Year of construction:
   - [answer]

   Appliances information: (Company/how often do you use it/years of use)

   a. Refrigerator
   - [answer]

   b. Range (Oven and Stove)
   - [answer]

   c. Microwave
   - [answer]

   d. Dishwasher
   - [answer]

   e. Smaller kitchen appliances: Grinder/Blender
   - [answer]

   f. Washing machine
   - [answer]

   g. Drying machine
   - [answer]

   h. Television set
   - [answer]

   i. Computers
   - [answer]

Specific information:

a. Starting point for what heating, cooling, and water heating systems they had:
- [answer]
b. Final heating, cooling, and water heating systems they installed:
- [answer]
c. Energy efficiency measures installed: (e.g. insulation, improved windows, or other envelope measures)
- [answer]
d. Passive measures installed: (e.g. seasonal sunlight design, use of vegetation as thermal mass, et cetera)
- [answer]
e. Lighting installed and their characteristics:
- [answer]
f. Generation of the photovoltaic system: (if applicable)
- [answer]
g. Battery backup characteristics: (if applicable)
- [answer]

2. Do you feel comfortable in your home during summer and winter? Is there any moment of the year or place in your home that is particularly uncomfortable temperature-wise?
[answer]

3. How did you become interested in Zero Net Energy Homes? What motivated you particularly to have a ZNE house (identify the motivation)
[answer]

4. How did you start converting your home into Zero Net Energy? What were the initial steps that you took to move forward with the plan of becoming a ZNE house owner? (identify the first actions taken)
[answer]

5. What are the first challenges you faced when you started converting your home to Zero Net Energy?
[answer]

6. How did you find answers to the challenges and questions that came up? (identify resources)
[answer]

7. Non financially speaking, what were the elements that helped you to select the technology that you are using today in your house? (E.g. product description comparisons)

[answer]

8. How did you estimate the financial aspects of your decisions? (identify the support of informed decision)
   [answer]

Examples: Cost of Technology; Savings; Return on Investment; Operation and Maintenance Costs; Life Cycle Costs; et cetera.

9. How different is your home now, with all the Zero Net Energy implementations verses before (or previous non-ZNE home)? Are you more comfortable?
   [answer]

10. What are your energy and emissions savings? How did you estimate them?
    [answer]

11. If you could go back in time, how different would you have started? (identify potential rookie mistakes and missed opportunities)
    [answer]

12. How did your daily routines, behaviors, and conservation practices change for you to achieve ZNE?
    [answer]

13. What advice would you give someone who is just starting to make their home ZNE? Especially from the perspective that they will do this in steps over time.
    [answer]

Annex 6: non-ZNE homeowners Interview Questionnaire

1. Tell us a little bit about your home
    a. Type of home (apartment/house/other):
    - [answer]
    b. No. of rooms in your house:
    - [answer]
    c. Yard/Backyard:
    - [answer]
    d. Basement:
    - [answer]
    e. Garage:
    - [answer]
    f. Construction material:
    - [answer]
    g. Year of construction:
    - [answer]

2. What type of cooling system do you have in your house? (centralized v/s split air conditioning) What type of water heater do you have? (electric or gas) (Company/usage/years of use)

[answer]

3. Do you feel comfortable in your home during summer and winter? Is there any moment of the year or place in your home that is particularly uncomfortable temperature-wise?

[answer]

4. Do you have any passive cooling system installed in your house? (fans/coolers) If yes, how many do you have in your house? How often do you use them?

    [answer]

5. What types of appliances do you have in your home? (use list as a reference) (Company/how often do you use it/years of use)
    a. Refrigerator
    - [answer]
    b. Range (Oven and Stove)
    - [answer]
    c. Microwave
    - [answer]
    d. Dish washer
    - [answer]

e. Smaller kitchen appliances: Grinder/Blender
- [answer]
f. Washing machine
- [answer]
g. Drying machine
- [answer]
h. Television set
- [answer]
i. Computers
- [answer]

6. What type of lightbulbs do you use in your house (standard / halogens / CFL)? How many lightbulbs do you have (by room)? How does your lighting consumption on a regular day look like?

[answer]

7. How did you become interested in Zero Net Energy Homes? (identify motivation)

[answer]

8. Have you taken any steps to start converting your home into Zero Net Energy? If yes, what steps have you taken and how did you try to implement them? (identify what made them choose to do that)

[answer]

