INTEGRATED ENERGY FOR DAVIS, CALIFORNIA

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GG

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Preliminary Analysis

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Empowering local action against climate change

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California

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Abstract

Davis, California is a medium sized city west of Sacramento in California's central valley. Energy service options for Davis include for-profit utility service (current), establishing a municipal utility or joining/creating a community choice energy agency. In order to provide an integrated view of the city's opportunities to engage in shaping its energy future, a multi-step integrated local energy analysis was completed.[1]

In order of completion: The city's population and housing statistics, energy profile, and electricity statistics were collected and summarized. Energy usage, energy supply and the supply/usage balance were modeled for three scenarios corresponding to the three service options. Scenario-specific models were developed to account for building energy usage, transportation energy usage and local solar, wind and clean vehicle deployment over a 20 year period from 2015 to 2035. Strategies to address monthly and daily usage and supply variability were evaluated quantitatively to determine electricity imports and/or exports in the three scenarios. Cost implications and carbon footprint outcomes for the three scenarios were also evaluated.

Results of the analytical tasks speak to a growing need for local jurisdictions to actively engage to influence and shape their energy futures according to locally specific planning information.

Cover photos: Communities vary widely in their rates of adoption of the technologies that enable achievement of local environmental stewardship goals. Technologies likely to have the greatest impact in reducing Davis's carbon footprint are in most cases also technologies that can easily be adopted by local residents, businesses and public agencies. Photos are from residential and other projects in which the author invested or personally contributed. They illustrate elements of supply and demand side energy localization that enable net positive electricity supply from a building or facility; they also enable carbon neutrality at the building or facility level. Clockwise from top right: residential heat pump outdoor unit, residential rooftop PV array, residential solar water heating panels, solar PV carport, and family electric vehicle.

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[1] The analysis was completed as a task of the "Future Renewable Energy and Efficiency" (Davis-FREE) project, which was supported by a grant from the California Energy Commission. The grant was administered by the City of Davis and the Valley Climate Action Center. DavisFREE targeted detailed and comprehensive integrated renewable energy and enhanced energy efficiency plans to guide the City of Davis in achieving climate action and energy building energy usage reduction goals. This report contains results informing local renewable deployment planning. Other DavisFREE results include provisional plans for a range of affordable bundled energy packages for specific neighborhoods and customer groups, guidelines for zero net energy retrofits for existing residential buildings, analysis of the viability and cost effectiveness of technologies that can deliver new renewable energy generation at the distribution grid level, and a fast-track solar thermal water heating deployment plan.

Integrated Energy for Davis, California

PRELIMINARY ANALYSIS

Preface

Though of historically peripheral interest to regional utilities, local renewable deployment is becoming a matter of significant economic and environmental benefit for small cities. In Germany, 97%[2] of the sources of renewable supply are connected to local distribution grids.

Significant local integration will be required as local renewable deployment gains traction.[3] As electricity is substituted for natural gas use in buildings and for petroleum products in transportation, and as new transportation fuels like hydrogen are produced from local renewable sources, every small city will need to do integrated analysis.

Analysis is essential where conjecture is a tempting substitute. Small cities differ markedly in ways that impact the design of integrated energy systems. Risks of over- and under-investment can only be identified by modeling changes occurring over decades.

Assumptions and analysis results in this report are specific to Davis, California. Except where noted they are the author's estimates and interpretation of trends, constraints and opportunities. They are preliminary and subject to refinement periodically as better information becomes possible. For example, a business as usual scenario is used as a reference case. There are certainly a number of possible events and policy changes at the state and national levels that could alter this case in major ways. However, as unlikely as twenty more years of business as usual may seem, correctly guessing which events or policy changes will actually happen and what their impacts will be is even more unlikely.

Analysis of the type presented is both necessary to local planning but also a piece of a larger puzzle. To consider one community's situation in isolation, however internally integrated the analysis may be, is to overlook important opportunities and contingencies.[4]

Acknowledgements

Work reported herein benefitted from support of sponsors, including the City of Davis, the California Energy Commission, and the Valley Climate Action Center. The following colleagues made significant administrative or technical contributions representing sponsors and/or as pro bono reviewers: Mark Braly, Ron Edelstein, David Erickson, Richard Flood, Rob Hammon, Tom Hoff, John Hingtgen, Veronica Holland, Jim Jungwirth, Rusty Klassen, Bill Knox, and Eric Veium offered comments resulting in numerous and important clarifications and corrections.

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[2] Source: http://www.ii-intelect.org/sites/ii-intelect.org/files/Vikram_%20Siemens_VG_Final_Jan17.pdf

[3] For a brief discussion of this hypothesis, see footnote 5 on page 4.

[4] These opportunities and contingencies are mostly beyond the reach of local integrated energy analysis at this time, but here are some questions the report does not address, let alone answer: Davis is an urban area surrounded by rural areas. What opportunities might exist for optimizing the combined local renewable electricity portfolio? How does the seasonal demand cycle of nearby agricultural irrigation power fit into the mix? Local natural gas generation is in effect proposed as a bridge to a local renewable based and low carbon future. What are the economics, locally, of using it while backing it out? If natural gas is increasingly used for flexible electricity generation, will demand for natural gas in the power sector peak as local or and regional demand peaks, and what are the implications for local generation costs? If locally generated hydrogen is used to fuel electric vehicles, will that not open up an opportunity to also supply heat in buildings? Likewise, if Davis were to set a zero waste goal along-side its carbon neutrality goal, and/or consider how to achieve scale economies in bio-methane production through collaborative arrangements with rural areas and other jurisdictions, could locally generated methane to off-set natural gas imports? In the latter case, what opportunities might there be for locally fueled baseload generation to complement variable solar and wind generation?

Contents

Executive Summary page 4

Introduction page 10

- Davis location and statistics

Local energy usage and production page 11

- Local energy usage
- Local renewable power
- Local solar and wind sites and resources

Scenarios, change drivers and integrated model page 14

- Scenarios
- Models and Assumptions
- Climate Strategy (Local carbon footprint reduction strategies)
- IOU Scenario (Pace will not change/Policy implementation lag)
- Building Usage – IOU Scenario
- Transportation Usage – IOU Scenario
- Local Renewable Power – IOU Scenario

Local Power Scenarios page 20

- Accelerated Local Energy Conservation and Substitution
- Accelerated Local Renewable Power Deployment
- Monthly Variations in Electricity Usage and Local Renewable Power
- Local Renewable Generation Expansion
- Seasonal Supply/Demand Balancing in the POU Scenario

Local Supply/Demand Balancing Page 24

- Enabling maximum local solar energy production
- Strategies to accommodate electricity usage and renewable supply variability
- Impacts of emerging vehicle fueling options on local energy supply
- Hourly Usage Variations – Four Seasons
- Hourly Renewable Power Supply Variations – Four Seasons
- Hour Net Supply – Four Seasons
- EV Charging as a Demand Response Tool
- Vehicle To Grid Energy Storage

Scenario Comparisons Page 27

- Carbon Footprint
- Cost of Service Considerations – Near Term
- Cost of Service Considerations – Long Term

Conclusions and Recommendations Page 29

- Integrated Energy Analysis
- Locally Accountable Energy Service
- Recommendations

Executive Summary

Introduction

This report presents the results of an integrated energy analysis for Davis, California. A working hypothesis motivating the analysis was that significant local integration will be required as local renewable deployment, currently accelerating in California, continues to gain traction[5].

Davis, California is a medium sized city west of Sacramento in California's central valley. Davis has a tradition of energy consciousness and innovation. Davis has recently been in the process of evaluating its energy service options. In general, they include for-profit utility service (current), establishing a municipal utility or joining/creating a community choice energy agency.

Table ES-1. Direct Energy and Emissions, Davis, California, 2012	**Annual Energy Bill**	**Carbon Footprint**
	$ millions	Metric Tons CO2
Electricity	43.5	66966
Natural Gas	16.4	63453
Light Vehicle Fuel	23.1	49691
Total	83.1	180110

Davis has a long term carbon neutrality goal. Accordingly, energy costs and energy related emissions are of particular concern. Table ES-1 summarizes the city's *direct* energy costs and carbon emissions, approximately 72% of which are attributable to building energy use and approximately 28% to light vehicle fuel use. *Indirect* costs and fuel use attributable to heavy vehicles, though quite significant, are not included, because they are mostly outside the city's control and influence.

The work reported here was intended to inform further evaluation of near and long term energy service options. The city's population and housing and energy usage statistics were collected and electricity load profiles determined. Energy usage, energy supply and the supply/usage balance were modeled for three scenarios corresponding to the three above-mentioned electricity service options. Scenario-specific models were developed to account for building energy usage, transportation energy usage and local solar, wind and clean vehicle deployment over the 20 year period from 2015 to 2035. Strategies to address monthly and daily usage and supply variability were evaluated quantitatively to determine electricity imports and/or exports in the three scenarios.

Building Energy Trends

Integrated energy analysis starts with the best available information on building energy usage. Analysis of usage and local renewable generation data for Davis creates a baseline or reference case. It also reveals trends that will continue unless the city decides to take a more active role in energy service. For example, Davis's energy use continues to inch upward in spite of intentionally slow population growth. Upward trends are driven by modest expansion in the non-residential (commercial and industrial) sector, while residential sector usage trends slightly downward.

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[5] Admittedly, local renewable deployment may not continue to gain traction in California, but recent solar PV industry projections (see Figure 8 on page 20) show that it will. Nor is it necessarily the quickest and most cost effective means for a local jurisdiction to shrink its carbon footprint in the short term. Longer term, local renewable deployment may be driven by a number of factors including the technical and economic opportunity to achieve better economic integration of local transportation and energy infrastructure than would occur in a scenario relying more on centralized renewable and storage resources. Benefits to local economies may also become a consideration when analysis methods are developed to better understand and quantify these benefits. Likewise, there are strong synergies between on-site solar and building energy efficiency that are becoming better understood and quantified.

Economic Benchmarks

Building energy usage information can also be used to evaluate the costs of electricity service and ways of managing costs. For example, Davis's energy usage per capita and its electricity load factor are significantly lower than those of comparable cities in northern California currently being served by municipal utilities. These two metrics have implications for both electricity service costs and revenues captured by service providers. Along with other metrics, their implications should be evaluated in any follow-up technical studies.

Transportation Energy

Transportation, i.e. vehicle energy use, accounts for only 20% of Davis's current energy use but 28% of Davis's direct carbon footprint and 50% of its carbon footprint when heavy vehicle use is included. Clean energy vehicle energy use is expected to increase rapidly, so a twenty year integrated energy analysis must take it into account.

Local Climate Strategy: Substitution

It is increasingly apparent that California's long term energy strategy hinges on efficiency and renewable energy. For purposes of near term local climate strategy, these elements are necessary but not sufficient. One missing element is the substitution of low carbon energy end use commodities for high carbon forms. For example, a major portion of Davis's building energy is used to generate heat using natural gas. In the building sector, substitution would mean heating water with solar energy and buildings with low carbon electricity and heat pumps. These steps can take a very large bite out of Davis's carbon emissions. In the transportation sector, substituting electricity and natural gas for currently dominant higher carbon transportation fuels can take comparably large bite out of Davis's carbon emissions.

Local Renewable Electricity – Energy Dollars Staying Home

A decision most businesses routinely face is whether to make what is needed or buy it…whether to hire or out-source. What is the best way to get the job done? Davis's electricity is currently almost all imported, i.e. not produced locally. So, the next step in integrated local energy analysis is similar to the step related to usage, i.e. to specifically identify current local area renewable energy production, resources and trends, plus opportunities to expand renewable electricity production locally.

As it happens, Davis is blessed with abundant cost-effective opportunities to generate solar electricity locally. Also, there are siting areas for cost-effective wind generation within 10 to 20 miles of the city limits and even higher quality, more economically attractive resources within 20 to 50 miles.

Solar water heating and bio-fuels are potential complements to solar and wind electricity, as is vehicle to grid electricity storage. Also, as fuel cell electric vehicles gain a foothold, solar electricity, along with natural gas, will be used to produce hydrogen for vehicle fuel cells. In the longer term, additional hydrogen can be economically produced from solar electricity used locally for heating purposes, displacing natural gas and reducing the city's carbon footprint.

On-site solar electricity installations, preferably matching or exceeding on-site use, will be the simplest and easiest pathway for increased dependence on local renewable resources. At current rates of deployment, on site solar electricity will supply 20% of the city's electricity need without any further action by the city. The potential for on-site solar PV[6] to supply a large amount, or even the majority of the city's energy needs is real but in the near term it is dependent on changes in rules that severely limit on-site and

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[6] Typically rooftop but also including carports and parking shade structures

local deployment. The potential in the longer term is also dependent on deployment of cost-effective energy storage technologies.[7]

Locally Accountable Electricity Service Models Enable Local Climate Action

In the current energy services paradigm, efforts to reduce energy usage or shift usage to less carbon intensive energy sources are not coordinated or adapted to specific local usage patterns. Other frameworks that empower locally accountable energy service can have a greater and more timely effect. For example, current net energy metering rules impose barriers to local on-site solar deployment which can be mitigated or eliminated by local load serving entities, with the result that rooftop and other on-site systems could come on stream faster, with some or many generating net positive electricity.[8]

Many electricity users lack suitable space for on-site generation. Locally accountable[9] energy service would also enable development of larger (but still local) projects as a complement to on-site power. Such "community" solar and wind projects currently are impeded by regulations and market rules that preclude designation of locally generated electricity for local use. Locally accountable energy service providers can capture direct benefits of on-site and community based projects and also indirect economic and resiliency benefits to local economies.

As discussed above, the amount of local power that can be economically be used locally depends on the electricity service model. It is true that solar panel cost reductions, combined with innovative business models, have made solar an attractive choice for consumers. However, for-profit utilities are concerned about recent trends. They are launching legislative, regulatory and rate-setting initiatives to slow or stop deployment of on-site solar in their service territories. Nonetheless, it is reasonable to assume current rates of adoption will continue where they are currently high, but this assumption may be widely off the mark in either direction.

In this context, it is important to note that cities served by publicly owned utilities (POUs) are free to plan and operate their power infrastructure to rely more (or even exclusively) on local power. For example, a local POU generation portfolio weighted toward variable local sources like solar and wind could feasibly be sized to over-generate during some seasons of the year to match under-generation during other seasons. Because a POU also plans and operates local grid infrastructure, POUs could in principle accommodate the local electric system planning and integration requirements attending full local self-reliance.

A local POU would neither under- or over-generate on an annual basis, except as part of a power pool, because it would have the planning and operations capacity to deploy flexible local generation and storage for seasonal and daily balancing purposes. It must be admitted that, absent stronger pressure from POU host communities than exists today, it might take a couple of decades for most existing POUs to make the shift from their current mostly centralized generation portfolios to fully localized portfolios. A new POU might start slower but have more flexibility to catch up and overtake its peers.