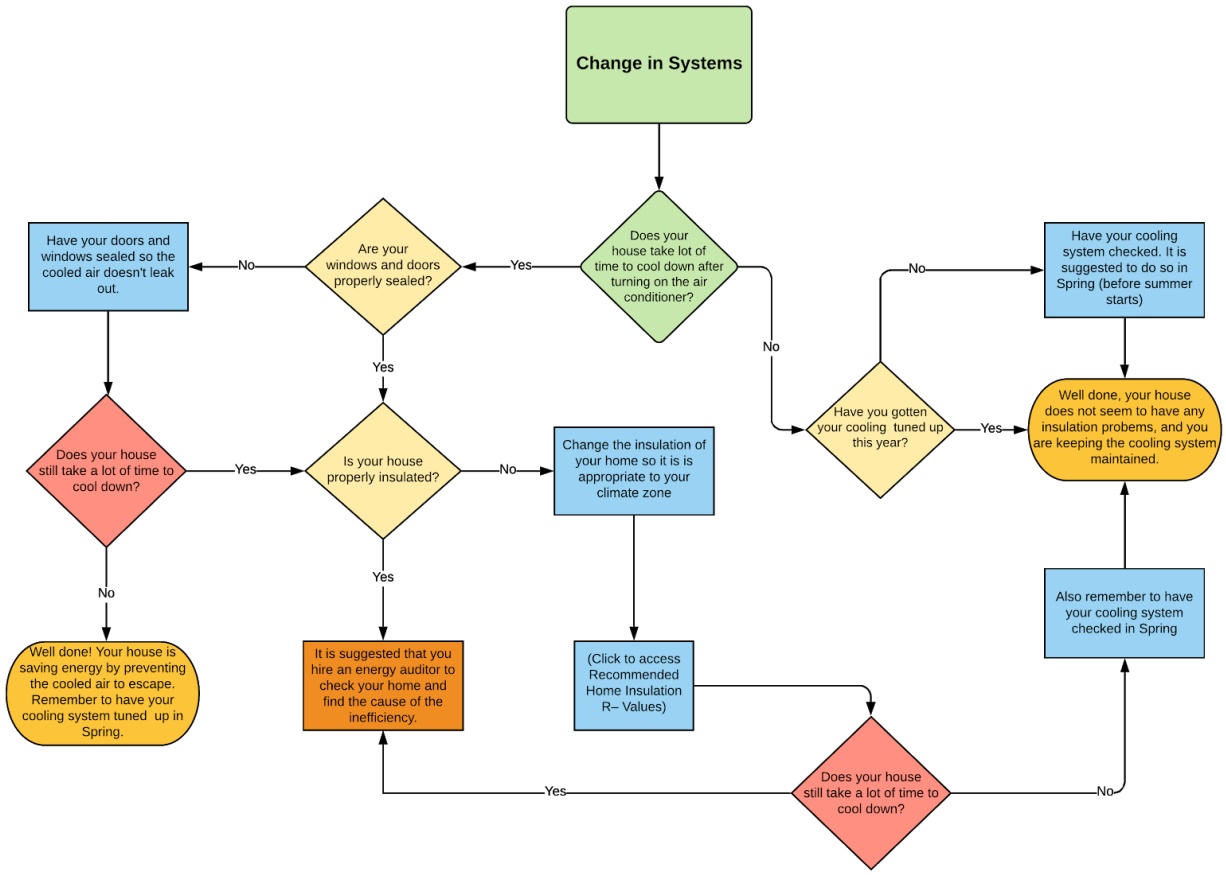
9. What would you say are the toughest challenges to convert your home to Zero Net Energy? (identify what the person perceives the most challenging)

[answer]

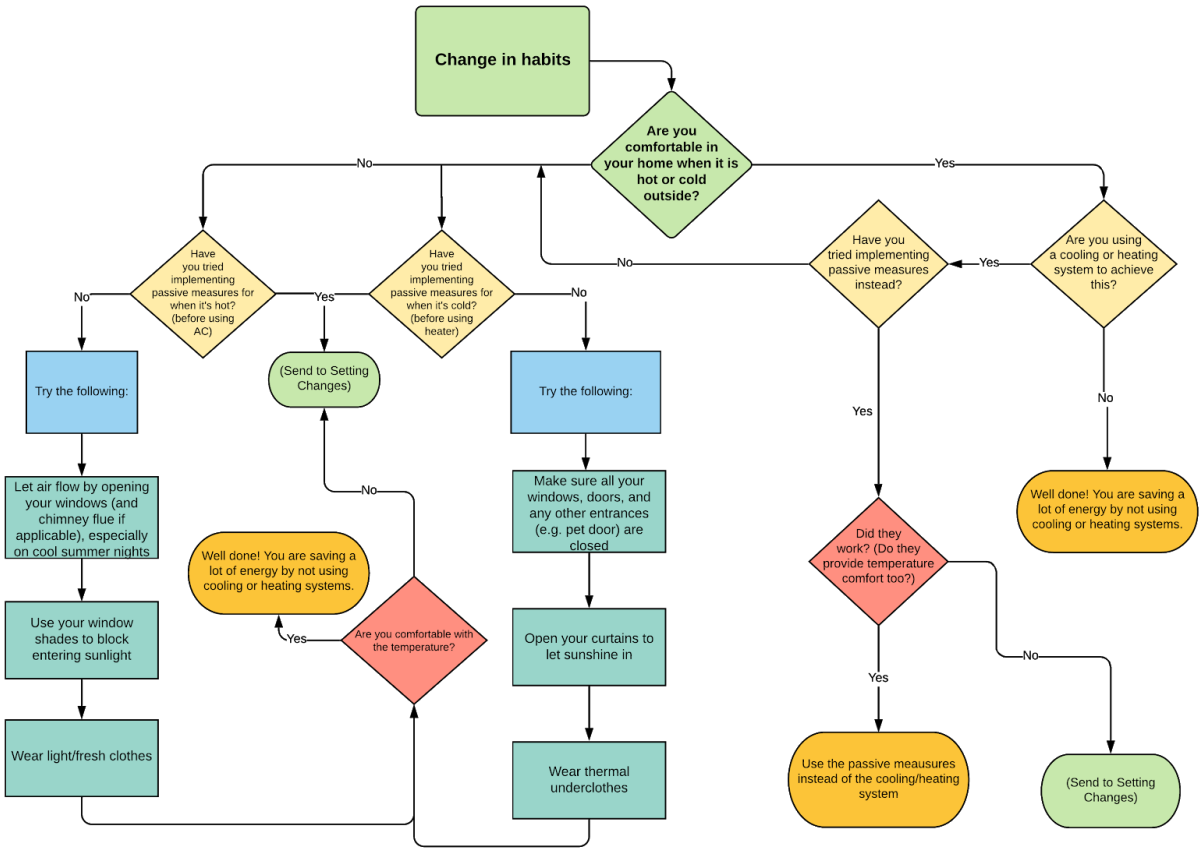
10. Have you searched for guidelines by yourself to become ZNE? If yes, how did these guidelines help you? (identify resources that helped)