Another emerging energy service model is called "community choice energy" (CCE). In this model, a Community Choice Aggregator (CCA), formed under state law, would take responsibility for sourcing electricity to be delivered by the incumbent for profit utility to local customers. A CCA or CCE, unlike a POU, does not, at present, plan and operate local grid infrastructure. A CCE's local renewable power portfolio

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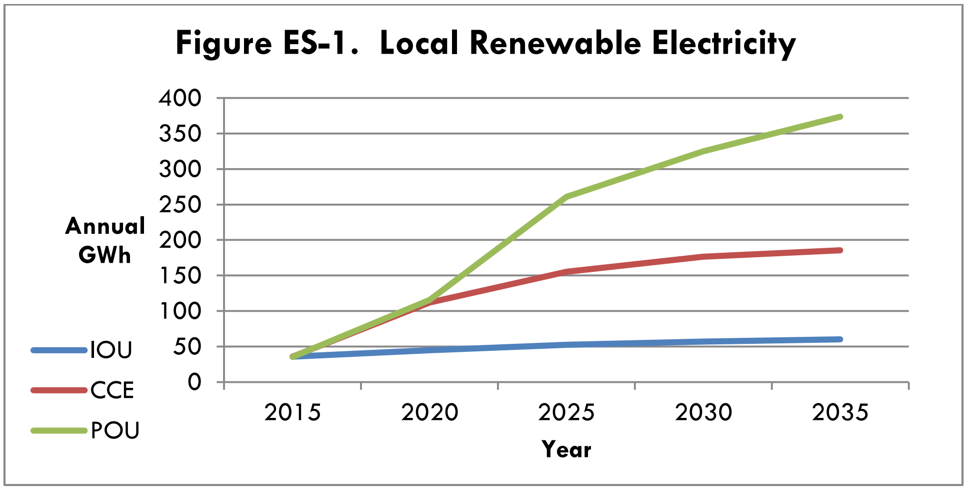
[7] The DavisFREE project analysis of just Davis's residential rooftop PV potential, assuming all reasonable roof segments were covered with PV, allowing access space per the fire-codes, and adjusting for orientation, tilt, and shading, determined that the current potential is over 280MW, producing 528,000MWh/year, sufficient electricity to supply the energy needs for nearly 4.5 times as many homes as exist in Davis today. Source: Rob Hammon, BIRA Energy, private communication

[8] Exploiting the potential to generate more electricity than individual sites use would require that Davis involve itself in providing energy service.

[9] For a brief discussion of local control and accountability, see footnote 21 on page 14.

would not likely be determined by tailoring local grid capacities to local generation opportunities. For example, local flexible generation and storage dedicated to balancing local supply and usage would be outside its operational purview. A CCE service's local solar/wind generation portfolio would be specified, not to achieve a real-time balance between locally produced power and local usage, but rather to generate as much cost effective locally generated power as the local grid owner would agree to accommodate or be required to accommodate by regulatory authorities.

To roughly assess the difference locally accountable electricity supply would make, renewable energy deployment and carbon footprint reduction trajectories were computed and compared as shown in Figures ES-1 and ES-2. Figure ES-1 below shows the assumed build-out of local renewable electricity generation in three scenarios, corresponding to the energy service options the City of Davis evaluated in 2013 and 2014, i.e. Investor Owned Utility (IOU), Community Choice Energy (CCE) and Publicly Owned Utility (POU). Consistent with the above discussion, local renewable electricity production would match annual usage by 2035 in the POU scenario while contributing significantly in the CCE scenario and modestly in the IOU scenario.



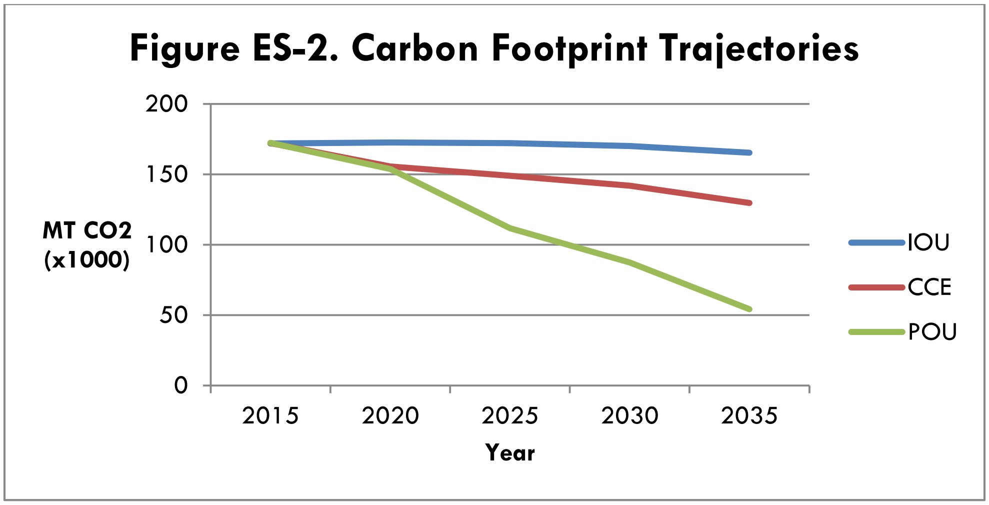


Figure ES-2 shows the combined effect on Davis's climate footprint of *local* renewable electricity build-out, substitution of electricity for fossil fuels in the building heating and transportation sectors, and more locally effective energy efficiency and conservation programs in the CCE and POU scenarios. It is important to point out that a CCE's combined (local plus imported) renewable electricity totals could match local usage as in the POU scenario, provided the CCE's overall electricity supply portfolio (local plus grid imports) were 100% renewable.[10]

Variability – The Once and Future Challenge

Electric grid operators have been managing variability since the first electricity grid commenced operation. As then, still now, electricity usage varies, and at the individual customer level is even somewhat "intermittent". It has been usage diversity that has made usage variability manageable. Just so, geographic diversity of variable renewable supply has been shown to ease operational management of generation portfolios including high percentages of variable renewables.

Strategies for managing variable and intermittent supply (run of the river hydro, for example) also preceded the advent of cost-effective solar and wind generators. As then, still now, as supply variability increases, the need for flexibility increases.

In the regional grid, some generators are flexible, some are not. Baseload plants are typically not designed for flexibility but for low marginal production costs. Solar and wind generators have even lower marginal production costs. So, instead of providing flexibility to complement inflexible baseload generation, the emerging need is to provide additional flexibility to accommodate solar and wind. The need for flexibility has always existed. It is easier to manage less flexibility than more. The good news is that the number of tools in the grid management toolkit is increasing. Small grids need smaller, more precise tools, but basically the same principles apply.

So, a local integrated energy analysis requires attention to variability and especially to the use of tools that are available to manage it locally. Integrated analysis is necessary if local resources are to be fully and economically exploited. A related requirement in our study was to develop monthly, daily and hourly usage and renewable electricity supply profiles for Davis using available information. Then, our analysis roughly determined the amounts of flexible distributed generation and/or energy storage that would be required in a full local renewable build-out scenario, i.e. one calling for all local electricity usage to be served by local renewable electricity generation.

Analysis of local residential and non-residential usage and solar and wind generation patterns pointed to a generation mix balanced approximately evenly between solar and wind.[11] Hourly solar production profiles better match non-residential usage profiles than residential profiles, while hourly wind production profiles better match residential usage profiles.

As expected, the match is far from perfect and, as expected, it is also better on a monthly basis, rather than a daily or hourly basis. So, for such maximum reliance on least cost local renewable resources, a potentially cost-effective strategy would be to deploy flexible distributed natural gas generation for use in balancing variable demand and variable supply. A secondary[12] strategy serving the same purpose would be to encourage residential and commercial combined heat and power units (currently there are none in

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[10] It is also important to note that the POU scenario's local renewable build-out could also be implemented in a combined CCE/POU scenario, i.e. sequentially by a CCE in an initial phase and by a POU in a later phase. Likewise, it is reasonable to assume that CCE frameworks in California will evolve, and there is even a possibility that a desirable evolution would allow the CCE and the incumbent IOU to undertake local renewable build-out according to the POU scenario.

[11] Economic modeling, based on the economics of a specific local solar and wind project portfolio, might shift the balance either in favor of local solar or local wind. Without project specific costs, local supply curves and further analysis, it is premature to speculate on the exact balance. Further, the balance would differ for cities with different ratios of residential and non-residential usage.

[12] Secondary, because heat load typically determines economically preferred CHP unit sizing, while economic operation typically favors high capacity factors, not dual service as flexible generation.

Davis) in conjunction with a program that would compensate their owners for grid support and local supply/demand balancing services.

Analysis of production to balance monthly demand indicates that in summer months, some renewable electricity would be available for export or sale, while in winter months local natural gas generation would be needed to round out monthly supply. Model results show that Davis can achieve the necessary balance with proportionally much less local natural gas electricity generation than current statewide percentages based on mostly centralized natural gas generation.

Analysis of production to match hourly variations in daily usage indicated that significant amounts of distributed electricity storage would be required to deliver daily renewable production according to demand over 24 hours of usage. A couple of basic related questions were asked and answered:

- First, would the likely amount storage embedded in electric and plug-in vehicles suffice as a demand response tool, e.g. encouraging charging during hours when local renewable supply exceeds building usage? Our analysis showed that it would not, per se. So, plug-in vehicles can have a prominent role in supply/demand balancing but other load management strategies will be needed as well.[13]
- Second, would the projected cumulative vehicular storage capacity suffice to store excess generation during some hours and return it to the local grid when needed each day? Our analysis showed that it would in most but not all months. So, some additional stationary storage might be required.

Conclusions

As electricity is substituted for natural gas use in buildings and for petroleum products in transportation, and as new transportation fuels like hydrogen are produced from local renewable sources, every small city will need to do integrated analysis. It will be feasible for Davis, California to use a mix of local solar and wind resources to make major strides toward carbon neutrality in the next two decades, essentially eliminating its direct carbon footprint. Figure ES-2 plots carbon footprints that include both direct and indirect emissions. In 2035, in the POU scenario, only the indirect component remains.

Cities having the interest and opportunity to take a leading role in local clean energy resource development will face an increasing need for locally specific, detailed and integrated renewable deployment analysis and planning. The required analyses will need to consider expected patterns of end use energy substitution, e.g. electricity for natural gas and for other fossil fuels. This will be tough and necessarily imprecise work until better information, now held as proprietary by investor owned utilities, is shared on a routine basis with local jurisdictions.

Development of local renewable resources is likely to be impeded except in cases where energy service is accountable to local citizens and their representatives. Locally accountable energy service may actually prove to be a necessary condition for locally integrated energy planning and deployment, especially where local economic and environmental improvements are targeted. If so, it must be planned and managed to account for surprisingly large local variations in energy usage metrics and local supply resources. In cases like Davis where environmental stewardship is a consideration, planning and management must also account for the environmental costs of purchased energy, whether renewable or carbon based.

Some other similarly sized northern California cities are positioned to take the biggest climate action strides because they are already served by municipal utilities. Still others that receive community choice energy service can also make significant strides, but the increasing need for collaborative regional utility and local planning will be more of a limiting factor in these cases.

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[13] Integrated and automated demand side management may be a future capability of local smart grid, but the pace of implementation may be slower than the pace of electric vehicle adoption.

Integrated energy analysis for a specific small city should be based on realistic assumptions and pragmatic scenarios. If this approach is taken, it confirms, calibrates and in some cases challenges intuitively generated expectations.

Introduction

Can most of a specific small city's energy needs be supplied by a mix of local renewable resources? Can the result be a near zero local carbon footprint within two decades?

This report is organized according to the modeling and analysis steps required to produce a preliminary answer for Davis, California. To evaluate quantifiable factors, locally specific assumptions and data are needed, including:

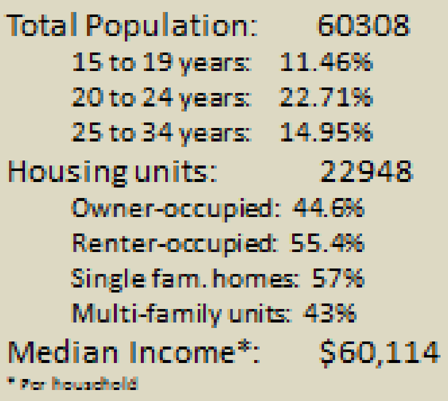
- Energy usage trends
- Low carbon energy usage and supply technology deployment status and long term trends
- Preferred local renewable electricity supply portfolios
- Energy service options
- Energy supply variations and limitations

Because these assumptions and data vary to a surprising extent even for small cities in the same climate zone, it follows that analysis results are location- and community-specific. So, valid conclusions for Davis, California may not be equally valid for other, comparable small cities. Nevertheless, the general approach to model development and analysis may prove useful in other cases, and our results do confirm the general feasibility of much greater reliance on local clean energy options.

Davis location and statistics

The map in Figure 1 below shows Davis, located in California's Central Valley. It is a compact, medium size city, bounded by zoned agricultural areas.

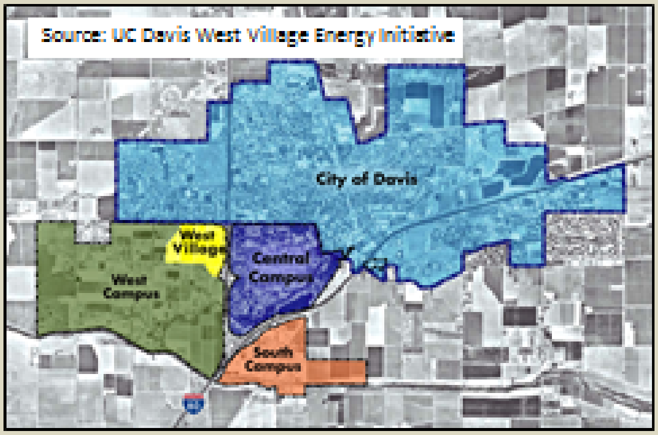
Table 1. Statistics (city only)



Total Population:	60308
15 to 19 years:	11.46%
20 to 24 years:	22.71%
25 to 34 years:	14.95%
Housing units:	22948
Owner-occupied:	44.6%
Renter-occupied:	55.4%
Single fam. homes:	57%
Multi-family units:	43%
Median Income*:	$60,114

* Per household

Figure 1. City and University



Source: UC Davis West Village Energy Initiative

As shown in Table 1 above, Davis has distinguishing income, age and housing ownership statistics. Nearly 50% of its population is under the age of 35. It has a large number of multi-family residential buildings supporting transitory university students and more permanent residents and resulting in split economic benefits and indirectly in building owner under-investment in energy system improvements.

The above population and housing statistics are not surprising for a city whose primary employer is a university. Its median income, equal to the California average, reflects a blend of relatively high professional salaries and relatively low student salaries, plus a relatively high percentage of rental housing units.

Local Energy Usage and Production

Local energy usage

Like some other northern California cities and counties, Davis has a climate action plan and a 2050 carbon neutrality goal[14].

Net zero buildings would seem consistent with such plans and goals. However, a low growth community cannot expect new high-performance building construction to suffice as a primary strategy for reducing community energy usage. Rather, existing building retrofits and behavior changes are needed to achieve better energy performance.

Table 2 below[15] shows that more than 80% of Davis's energy use is attributable to buildings, with residential buildings accounting for the lion's share.

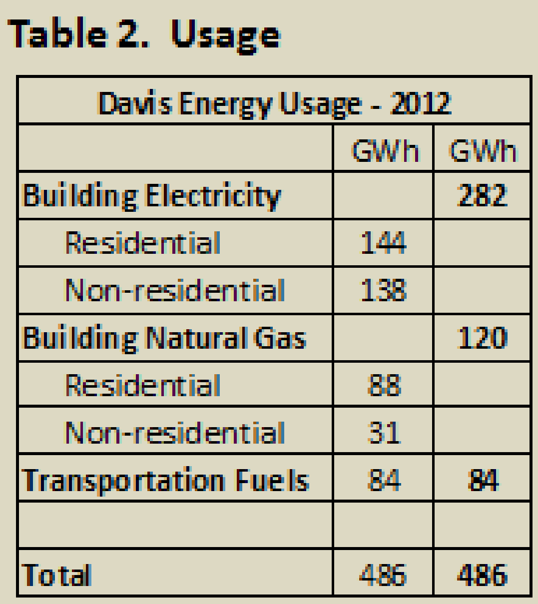


Table 2. Usage

Davis Energy Usage - 2012		
	GWh	GWh
Building Electricity		282
Residential	144	
Non-residential	138	
Building Natural Gas		120
Residential	88	
Non-residential	31	
Transportation Fuels	84	84
Total	486	486

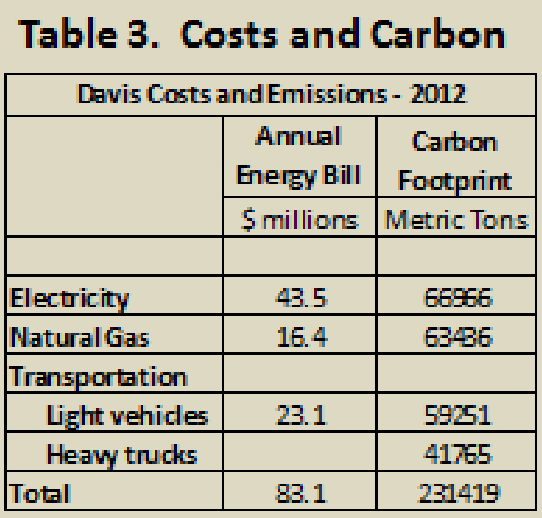


Table 3. Costs and Carbon

Davis Costs and Emissions - 2012		
	Annual Energy Bill	Carbon Footprint
	$ millions	Metric Tons
Electricity	43.5	66966
Natural Gas	16.4	63436
Transportation		
Light vehicles	23.1	59251
Heavy trucks		41765
Total	83.1	231419

As shown in Table 3 above, Davis's direct annual bill for locally used energy is estimated to be greater than $80 million, or about $1400 per capita. This estimate intentionally excludes the cost of fuel for heavy duty trucks, an indirect cost.

Low per capita energy use, especially by students, and an electricity customer mix lacking an industrial or significant agricultural component results in a carbon footprint significantly lower (by a factor of three) than California's per capita average footprint, even when emissions from heavy trucks are included. Building and light vehicle costs and carbon footprints are in an approximate 70/30 ratio.

About half of a typical California city's electricity service costs are determined by the cost of electricity production. The remaining half is driven by costs of electricity delivery and customer service. Table

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[14] Carbon neutrality is defined as a 100% reduction in Davis's 2010 baseline greenhouse gas allowance of 8.1 annual metric tons of CO2 per person. Senate Bill 375, enacted in 2008, required metropolitan planning organizations (MPOs) to meet GHG emission reduction targets through integrated transportation, land use and housing planning. While SB 375 sets planning requirements for MPOs, it is ultimately up to local jurisdictions to implement many of the land use and transportation strategies.

[15] Note: End use rather than source energy metrics were used consistently throughout the model and analysis.

4 below compares electricity statistics for Davis and comparably sized California cities served by municipal utilities.[16]

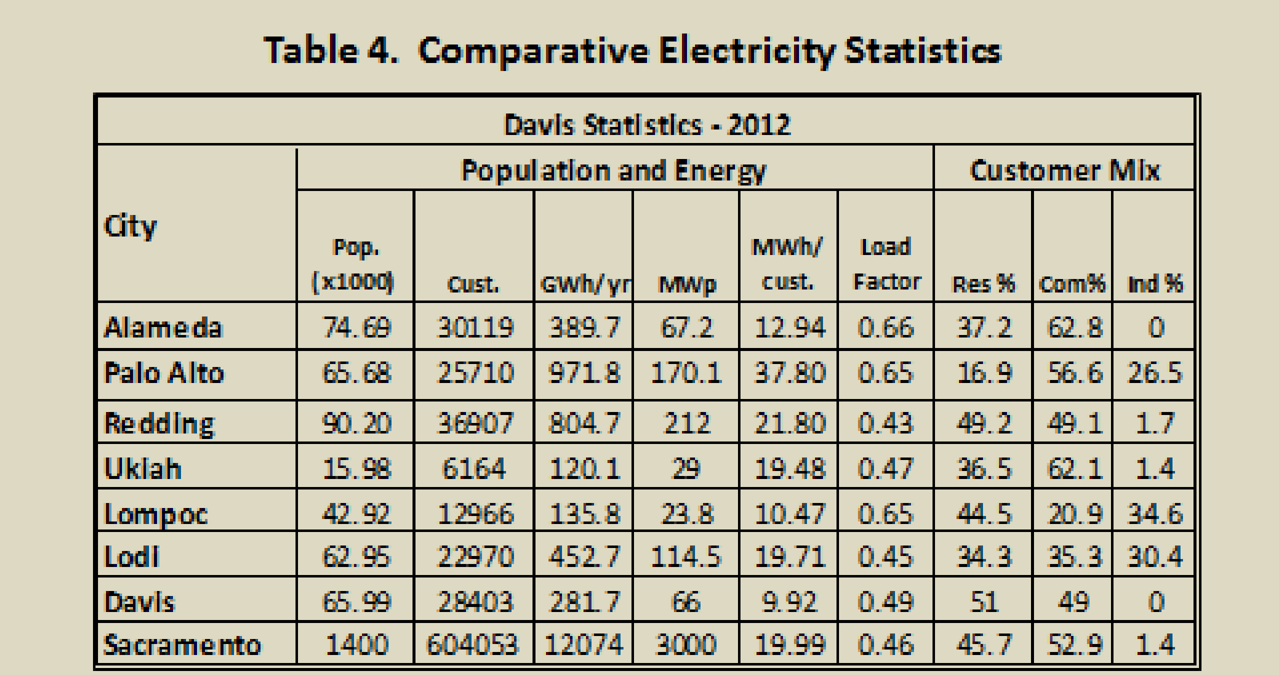

Table 4. Comparative Electricity Statistics

Davis Statistics - 2012									
	Population and Energy						Customer Mix		
City	Pop. (x1000)	Cust.	GWh/yr	MWp	MWh/ cust.	Load Factor	Res %	Com%	Ind %
Alameda	74.69	30119	389.7	67.2	12.94	0.66	37.2	62.8	0
Palo Alto	65.68	25710	971.8	170.1	37.80	0.65	16.9	56.6	26.5
Redding	90.20	36907	804.7	212	21.80	0.43	49.2	49.1	1.7
Ukiah	15.98	6164	120.1	29	19.48	0.47	36.5	62.1	1.4
Lompoc	42.92	12966	135.8	23.8	10.47	0.65	44.5	20.9	34.6
Lodi	62.95	22970	452.7	114.5	19.71	0.45	34.3	35.3	30.4
Davis	65.99	28403	281.7	66	9.92	0.49	51	49	0
Sacramento	1400	604053	12074	3000	19.99	0.46	45.7	52.9	1.4

Table 4 terms: MWp = Annual Local Peak Demand in MW. Customer Mix percentages refer to residential, commercial and industrial customer annual MWh usage.

Davis's electricity usage per capita is relatively low, potentially resulting in higher fixed operating costs per unit of energy served. Davis lacks industrial base-load demand. As a result, its load factor, the ratio of average annual demand to annual peak demand, is relatively low, potentially resulting in higher costs for required amounts of generation, transmission and distribution capacity per unit of energy served.

Local Renewable Power

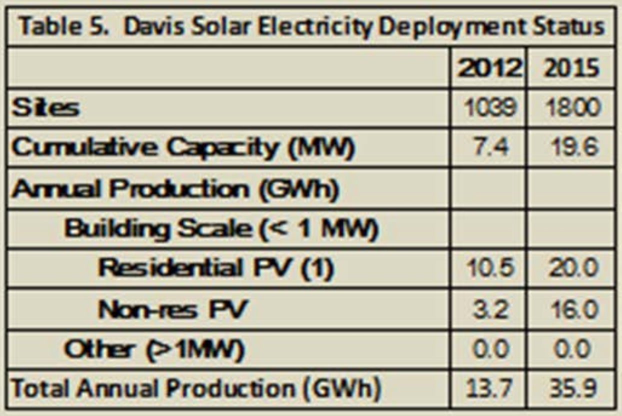

Table 5. Davis Solar Electricity Deployment Status		
	2012	2015
Sites	1039	1800
Cumulative Capacity (MW)	7.4	19.6
Annual Production (GWh)		
Building Scale (< 1 MW)		
Residential PV (1)	10.5	20.0
Non-res PV	3.2	16.0
Other (>1MW)	0.0	0.0
Total Annual Production (GWh)	13.7	35.9

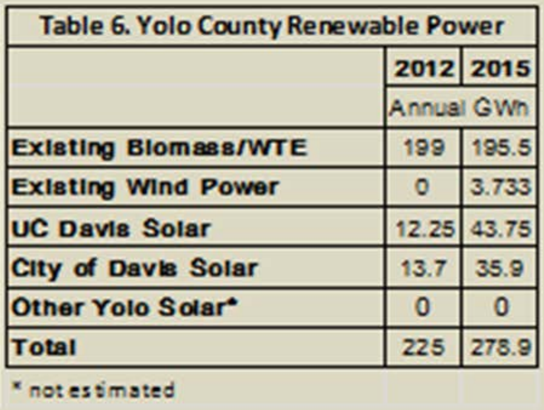

Table 6. Yolo County Renewable Power		
	2012	2015
	Annual GWh	
Existing Biomass/WTE	199	195.5
Existing Wind Power	0	3.733
UC Davis Solar	12.25	43.75
City of Davis Solar	13.7	35.9
Other Yolo Solar*	0	0
Total	225	278.9

* not estimated

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[16] Note: Sacramento statistics were included for reference. Davis GWh/yr includes direct access usage. Data sources include: City of Davis consultant reports, NCPA and PG&E

Based on information in the Table 5 above, Davis is on a much faster (5x) pace for net metered on site solar deployment than the average California city. Extrapolating from 2012 production estimates and subsequent numbers of new sites in 2013 and 2014, annual local solar power production in the baseline year 2015 will exceed 35 GWh.

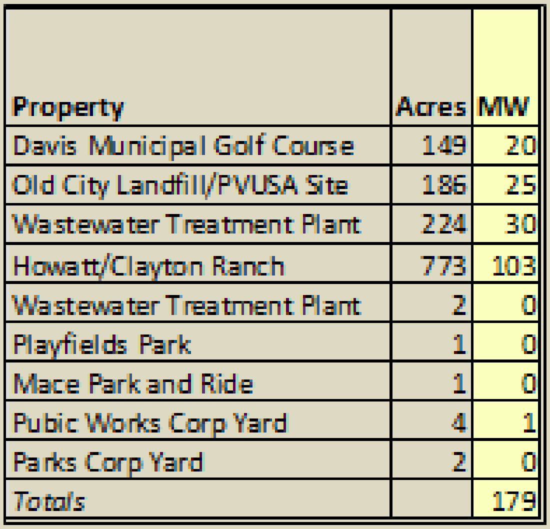
The potential for on-site PV to supply a large amount, or even the majority of the city's energy needs has been confirmed by BIRA Energy in a parallel study, also included in the DavisFREE project.[17] This analysis of Davis's rooftop PV potential, assuming all reasonable roof segments would be covered with PV, i.e. allowing access space (per fire-codes) and adjusting for orientation, tilt and shading, determined that Davis's current rooftop solar PV potential is more than 280MW, potentially producing 528,000MWh/year, or an amount sufficient to supply the electricity needs for nearly 4.5 times as many homes as exist in Davis today. Of course, realizing the full potential would be dependent on grid balancing effects of local flexible generation and cost-effective energy storage technologies, but the result does suggest a technical and economic opportunity for a portion of the city's homes to power all of the city's homes.

A long term local renewable electricity portfolio for Davis would also include additional on-site solar electricity from parking structures and commercial rooftops, augmented if possible by larger community scale projects, not necessarily inside Davis's city limits but perhaps in adjacent areas of Yolo county.

Table 6 above shows that Yolo County and UC Davis already have significant existing and planned community scale renewable resources. Most of the generation summarized in Table 6 is purchased by the regional electric utility or UC Davis and so is not a candidate for inclusion in the city's renewable portfolio. New local renewable power projects will need to be developed.

Community Wind and Solar Sites and Resources

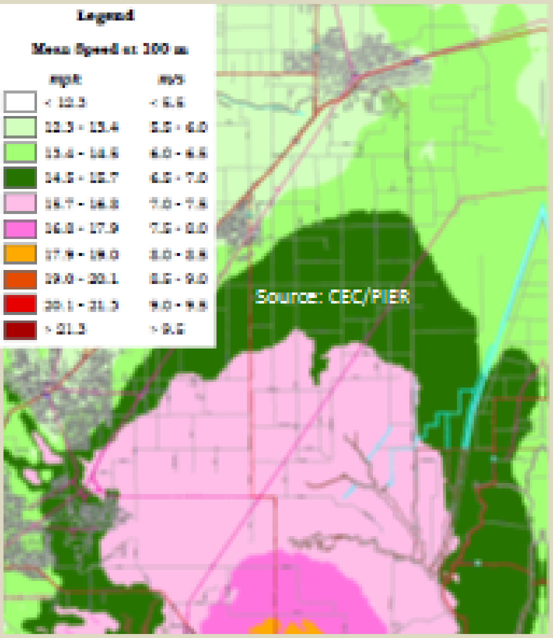
Table 7. City Controlled Community Solar Sites



Property	Acres	MW
Davis Municipal Golf Course	149	20
Old City Landfill/PVUSA Site	186	25
Wastewater Treatment Plant	224	30
Howatt/Clayton Ranch	773	103
Wastewater Treatment Plant	2	0
Playfields Park	1	0
Mace Park and Ride	1	0
Pubic Works Corp Yard	4	1
Parks Corp Yard	2	0
Totals		179

Source: City of Davis/UCD

Figure 2. Community Wind Resource Area



Source: CEC/PIER

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[17] Rob Hammon, BIRA Energy, private communication

Opportunities for Davis to purchase power from local community-scale generation sources are excellent, because of the high quality solar resource in the central valley and the high quality wind resources near Davis. According to Table 7[18] above, the City of Davis controls twice as much community solar siting area as required in the local power scenarios we analyzed, i.e. enough for nearly 200 MW of generating capacity. Current installed community scale solar capacity serving Davis municipal demand is about 1 MW or less than 1% of the potential within the direct control of the city.

As shown in Figure 2 above, there are also large areas suitable for community wind development twenty to fifty miles to the south and east of Davis (Davis is the grey area at the top).[19] Areas closer by, i.e. within ten to twenty miles, are also potentially useful, but average wind speeds are lower. (A wind turbines in the light pink area would generate roughly 60% more electricity than the same turbine located in the light green areas to the immediate southeast of Davis.) The best sites for local electricity supply, as in the case of regional electricity supply, will depend on the choice of feasible and economically preferred options for transmission of electricity from site to city.

Local Davis area wind and solar resources are excellent relative to other areas of the US and even other areas of California. They can be developed to produce electricity at competitive costs. Other local renewable electricity resources, including bio-power and geothermal in the Davis area may supplement solar and wind but do not appear to suffice in either quality or quantity to make a major cost-effective contribution at this time.