[answer]

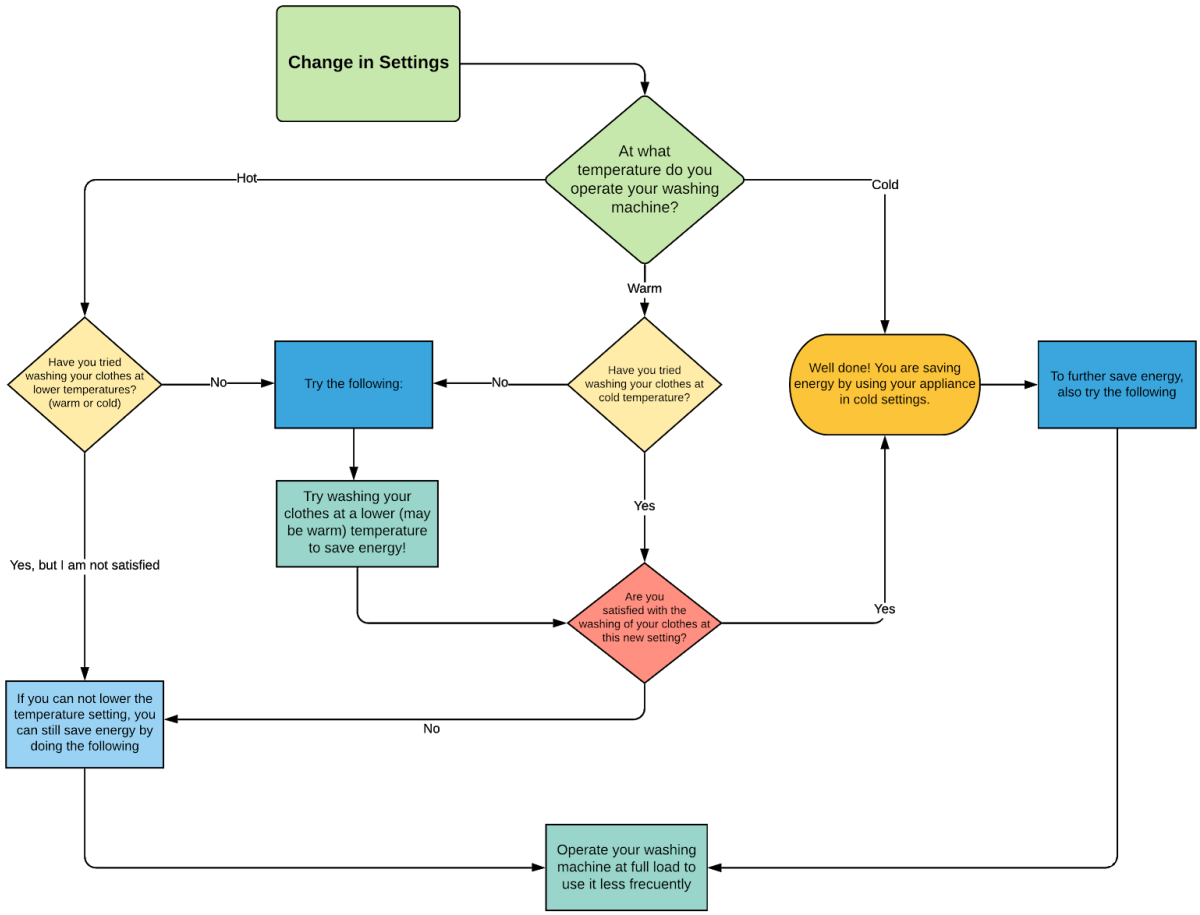
Annex 7: Sample Roadmap for Change in Systems



Annex 8: Sample Roadmap for Change in Habits



Annex 9: Sample Roadmap for Change in Settings



Annex 10: Sample Roadmap for Change in Products