Scenarios, Change Drivers and Integrated Model

California electric utilities and community choice energy (CCE) service providers are the current primary agents of state policies mandating purchase of renewable electricity. Current state regulations and interconnection rules enable but also significantly constrain local renewable power development. For example, customer self-generation is generally limited to the amount of electricity consumed on-site rather than the potential amount that could be economically generated on-site. Feed in tariffs offered by investor owned utilities (IOUs), publicly owned utilities (POUs) and CCEs have been the primary impetus for development of community scale solar resources, but to date their use has been limited. The actual local implications of legislation originally intended to enable communities to participate in the process of local resource development and purchase[20] remains uncertain after years of debate, proposals and counter-proposals.

The study's reference case is referred to as the "IOU scenario", and local power cases are called CCE and POU scenarios. In the IOU scenario, electricity and natural gas service continues to be supplied by the incumbent for-profit utility (in Davis's case, PG&E). In the CCE scenario a locally accountable[21] CCE agency is assumed to be sourcing electricity for delivery within the community, while energy distribution service continues to be provided by PG&E. In the POU scenario, a newly formed and locally accountable electricity service provider (POU) is assumed, with continuing natural gas service by PG&E.

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[18] Includes larger sites. List is not complete.

[19] No assessment has been made to determine siting factors such as land ownership and other barriers and opportunities for development, e.g. participation in repowering existing wind farms with larger and more economically productive turbines.

[20] California's SB 43, enacted on September 28, 2013 established a 600MW statewide Green Tariff/Shared Renewables Program.

[21] Local control is often cited as motivation for interest in public power and more recently, community choice aggregation. In a political context it implies a level of accountability by a local energy service to the local jurisdiction and local customers. In Davis and increasingly elsewhere in California, this motivation has been demonstrated, but it is not a given that all or even most other jurisdictions would be similarly motivated. Local control also implies local capacity for management of an energy service in a way that is accountable and effective. Most local jurisdictions do manage comparable non-energy services in an accountable and effective way. The existence of a strong public power industry in the US suggests that locally accountable energy service is also technically and economically feasible where it is politically feasible.

Using scenarios differentiated according to the electricity procurement agent begs the question: What evidence exists to suggest that the primary agent of local renewable deployment in each case can and will act to enable it?

All three certainly can. However, there are substantial differences in motivation and capacity. All that can be reasonably assumed is that locally based and accountable service providers are in a better position to enable local resource development than regional utilities. Motivation is another matter. To date most California renewable electricity purchases have been by either for-profit or publicly owned utilities. The lion's share of purchases have been from "utility scale"[22] projects which suggests limited motivation and/or capacity to source locally.

Newly formed CCE providers aim for portfolios more heavily weighted toward renewables even while initially purchasing renewable electricity from the same menu of sources as their IOU and POU counterparts. They do express interest in aiming for increasing levels of local renewable energy "build-out" over time, but they are necessarily lightly staffed and must focus on core functions, notably wholesale electricity procurement. Operational efficiency of electricity procurement tends to be inversely proportional to the number of power purchase transactions. So, a focus on purchases from smaller, local sources must be intentional and driven by other considerations.

A newly formed POU might also aim for increasing levels of local renewable build-out and also (over time if not initially) would have greater financing and administrative capacity (assets and staffing) to source locally and to do so in a more locally integrated way than currently achieved by existing POUs.

Models and Assumptions

Our analysis required setting up spreadsheet models, making baseline assumptions and adjusting these assumptions according to assumed trends over the two decade period of interest, i.e. 2015-2035.

It is impossible to confidently foresee changes in state and local policies and goals. Accordingly, we assumed no changes in current state policies, IOU business models, or local goals, e.g. Davis's Climate Action Plan and 2050 Carbon Neutrality Goal. However, it was possible to consider current trends and the likely effects of locally accountable energy service planning and operations on energy usage and local renewable energy deployment.

Likewise, integrated analysis requires accounting for "substitution" of energy sources for one another. So, it was important to account for how changes in each major usage or supply category affected usage or supply in other categories. For example, we accounted for shifts of heating energy use from natural gas to electricity and solar heat as well as shifts of transportation energy use from petroleum to electricity and natural gas. Such actual shifts are already occurring, so trend information and market projections are available. For example, substitution of solar electricity for grid electricity is already occurring at a meaningful scale in Davis. Likewise, Davis residents are purchasing electric vehicles in higher proportions than other comparable jurisdictions.

Local energy analysis must be integrated across all uses and sources. Making sense of overall trends requires that the energy units used as metrics be the same whether applied to fuel or electricity use and production. We assumed significant levels of electricity substitution over two decades. So, equivalent end use electricity in units of megawatts, megawatt hours and gigawatt hours was used as a comparative metric.[23]

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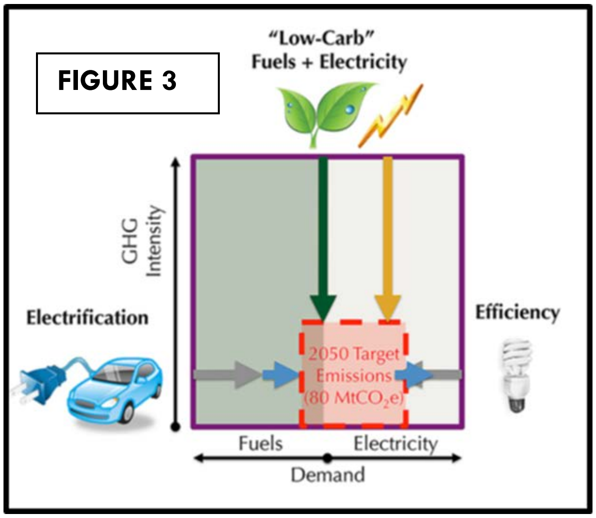
[22] >20 MW according to electricity market regulations

[23] In a low carbon future hinging in part on substitution of renewable electricity for carbon based fuels, the impacts of substitution on overall electricity demand must be carefully and accurately assessed.

Climate Strategy

Figure 3 shows the California Center for Science and Technology's recommended strategy to achieve California's 2050 carbon footprint target. One thrust is electricity substitution for carbon based fuels. Another is more efficient use of both electricity and fuel. A third is "decarbonization" of both electricity and fuels through reliance on renewable sources. The strategy is valid at whatever scale it is applied. The elements of strategy to reduce global emissions apply locally as well as globally. Carbon emissions from local sources add up to carbon emissions from state sources. Global emissions are the sum of local, state and national footprints. .

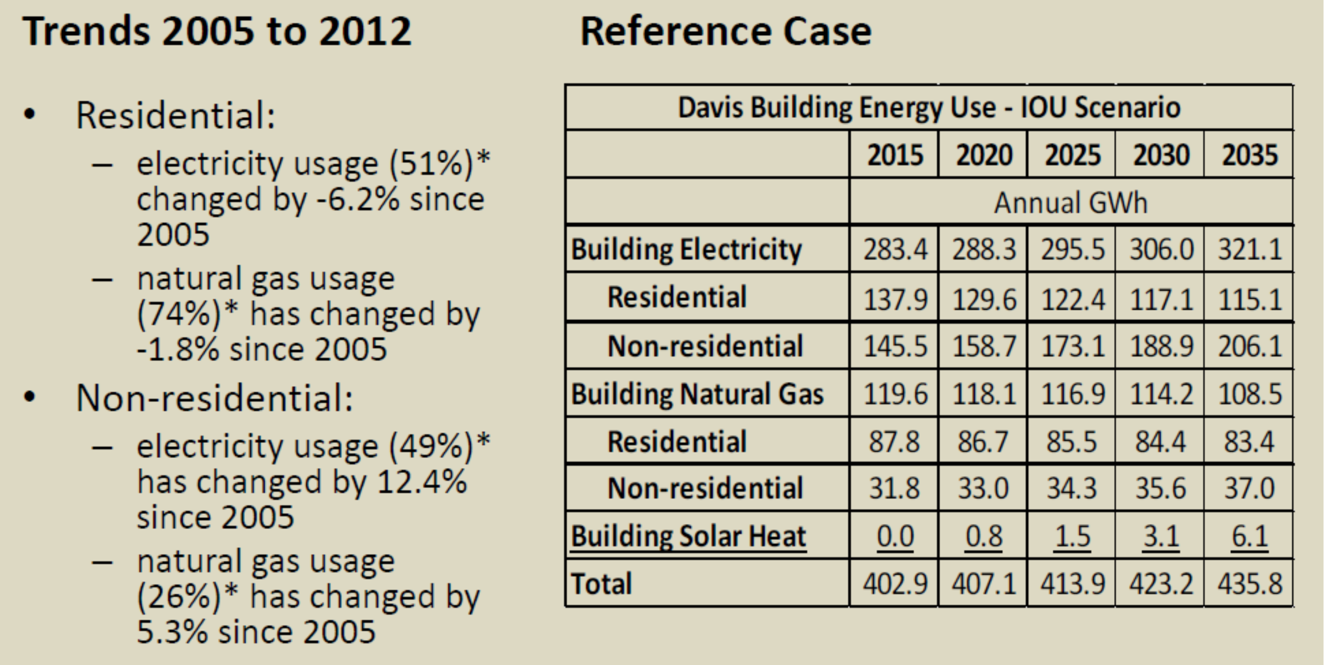
FIGURE 3



Renewables, efficiency and electrification are the long term strategy elements, but energy user decisions are where everything starts. They determine the direction and pace of local change. Early stage decisions are profoundly important because they influence larger numbers of later decisions.[24] Davis is fortunate to have a disproportionate share of the thoughtful and pro-active "early adopters" other community members can learn from and emulate.

Data for Davis makes it clear that such individual choices are moving the needle in a lower carbon direction, especially as to on-site solar and plug-in vehicle adoptions. Under these circumstances, a locally accountable energy service provider could act to remove roadblocks to broader and more rapid adoption.

Building Usage – IOU Scenario



Trends 2005 to 2012

- Residential:
  - electricity usage (51%)* changed by -6.2% since 2005
  - natural gas usage (74%)* has changed by -1.8% since 2005
- Non-residential:
  - electricity usage (49%)* has changed by 12.4% since 2005
  - natural gas usage (26%)* has changed by 5.3% since 2005

Reference Case

Davis Building Energy Use - IOU Scenario					
	2015	**2020**	**2025**	**2030**	**2035**
	Annual GWh				
Building Electricity	283.4	288.3	295.5	306.0	321.1
Residential	137.9	129.6	122.4	117.1	115.1
Non-residential	145.5	158.7	173.1	188.9	206.1
Building Natural Gas	119.6	118.1	116.9	114.2	108.5
Residential	87.8	86.7	85.5	84.4	83.4
Non-residential	31.8	33.0	34.3	35.6	37.0
Building Solar Heat	0.0	0.8	1.5	3.1	6.1
Total	402.9	407.1	413.9	423.2	435.8

* Trend information (source energy basis) was provided by the PG&E Green Communities Program

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[24] For example, rooftop solar power adoption results in installer experience and cost reductions which in turn result in more rapid further adoption.

In the IOU scenario, recent historical energy usage trends for Davis were assumed to continue over the next decades, subject to minor off-sets, e.g. due to gradual uptake of residential solar water heating. Generally, as shown in Table 8, residential energy usage declined by smaller percentages than non-residential usage increased.[25] Table 9 shows that, if these trends *do* continue in the longer term, there will be a modest increase in total building energy consumption over the next 20 years.

Local programs focused specifically on energy efficiency and conservation could alter this trajectory, but their impact would depend on their funding, design, and execution.[26] In estimating impacts for other scenarios, we assumed that such programs would be better funded and implemented and more comprehensive in the POU scenario than the CCE scenario.[27]

There are certainly a number of possible events and policy changes at the state and national levels that could change this assumption. As unlikely as twenty more years of business as usual may seem, correctly guessing which events or policy changes will actually happen and what their impacts will be is even more unlikely.

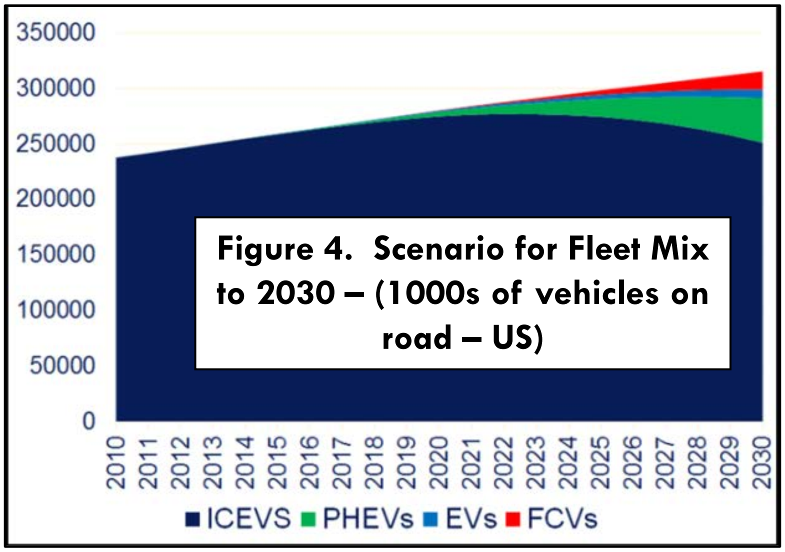

Figure 4. Scenario for Fleet Mix to 2030 – (1000s of vehicles on road – US)

Transportation Usage – IOU Scenario

As shown in Figure 4 to the right[28], though internal combustion engine vehicles (ICEVs) currently dominate, within a decade and a half, plug-in electric vehicles (PHEVs), electric vehicles (EVs) and fuel cell vehicles (FCVs) will achieve significant penetration of the US vehicle fleet. If so, it is reasonable to assume that California's uptake of these vehicles will be significantly more rapid than the US average rate and that Davis's uptake will be more rapid than California's rate. It is therefore especially important, from an integrated local energy perspective, to monitor and update actual local penetration in order to anticipate infrastructure requirements and energy fuel substitution outcomes.

Near term trends in PHEV, EV and FCV deployment are of particular importance in an integrated local energy context. PHEVs and EVs vehicles will increase electricity usage and local grid flexibility as well. Fuel cell electric vehicles may require locally generated hydrogen produced either from electricity or natural

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[25] Specifically, between 2005 and 2012, residential electricity usage (51% of total electricity usage) changed by -6.2%, non-residential electricity usage (49% of total electricity usage) changed by +12.4%, residential natural gas (NG) usage (74% of total NG usage) changed by -1.8%, and non-residential NG usage (26% of total NG usage) changed by +5.3%

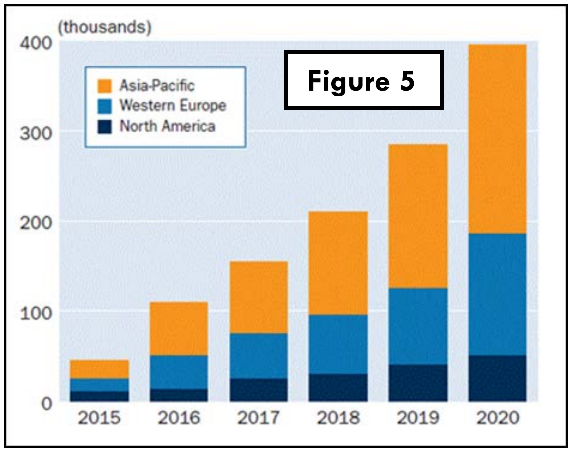
[26] Comparative statistics cited earlier represent the surprising, striking and consequential differences in energy usage, resource opportunities, demographics from one community or climate zone to the next. These differences need to be accounted for if investments in energy efficiency and conservation programs are to be applied effectively. Increasingly, effectiveness will depend on the local integration of transportation uses with building uses, on-site solar production with building uses, and community scale energy facilities with local water and waste management programs and investments. In short, local differences will need to be understood and addressed, and consumer protection cannot be cost-effectively be assured through one-size-fits all programs conceived and managed at the state level.

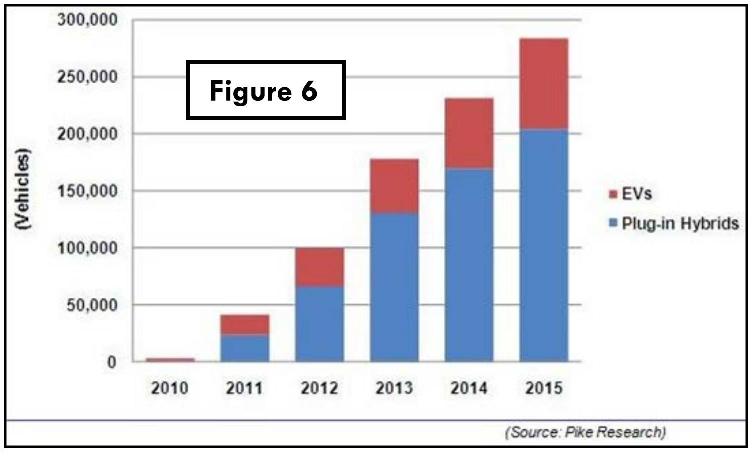
[27] At present California POUs have control of all of the public purpose funds they collect. CCEs on the other hand have access to only a portion of public purpose funds collected from their customers and therefore are dependent primarily on the local effectiveness of statewide programs.

[28] Source: http://steps.ucdavis.edu/files/08-13-2014-08-13-2014-NextSTEPS-White-Paper-Hydrogen-Transition-7.29.2014.pdf

gas. In our analysis, projected near term adoption rates for clean energy vehicles shown in the figures below were used to determine impacts on local electricity and natural gas consumption. Figures 5 and 6 below suggest that over the next five years rapid expansion of the still small local fleets may and probably may occur assuming deployment of fuel cell vehicles proceeds as shown in Figure 5 on the left, and if deployment of EVs and plug-in hybrid market growth at the rate shown in Figure 6 on the right.

Figures 5 & 6. Assumed Fuel Cell Vehicle[29] and Electric/Plug-in Hybrid Adoption Rates[30]





(Source: Pike Research)

Davis's early reference case (IOU Scenario) plug-in vehicle (PHEV and EV) adoption was assumed to imitate early Davis rooftop solar adoption, i.e. to proceed at five times California's average per capita adoption rate. Substitution of hydrogen for FCVs from solar powered electrolysis and natural gas reformation was also estimated and accounted for, again assuming higher than average adoption rates.

Table 10. Davis Transportation Energy Use - IOU Scenario

	2015	2020	2025	2030	2035
	Annual GWh				
Car					
ICEV gasoline	29.8	28.7	26.6	22.9	17.1
EV - elect.	0.6	1.1	2.3	3.7	6.0
FCEV - NG H2	0.0	0.2	0.5	0.9	1.9
FCEV - Solar H2	0.0	0.1	0.4	1.6	3.2
Van/Lt. Truck liq.	39.1	39.1	37.1	33.3	27.9
Van/Lt. Truck elec.	0.0	0.0	0.9	1.8	2.9
Heavy Trk/Bus liq.	30.6	24.5	18.4	12.3	6.1
Heavy Trk/Bus NG	0.0	6.1	12.3	18.4	24.5
Other	0.4	0.4	0.4	0.4	0.4
Totals	100.5	100.3	98.8	95.3	89.9

As shown in Table 10 on the right, transportation fuel substitution may have significant impacts over the next 20 years even in a business as usual scenario. (Recall that that fuel usage comparisons use equivalent electricity metrics.) Some shifts will be more important to local energy integration than others, i.e. those for cars and light trucks. Whether or not heavy truck usage shifts strongly to natural gas is of interest but would likely have only an incidental impact on local energy integration.

Renewable Power – IOU Scenario

Over the next two decades, in the expected absence of major incumbent utility business model changes, expansion of Davis residential solar power capacity can be expected to continue at current rates,

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[29] FCEV Source: http://www.platts.com/news-feature/2013/electricpower/powergen/fuelcellcars

[30] EV/PHEV Source: Pike Research

i.e. one hundred or more new installations per year. Even at this slow but steady rate, the installed on site solar PV capacity in 2035 will have a significant contribution, i.e. nearly 20% of local electricity consumption, as shown in Table 11 below.

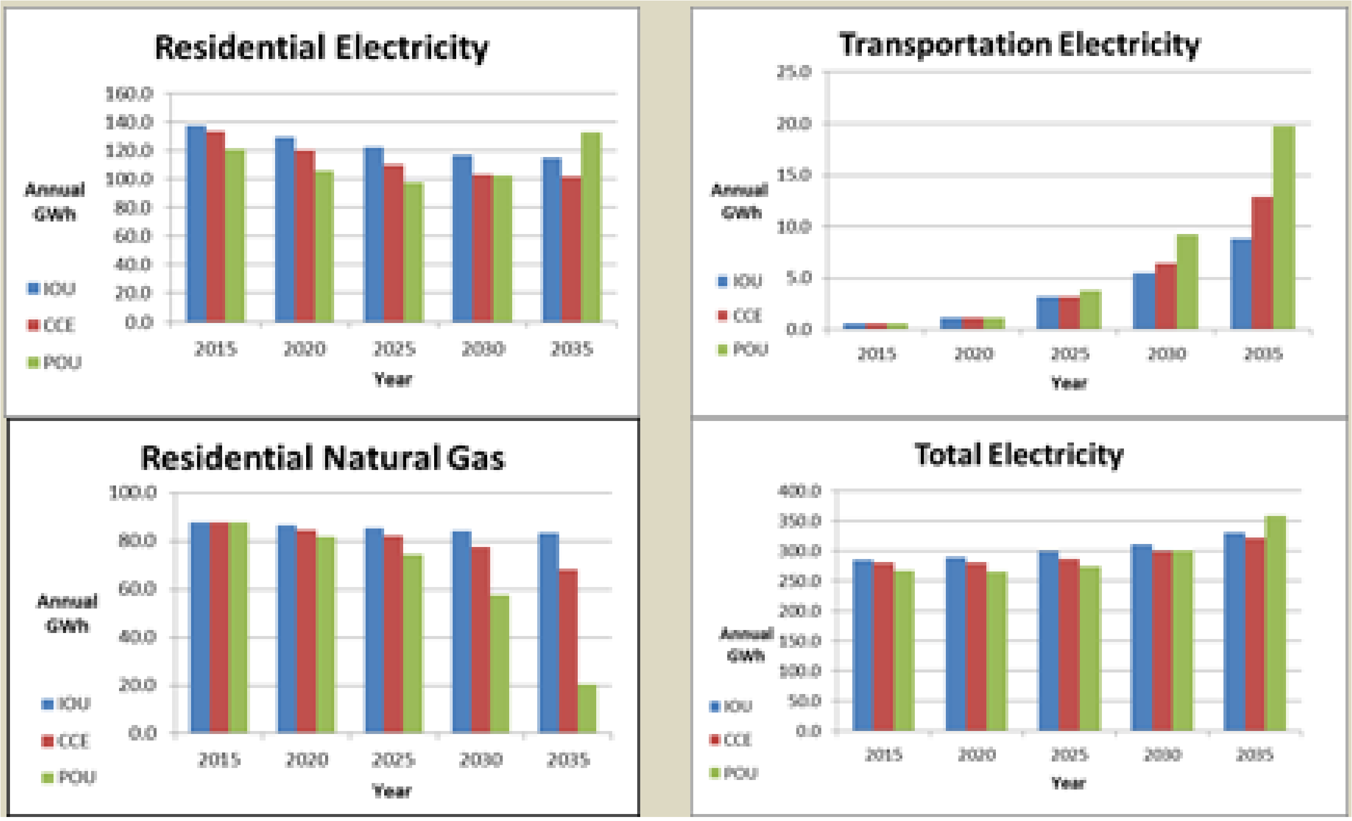
Table 11. Local Renewable Power Deployment - IOU Scenario					
	2015	2020	2025	2030	2035
Solar Target (Annual GWh)	N/A	N/A	N/A	N/A	N/A
Wind Target (Annual GWh)	N/A	N/A	N/A	N/A	N/A
On Site Solar (GWh)	35.9	44.9	52.4	57.1	60.3
Community Solar (GWh)	0.0	0.0	0.0	0.0	0.0
Community Wind (GWh)	0.0	0.0	0.0	0.0	0.0
Total (Annual GWh)	35.9	44.9	52.4	57.1	60.3
Solar Capacity (MW)	19.6	24.9	29.1	31.7	33.5
Wind Capacity (MW)	0.0	0.0	0.0	0.0	0.0

In light of continuing incumbent utility opposition and related uncertainty regarding whether local purchase of local solar garden output will be allowed, no significant increases in non-residential solar PV and local wind power capacity are assumed in the IOU Scenario.[31]

Local Power Scenarios

Accelerated Local Energy Conservation and Substitution

Figure 7. Energy Usage in Three Scenarios



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[31] This assumption is consistent with IOU proposals for implementation of SB 43, which in northern California do not provide local electricity users an opportunity to purchase electricity from local or nearby wholesale renewable electricity production facilities. Instead, the output of a portfolio of such resources is offered to all users across regional service areas. The facilities are community scale but not community based. Further, savings in transmission costs and losses based on proximity of use to generation are not accounted for.

Local energy integration has impacts on both electricity and natural gas usage. In the POU scenario[32], there could be major impacts. Lesser but significant impacts are possible in the CCE scenario, while in the IOU scenario neither local energy integration nor its impacts can be reasonably expected. As shown in the bottom right pane of Figure 7 above, in all scenarios, electricity usage increases, primarily as a result of substitution of electricity for carbon based fuels in heating and transportation applications.

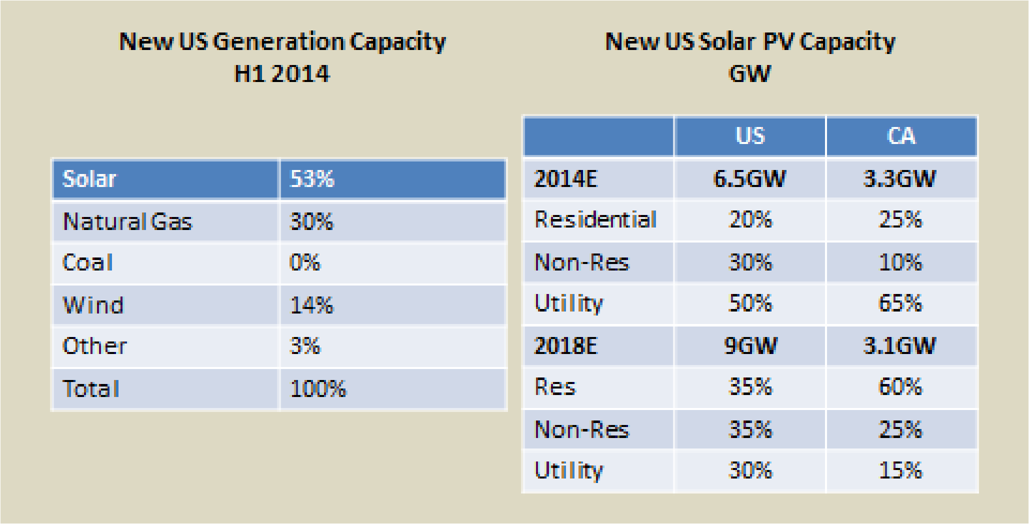
The impacts of transportation electricity usage (top right pane) on overall electricity usage are modest in all scenarios, even in 2035. Likewise, even in 2035, residential electricity usage (top left pane) remains in the same range in all scenarios in spite of different (and in some cases off-setting) effects of varying usage growth and usage reduction rates for specific sub-segments.

Higher levels of electricity and solar heat substitution for natural gas in the residential sector in the POU scenario results in reduced natural gas usage (bottom left pane). The reduction is quite substantial in the POU scenario by 2035. Substitution of electricity for fossil fuels in general tends to off-set electricity usage efficiency gains, resulting in increases in electricity usage in the second decade (top left and bottom right panes), especially in the POU scenario.

In making assumptions for the local power cases, i.e. the CCE and POU scenarios, near term usage projections are a useful benchmark, just as they were in estimating impacts of fuel substitution on the local integrated energy balance.

Accelerated Local Renewable Power Deployment

Figure 8. Renewable Power Deployment Trends – US and California[33]



New US Generation Capacity
H1 2014

Solar	53%
Natural Gas	30%
Coal	0%
Wind	14%
Other	3%
Total	100%

New US Solar PV Capacity
GW

	US	CA
2014E	6.5GW	3.3GW
Residential	20%	25%
Non-Res	30%	10%
Utility	50%	65%
2018E	9GW	3.1GW
Res	35%	60%
Non-Res	35%	25%
Utility	30%	15%

There is a sea change underway in new electricity generation capacity investments nationally. The left hand table in Figure 8 above shows that in 2014 generation capacity additions were dominated by solar and natural gas in the first half of 2014. The right hand table shows projected near term solar PV deployment in California increasing at the recent brisk pace. The expected result is that California's additions of solar PV generation will account for about half of the US total of 6.5GW in 2014, on the strength of a receding wave of utility scale (>20MW) plants in desert regions of California and southwest US states.[34]

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[32] i.e. assuming a newly formed POU

[33] Sources: Right chart: SEIA, GTM Research, Other; Left chart: FERC

[34] Note: In the reference case, Davis's share of this state-wide deployment, based on its share of state electricity consumption, would be 1-2 MW per year. This is consistent with reference case assumptions.

By 2018 distributed PV production will exceed utility scale by a factor of two in the US and nearly a factor of six in California, driving decentralized energy forward along altogether new pathways at least in those cities and counties that are free to empower local deployment.

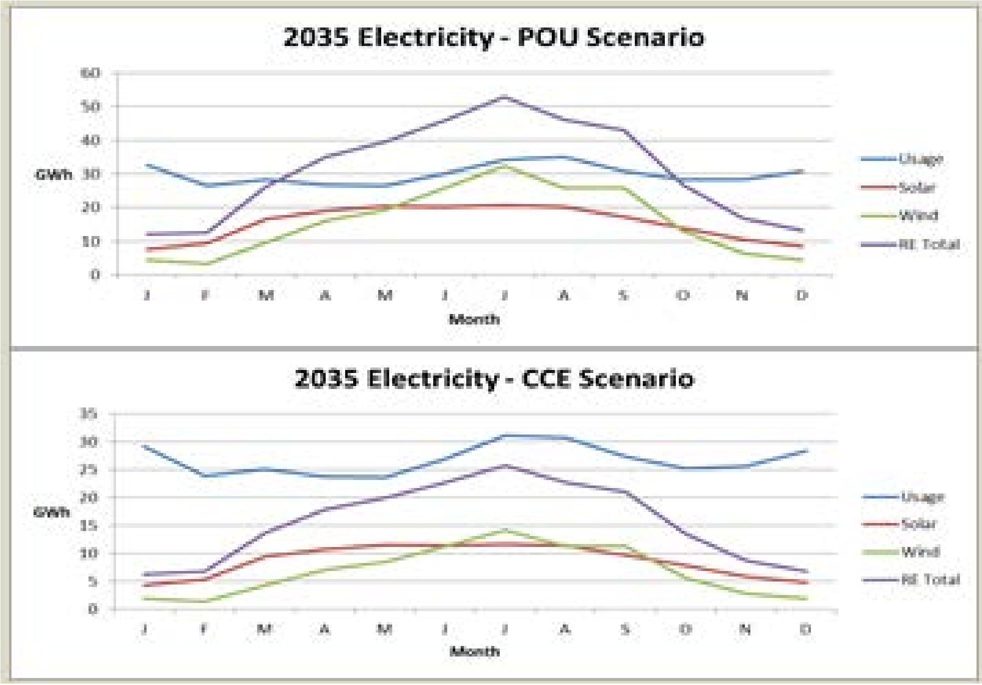
Monthly Variations in Electricity Usage and Local Renewable Power

Local renewable power deployment can be accelerated in the CCE and POU scenarios, resulting in a need for capacity and generation mix targets in these cases. In the CCE scenario there could be significant economic penalties for over-generation, so the local renewable electricity portfolio in this scenario was specified to roughly meet and sometimes exceed peak demand, but not to supply 100% of annual electricity demand.

In the POU scenario, annual local renewable electricity production was specified to match annual usage by the end of the twenty year forecast period, i.e. in 2035.[35] Preparing for this outcome would involve development and investment in local distribution grid upgrades as well as flexible generation and storage resources to achieve local monthly and real time supply/demand balance. These considerations will be covered in more detail in later sections. Detailed cost analysis based on competitive proposals would be needed to determine the optimum local renewable power portfolio in local power scenarios.

The sum of daily wind and solar supply profiles, delivering at least some electricity 24/7, results in a better match to Davis usage profiles than either solar or wind per se. So, as a test case, a 50/50 solar/wind mix was selected for both the CCE and POU scenarios. The results are shown in Figure 9 below.

Figure 9. Local Renewable Power – Monthly Under- and Over-generation



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Note that the match between demand and supply is best in the CCE scenario (bottom chart) in the summer, and best in the POU scenario (top chart) in the spring and fall. In no scenario or season is it perfect.

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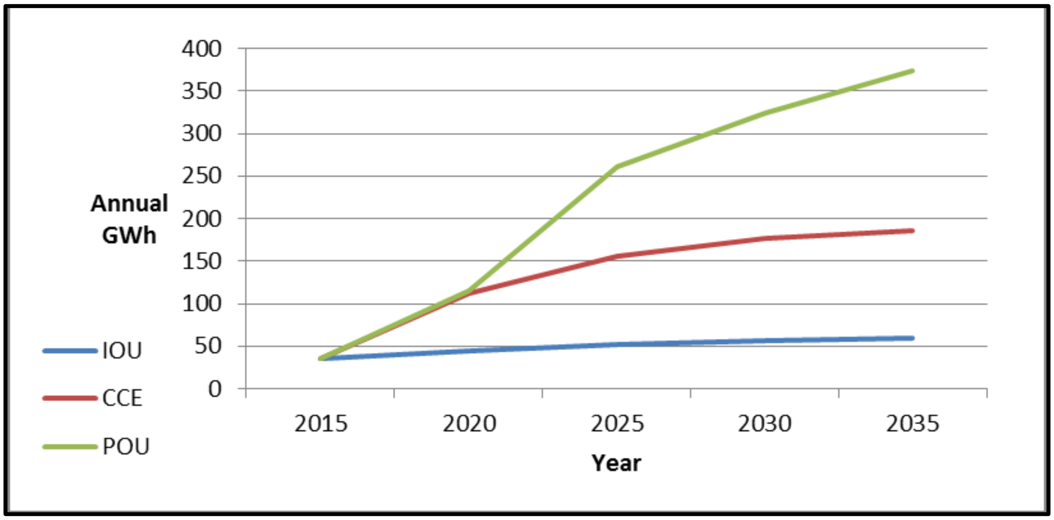
[35] Underlying this assumption is Davis's goal of climate neutrality and the assumption that configuration of statewide grids to accommodate 100% total renewable supply will take longer and perhaps be more costly than configuration of the local Davis grid to accommodate 100% local renewable supply.

A seasonal and daily match is achievable relying on imports from and exports to the regional grid. However, in the POU scenario it would be prudent to consider how a match can be achieved relying on local sources.

Local Renewable Generation Expansion

Figure 10 below compares local renewable deployment rates in the three scenarios. Predictably, local renewable deployment rates are initially comparable for the POU and CCE scenarios, but the lack of integration flexibility in the CCE scenario penalizes and limits long term *local* renewable deployment. [36]

Figure 10. Local Renewable Power Expansion in Three Scenarios



Bear in mind that the figure refers only to *local* renewable power production. In the CCE and IOU scenarios, local renewable electricity consumption may be assumed to be met with a combination of imported and locally produced renewable electricity. Absent an assumption of major changes in electricity market structure and local energy integration, the state's overall renewable electricity portfolio cannot reasonably be projected to reach much beyond 50% in the next 20 years. Meanwhile, local power scenarios can result in local renewable portfolios of 50% to 100%, perhaps opening a window of higher total overall percentages.

As a wholesale electricity purchaser, the CCE service would not have the means or opportunity to achieve a real time balance between locally produced power and local usage.[37] Thus, on average it would under-generate, while a POU's local generation portfolio could feasibly be sized to over-generate during parts of the year to match under-generation during other parts, so that on the average it would neither under- or over-generate.

It is important to underscore that a CCE service could have a *total* renewable supply portfolio equal to the projected *local* renewables portfolio in the POU scenario, but it would likely need to count on a major contribution from imported renewable electricity. In the CCE case, the CCE service's *local* solar/wind generation portfolio would be sized, not to meet the city's annual electricity usage but rather to generate as

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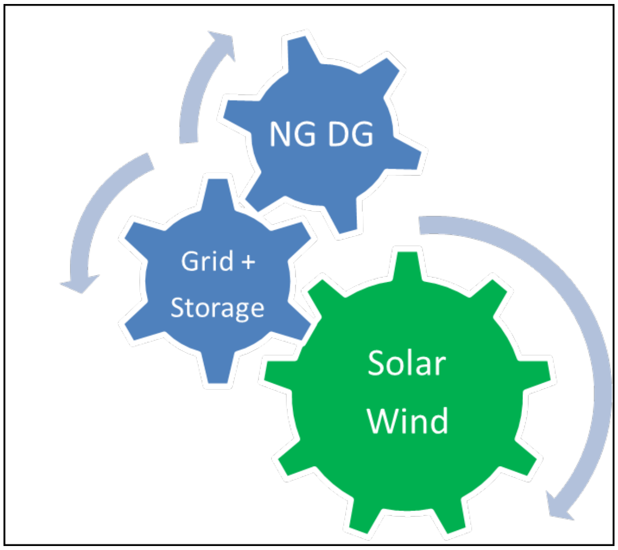
[36] At present the core business of a CCE is purchasing amounts of wholesale electricity to exactly meet instantaneous demand.

[37] A CCE does not directly dispatch generation or storage, nor can it buy/sell power from/to owners of on-site energy storage except through arrangements with the local distribution utility. Any over-generation by a portfolio of local sources contracting with a CCE would be valued according to transmission system operator market rules. Lacking an ability to predict what the future season- and time-dependent prices would be, a CCE would prudently choose not to contract for more electricity than needed any hour of the year. This means that a city CCE's local solar/wind generation portfolio would be sized accordingly, not to meet the city's annual electricity usage but rather to generate as much as possible without ever significantly over-generating. By contrast, a POU can integrate the operation of local solar/wind generation with local storage, local natural gas generation and local demand side programs.

much as possible without ever significantly over-generating, i.e. to meet demand during hours of the year when demand peaks, but not to supply all annual usage.

Local Supply/Demand Balancing

Seasonal Supply/Demand Balancing in the POU Scenario



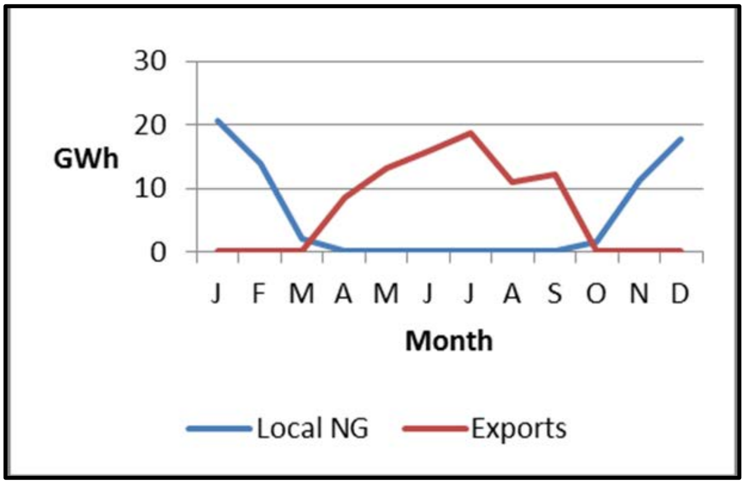
As noted above, seasonal variations of a local Davis area 50/50 solar and wind generation mix result in over-supply in the summer and under-supply in the winter in the POU scenario.

The schematic to the right identifies the mechanisms necessary to accommodate variations in local demand and supply in this scenario. Note that regional electricity grids generally use such mechanisms. Deploying and operating them locally is technically achievable according to comparable technologies and practices.

How the conceptual system to the right would be operated depends on scenario assumptions. The system elements shown might exist in any scenario but are more likely to be the main elements a community's electric system in the POU scenario. In the CCE scenario they could play a larger role than in the IOU scenario, but they would be more likely to be operated as part of the regional grid than in relation to local usage and reliability requirements.

As shown in Figure 11 below, in the POU scenario local commercial and residential combined heat and power (CHP) systems and/or flexible natural gas generation can feasibly and economically supplement local renewable generation in winter months in amounts that would be off-set by renewable electricity exports during summer months. In this scenario in 2035, exports in the summer months would equal the electricity produced with local NG fueled generators in the winter months. Summer exports would thereby potentially off-set the cost of annual local NG electricity production.

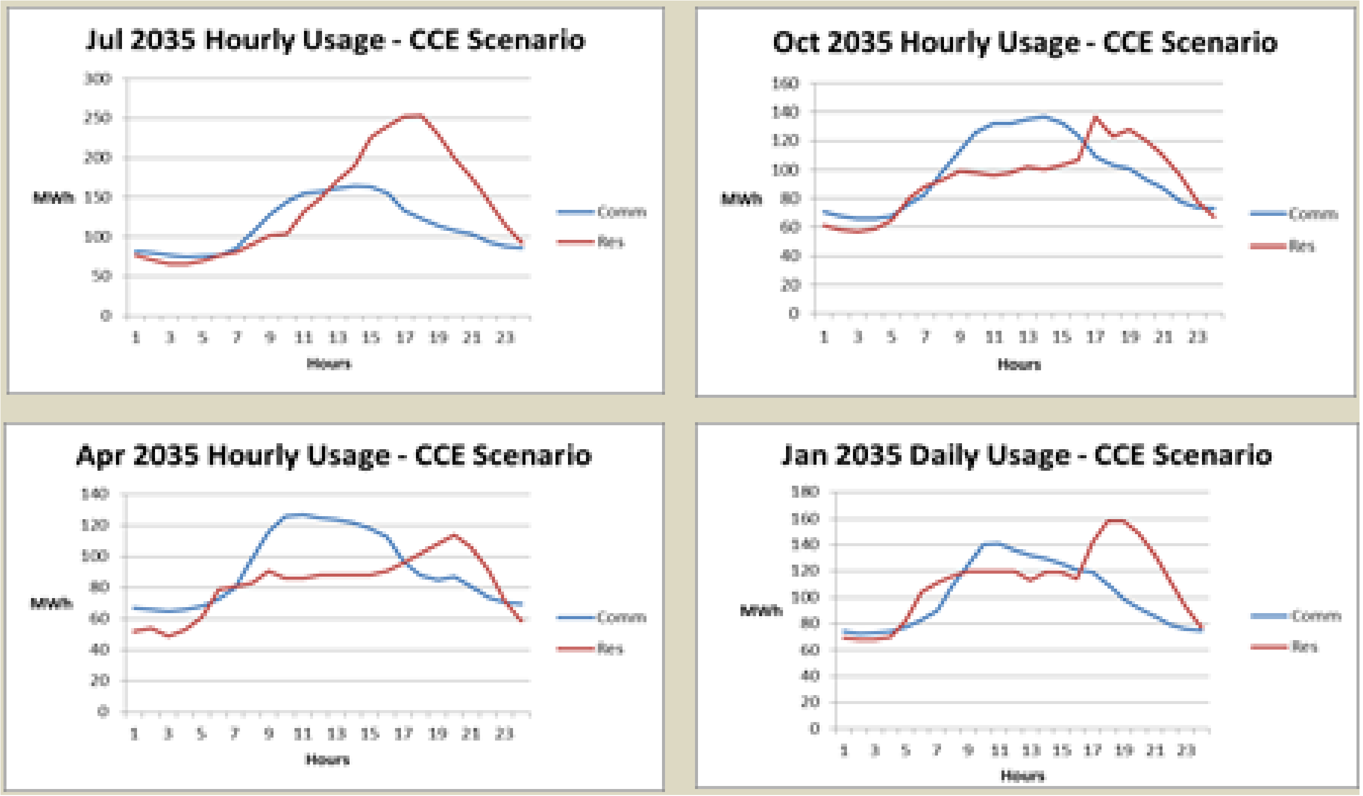
Figure 11. Monthly Exports and Balancing Generation – POU Scenario – 2035



Hourly Usage Variations – Four Seasons

Figure 12 below shows the average daily variations in Davis residential and non-residential usage in summer, fall, winter and spring months in the POU scenario in 2035. Note that vertical scales differ in the four panes of the figure. It will be important to local power system planning and operation that average daily peak demand differs substantially from season to season. The combined residential and non-residential demand profiles also have somewhat different shapes in each season as shown in Figure 13.

Figure 12. Hourly Building Usage Profiles – Local Power Scenarios – 2035


Jul 2035 Hourly Usage - CCE Scenario

Oct 2035 Hourly Usage - CCE Scenario

Apr 2035 Hourly Usage - CCE Scenario

Jan 2035 Daily Usage - CCE Scenario

Hourly Renewable Power Supply Variations – Four Seasons

Like daily usage variability, daily renewable power variability, as shown in Figure 13 below for the POU scenario in 2035, is also greater than monthly. It is relevant to more detailed renewable portfolio design and expansion that solar production profiles are a better match to non-residential usage, and wind electricity production profiles are a better match to residential profiles. So, the 50/50 solar/wind portfolio achieves a better match to the total daily usage profiles than either solar or wind by itself.

Hourly Net Supply Variations – Four Seasons

Figure 14 below shows how the daily variations in usage and supply play out in terms of net hourly supply in the four seasons. The net supply curve is indicative of the amount and timing of local under- and over-generation. As discussed above, local load-following generation would be used to meet the monthly winter balancing requirement. In summer months surplus wholesale electricity can be exported to other users via the regional grid, much as net metered solar electricity is exported from a building other buildings connected to the local distribution system. Use of local NG generation capacity for daily load-following purposes on a year round basis is technically feasible but would likely result in a mix of natural gas and renewable generation comparable to that of the regional grid.

Figure 13. Hourly Solar and Wind Power Profiles – Local Power Scenarios – 2035

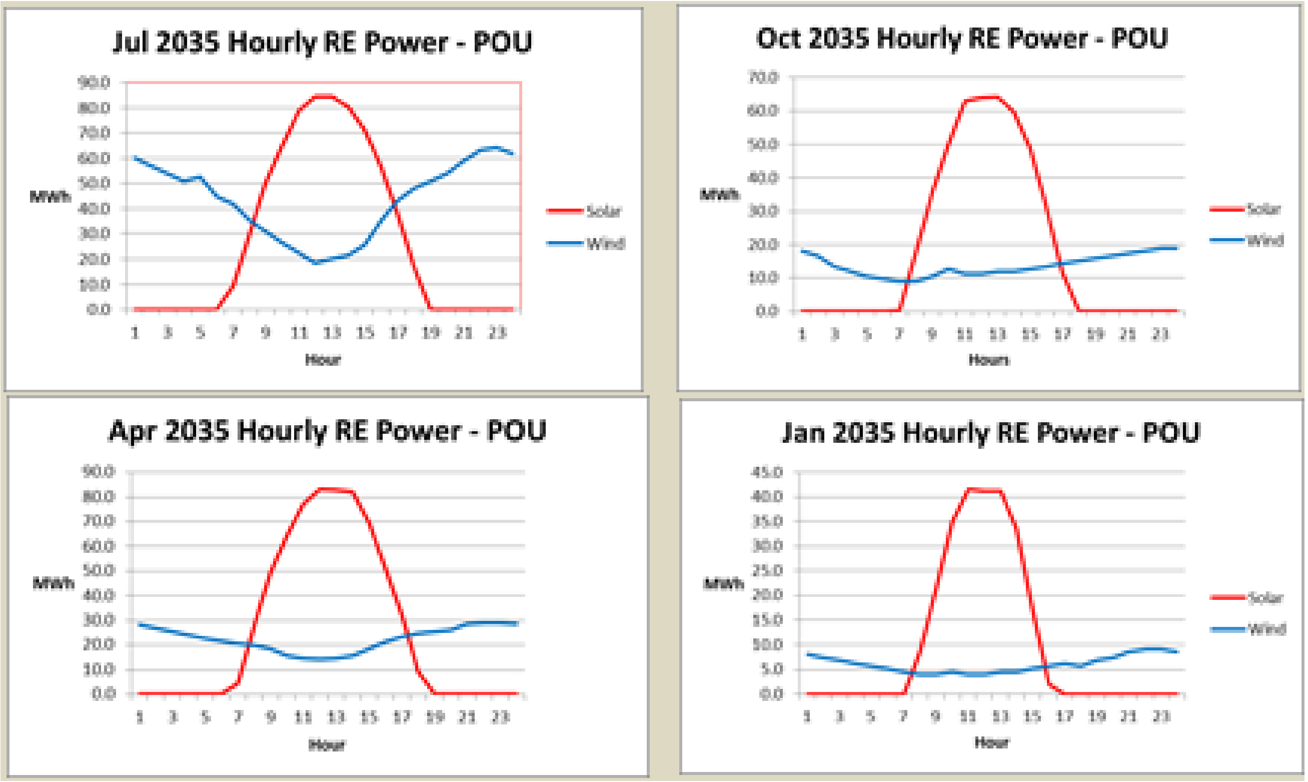
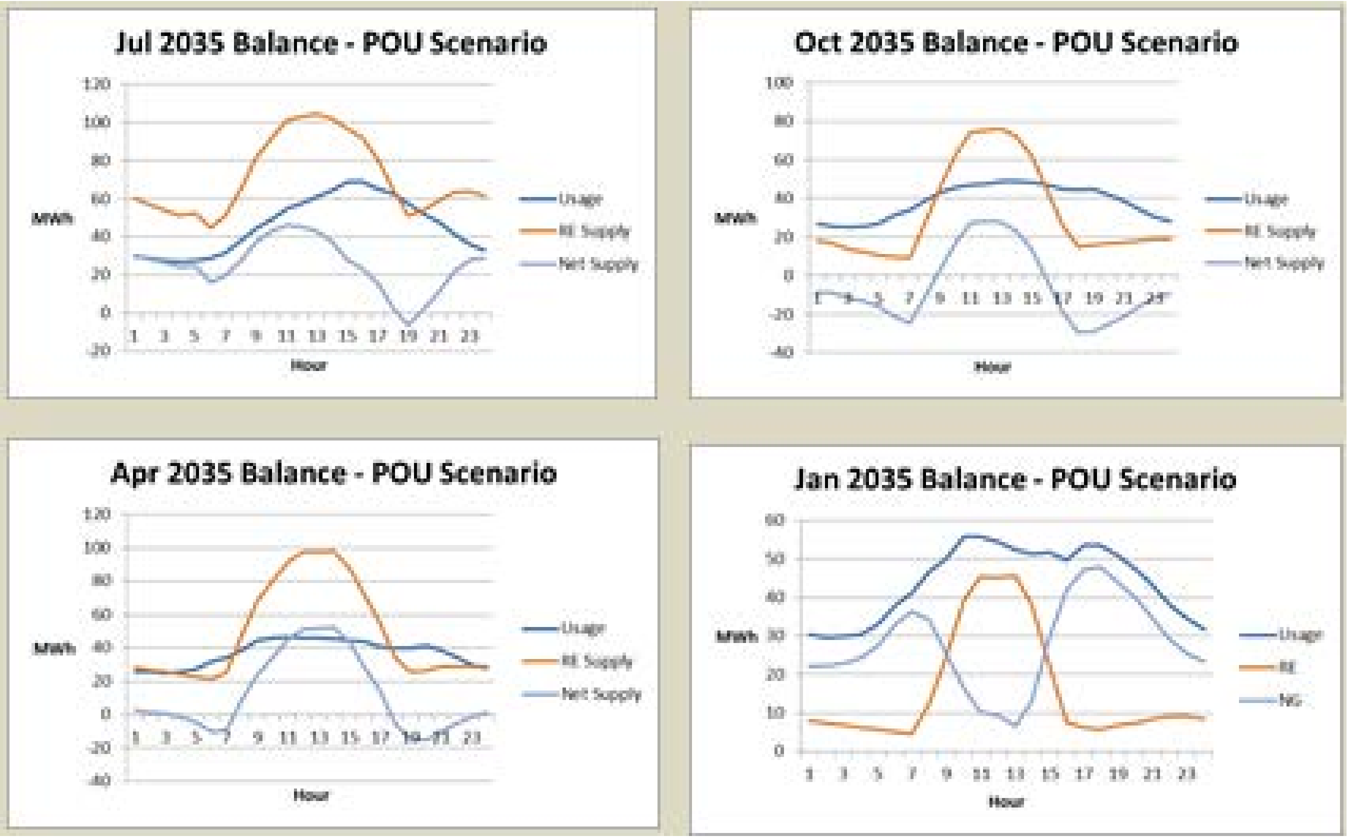


Figure 14. Hourly Building Net Supply – POU Scenario – 2035



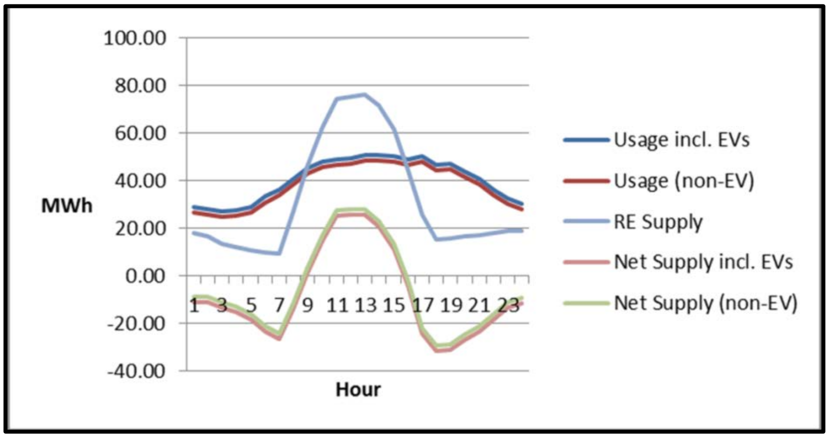
Load shifting or small grid/big grid exchange is required most of the year, even if flexible local NG generation is available. Are there local mechanisms that can achieve a better match without relying so much on local natural gas generation? Specifically, can plug-in electric vehicle based storage help?

EV Charging as a Demand Response Tool

At first blush, EV charging has potential to be a cost-effective and flexible demand response tool. Figure 15 below shows electricity usage in the last year of the POU scenario in the lowest overall usage month. Usage and net supply are shown for cases that include and do not include EV charging increments. One conclusion to be drawn from the usage comparison, i.e. with and without accounting for EV charging, is that demand response relying only on the timing of EV charging will be inadequate for small (or big) grid balancing purposes. Nevertheless, automated and locally demand response will be an important part of the tool kit for small grid balancing.

The over-arching question is how best to ensure that EV charging will be done at the at the right times and in the right amounts.

Figure 15. Electricity Usage and Net Supply – POU Scenario – October 2035



Vehicle to Grid Energy Storage

In the schematic above energy storage was shown as an element of the local grid. How much electricity storage would be required to meet the need in Davis for real time balancing of local renewable electricity supply and local usage?

In months where there is over-generation of renewable electricity, storing it and injecting it back into the local grid later is an option. The daily over-generation amounts vary from season to season, from an average of 200 MWh on an average spring day to 550 MWh on an average summer day.

The former amount is in the same range as the electricity storage capacity that would be embedded in the local plug-in vehicle fleet in the POU scenario, i.e. 6000 local EVs averaging 33kWh of storage capacity each. This fleet would represent 200MWh of storage capacity potentially capable of multiple daily charge/discharge cycles.

The complete storage solution may be a combination of stationary and vehicular storage, supplemented by continuously automated demand response and stand-by NG generation. This may suffice, assuming some excess generation can be sold to other small grids.

It is worth mentioning that small isolated grids around the world will be the proving grounds for design and operational concepts and mechanism that will be required for this level of local grid integration.

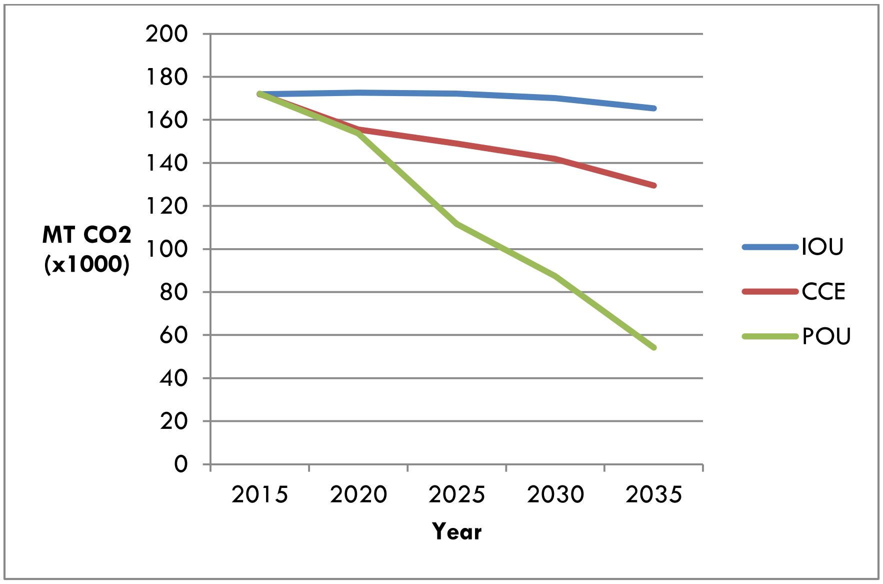
Scenario Comparisons

Carbon Footprint Comparison

Figure 16 below shows carbon footprint trajectories computed for the three scenarios. The curves may be useful in goal setting and evaluating progress on the energy service pathway selected by the city. In at least one scenario, i.e. POU, a two thirds reduction appears to be possible over the next two decades. In this case Davis's total carbon footprint would shrink to that related to heavy truck emissions.

Why are the trajectories so different? It turns out that reducing the natural gas component of Davis's energy supply is pivotal. The key thrusts are: 1) electricity and solar heat substitution for natural gas end use, and 2) reducing the natural gas share of the local electricity generation mix serving Davis.

Figure 16. Carbon Footprint Trajectories – All Scenarios



Cost of Service Considerations – Near Term

The above analysis would lack appropriate context in the absence of some discussion of comparative economics. The analysis addresses integrated local energy for a specific city. Based on rate comparisons generated by Davis consultants[38], the three scenarios would result in comparable electricity service charges at the start.

Where they would differ would be in the tariff options available to electricity customers. Tariff options currently offered by IOU and POU service providers are typically not differentiated according to sources of electricity or whether the electricity is generated locally or imported into a city from distant sources. As shown in the Figures 17 and 18 below, California CCE service providers do offer rate options according to alternative source portfolios.

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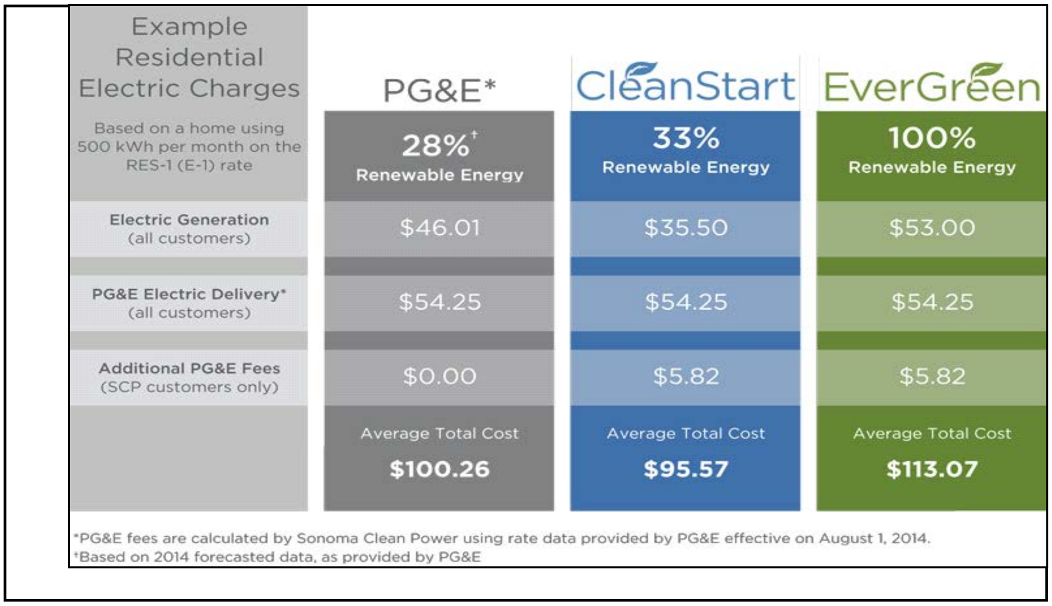
[38] http://city-council.cityofdavis.org/media/default/documents/pdf/citycouncil/councilmeetings/agendas/20131210/08-energy-service-options.pdf

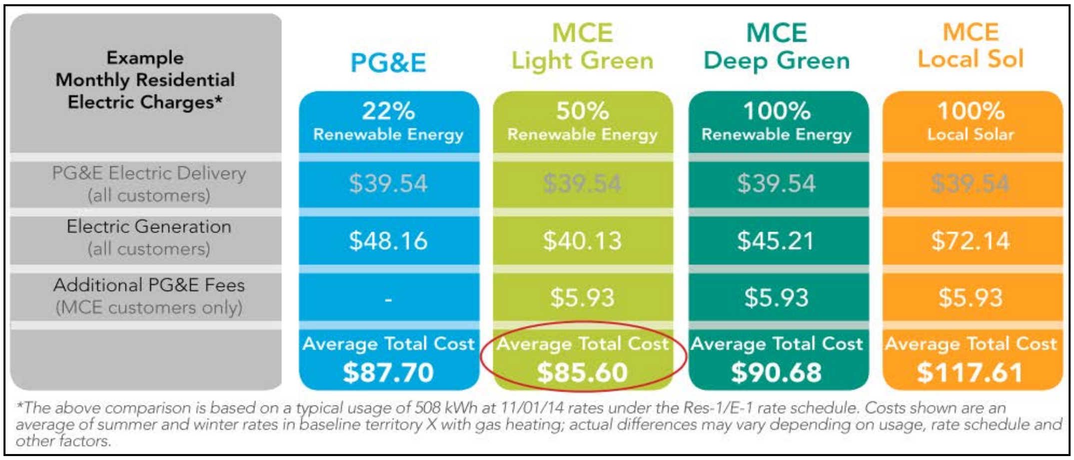
Figure 17. Sonoma Clean Power Residential Rate Comparison



Example Residential Electric Charges Based on a home using 500 kWh per month on the RES-1 (E-1) rate	PG&E* 28%† Renewable Energy	CleanStart 33% Renewable Energy	EverGreen 100% Renewable Energy
Electric Generation (all customers)	$46.01	$35.50	$53.00
PG&E Electric Delivery* (all customers)	$54.25	$54.25	$54.25
Additional PG&E Fees (SCP customers only)	$0.00	$5.82	$5.82
	Average Total Cost **$100.26**	Average Total Cost **$95.57**	Average Total Cost **$113.07**

*PG&E fees are calculated by Sonoma Clean Power using rate data provided by PG&E effective on August 1, 2014.
†Based on 2014 forecasted data, as provided by PG&E

Figure 18. Marin Clean Energy Residential Rate Comparison



Example Monthly Residential Electric Charges*	PG&E 22% Renewable Energy	MCE Light Green 50% Renewable Energy	MCE Deep Green 100% Renewable Energy	MCE Local Sol 100% Local Solar
PG&E Electric Delivery (all customers)	$39.54	$39.54	$39.54	$39.54
Electric Generation (all customers)	$48.16	$40.13	$45.21	$72.14
Additional PG&E Fees (MCE customers only)	-	$5.93	$5.93	$5.93
	Average Total Cost **$87.70**	Average Total Cost **$85.60**	Average Total Cost **$90.68**	Average Total Cost **$117.61**

**The above comparison is based on a typical usage of 508 kWh at 11/01/14 rates under the Res-1/E-1 rate schedule. Costs shown are an average of summer and winter rates in baseline territory X with gas heating; actual differences may vary depending on usage, rate schedule and other factors.*

The rate options shown in the figures obviously relate to reasons a city might elect to take charge of sourcing electricity, e.g. acting to create demand for renewable energy, acting to enable development of local resources and acting to allocate costs according to specific local policies goals. Cost allocation may be secondary to a goal of stabilizing a CCE entity financially by offering options at prices above cost and thus generating operating reserves and franchise payments the local jurisdiction can use at its discretion.

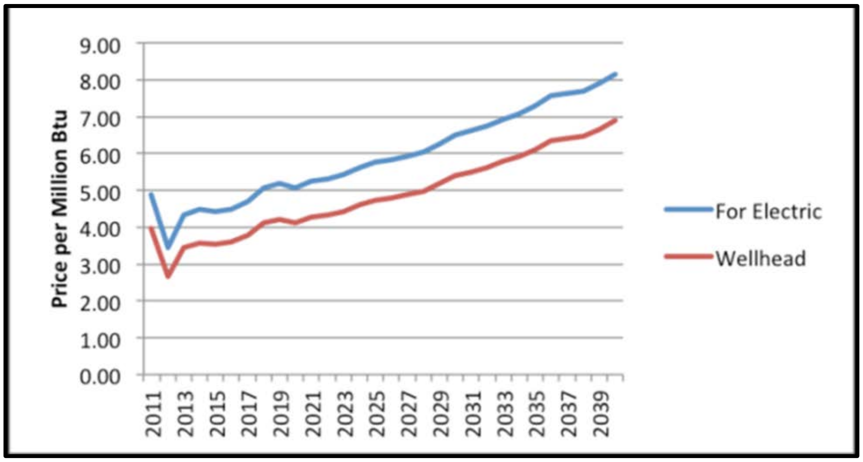
Cost of Service Considerations – Long Term

Regarding longer term cost trajectories, some general observations will have to suffice. The basic question is whether there is an economic benefit to the local community and local energy users resulting from local accountability and local technical and economic integration. The answer will come from communities that choose to rely more on local power sources and less on imported energy. All around the world these choices are being made, whether out of economic necessity or opportunity.

Meanwhile, no city lacks general and highly relevant cost trends to consider. On-site and community solar and wind generation costs are already at parity with natural gas generation costs and are expected to continue to decline as technology and manufacturing innovation continues. 45% of Davis's current electricity usage is supplied by natural gas. In the IOU scenario, there is currently little basis for assuming a dramatically lower percentage in 2035. Renewable portfolios will expand if state policies are effective and stable, but nuclear and hydroelectric contributions are diminishing as a percentage of total electricity supply.

As shown in Figure 19 below, natural gas prices (and therefore IOU electricity prices) are expected to escalate. In heavily *local* power scenarios, 2035 electricity usage supplied by natural gas can be in the 10 to 20% range, thus nearly de-coupling Davis costs from predictable escalation in costs of electricity produced from natural gas.

Figure 19. Long Term Natural Gas Price Forecast[39]



Conclusions and Recommendations

A working hypothesis motivating the analysis was that significant local integration will be required as local renewable deployment, currently accelerating in California, continues to gain traction[40]. As electricity is substituted for natural gas use in buildings and for petroleum products in transportation, and as new transportation fuels like hydrogen are produced from local renewable sources, many or most medium sized cities will need to do integrated analysis.

It will be feasible for Davis, California to use a mix of local solar and wind resources to make major strides toward carbon neutrality in the next two decades, essentially eliminating its direct carbon footprint. Figure 20 shows an ideal build-out of local clean energy resources that could be implemented over the next twenty years according to the modeling assumptions for the POU scenario. It is important to note that this build-out could also be implemented in a combined CCE/POU scenario, i.e. sequentially by a CCE in an initial phase and by a POU in a later phase. Likewise, it is reasonable to assume that CCE frameworks in California

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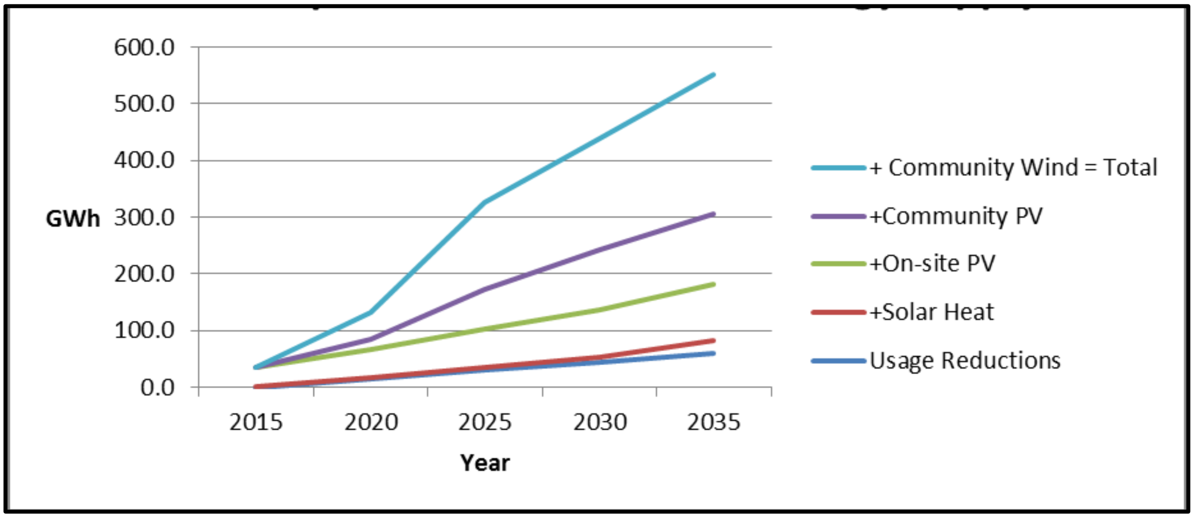
[39] US Energy Information Agency 2014 Annual

[40] Admittedly, local renewable deployment may not continue to gain traction; nor is it necessarily the quickest and most cost effective means for a local jurisdiction to shrink its carbon footprint in the short term. Longer term, local renewable deployment may be driven by a number of other factors including the technical and economic opportunity to achieve better economic integration of local transportation and energy infrastructure than would likely occur in a scenario relying more on centralized renewable and storage resources. Benefits to the local economy may also become a consideration when tools become available to better understand and quantify them. Likewise, there appear to be strong synergies between on-site solar building energy efficiency that are only beginning to be understood and quantified.

will evolve, and there is even a possibility that a desirable evolution will allow the CCE and the incumbent IOU to undertake build-out according to our POU scenario.

Figure 20. Ideal Expansion of Davis's Local Energy Supply



Conclusions - Integrated Energy Analysis

Integrated energy analysis for a specific small city should be based on realistic assumptions and pragmatic scenarios. If this approach is taken, it confirms, calibrates and in some cases challenges intuitively reasonable expectations.[41]

A combination of factors, especially in northern California, is rapidly creating a new need that will confront increasing numbers of cities in the next decade, i.e. for locally specific and detailed renewable deployment analysis and planning.

The required analysis will have to account for expected patterns of end use energy substitution, e.g. electricity for natural gas and other fossil fuels. This will be unfamiliar and especially tough work unless better information, now held as proprietary by regional utilities, is routinely shared with local jurisdictions.

Conclusions - Locally Accountable Energy Service

Development of local renewable resources, while essential to achievement of local carbon footprint reduction goals, is likely to be slow except in cases where energy service is:

- accountable to local citizens, and
- planned and managed to account for surprisingly large local variations in energy (electricity and natural gas) usage and seasonal and hourly local supply variability

Ultimately, locally accountable energy service may be a necessary condition for locally integrated energy planning and deployment, especially where local economic and environmental improvements are targeted.

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[41] For example, it might be expected that energy use in a low growth city like Davis would be decreasing in response to climate action goals and plans adopted by the city in 2010. However, between 2005 and 2012 there was actually an increase in total building energy consumption in spite of the off-setting effects of displacement of energy imports by local solar energy generation toward the end of the period.

In the near term, a community choice energy framework, like those being adopted by other California communities, could enable development of local solar and wind resources that would not otherwise be developed. However, the increasing need for integration between regional utility and local planning will be a limiting factor when peak local electricity production reaches and begins to exceed coincident local electricity demand.

Davis, California's building energy usage, and much of its transportation usage could, realistically and economically, be supplied by a mix of local solar and wind resources, resulting in a near zero local carbon footprint within two decades. However, this would require local planning and operation of local electricity infrastructure similar to that currently accomplished by other small and medium sized cities in northern California through the agency of municipal electric utilities.

Recommendations

The results presented in this report provide a generally integrated outlook for one specific and relatively unique city, an outlook that raises specific integration questions needing attention in further analysis. The present analysis probably suffices for Davis until Davis adopts and implements a new energy service pathway.

In approaching the preliminary analysis reported above, data shared by the incumbent energy utility currently serving Davis was quite helpful in some aspects, but restrictions and formatting also limited timely usefulness. Unfettered access to better, more complete, appropriately formatted and less restricted data and information will result in more reliable planning guidance. Models and data sources must also be upgraded to allow more confident evaluation of more detailed scenarios, more variations on key assumptions and easier updating in support of consequential planning and investment decisions.

Throughout the report the term "local" was used without a clearly stated definition, on the assumption that the difference between local and centralized required no clarification. In retrospect, clarification is required and recommended for purposes of further analysis. Our implied definition of local renewable power included on-site solar PV and community wind plants within ten to twenty miles and community solar plants somewhere in between. Meanwhile, at least one CCE operating in California offers a tariff that allows its customers to choose electricity from a "local solar farm located in our service area", i.e. within 100 miles. Were a larger regional utility to use a similar definition, local could mean within 500 miles or more. A better context for defining local would be "feeding in to a specific community's electric system circuits", i.e. as opposed to feeding in to a regional transmission system.

The following partial list identifies a few of the more obvious issues not accounted for by models and assumptions of the present analysis in their current stage of development. Should Davis or other cities aim to meet local energy needs with a mix of solar and wind resources similar or comparable to that assumed in the POU scenario, further analysis is recommended to address:

- The need for a more careful economic evaluation of community solar and wind siting opportunities
- Projected changes in the non-residential segment of specific local electricity and natural gas usage
- Projected changes in on-site electricity and heat supply resulting from implementation of local combined heat and power deployment goals and strategies[42]
- Options for long term finance and ownership of on-site power supply and grid infrastructure.[43]

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[42] Growth is expected in residential and commercial segments of the US combined heat and power market in the coming years. Local CHP capacity would be a welcome and valuable complement to local solar and wind generation capacity. At present Davis has no residential or commercial CHP installations.

[43] A separate report points to the economic advantages of local investment in local energy resources and infrastructure. See G. Braun and S. Hazelroth, "Energy Infrastructure Finance: Local Dollars for Local Energy", Electricity Journal, June, 2015.

- Evolution of the city's capacity to provide integrated local energy service.[44]
- Infrastructure integration for fuel cell electric vehicle fleets and local solar hydrogen production/distribution.[45]
- Economic and local generation capacity implications of energy storage round trip losses. [46]
- Potential for thermal (hot and cold) storage for supply/demand balancing, esp. storage coupled solar thermal power plants.[47]
- Scenario comparisons that account for local macro-economic benefits of local energy related services and programs.[48]

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[44] There are a number of on-going state regulatory proceedings addressing the possibility of power sector transformation. None are addressing the expected evolution of public power frameworks, including municipal utilities and community choice energy.

[45] The integration of electricity and transportation infrastructure is starting to receive attention in California, and the National Renewable Energy Laboratory is addressing the broader, longer term integration involving renewable fuels as well as renewable electricity, there is as yet no credible locally specific analysis of the important trade-offs and infrastructure integration issues. The natural gas industry is conspicuously absent from the conversation.

[46] Vehicle to grid energy storage is receiving increasing policy and commercial attention, but as yet there is little or no public domain data with which to evaluate the economics implications of losses that will be incurred using vehicle batteries for demand response or load shifting purposes.

[47] A primary advantage of solar thermal power, aka CSP, and cold water storage, is the roundtrip efficiency of thermal storage in general. While CSP plants tend to have greater economies of scale than solar PV plants and are therefore typically seen as a central station power plant option, their evolution and their value in operating and optimizing small, local grids will deserve attention as some local grids begin to require the extensive use of flexible generation and energy storage for balancing, load shifting, demand response and other purposes.

[48] Specifically, revenue generation and cost saving options that are possible in the local power scenarios