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February 26 2015

State of California Air Resources Board
Research Division
FY2015-2016 Research Plan Implementation

SUBJECT: Draft Proposal entitled "*Zero-Carbon Buildings in California: A Feasibility Study*"
UC Berkeley Principal Investigator: Professor Louise Mozingo
Period of Performance: 9/1/2015 – 6/30/2017
Amount of Request: $345,542
UCB Proposal Number 6748

To Whom It May Concern:

On behalf of the Regents of the University of California, we are pleased to submit the above referenced proposal to the to the California Air Resources Board in response to the FY2015-2016 Research Plan Implementation solicitation.

Please note: An indirect costs rate of 10% has been included in this draft proposal on the assumption that any resulting award will contain terms that are consistent with the agreed upon Standard UC – ARB Interagency Agreement Terms. Should these terms not be used, an indirect cost rate of 25% would then apply which would increase the total amount requested.

The University representative to whom questions may be directed and with whom award negotiations may be conducted is Paul S. Martinez who may be reached at psmartin@berkeley.edu or at (510) 642-8115.

Contract and grant documents should be issued in the University's corporate name:
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c/o Sponsored Projects Office
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Award documents that are sent electronically should be forwarded to spoawards@berkeley.edu.

Thank you for your consideration of this proposal.

Sincerely,

Paul S. Martinez
Contracts and Grants Officer
Sponsored Projects Office

DRAFT PROPOSAL

Zero-Carbon Buildings in California: A Feasibility Study

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February 20, 2015

Check if applicable:

_____ Animal Subjects
_____ Human Subjects

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Abstract

The purpose of this research project is to assess the feasibility of building-scale transportation, water, and waste management strategies to supplement existing zero net energy (ZNE) goals to achieve zero carbon building in California. The research team will quantify, for each of several building types, the potential for each strategy to reduce greenhouse gas (GHG) emissions below anticipated future baseline levels and then assemble those strategies as graphical "wedges" that, over time, fully displace the area under the curve of anticipated building-related emissions. These future baseline levels will be established through analysis of the 2013 California Green Building (CalGreen) standards and other state laws, regulations, and targets that will impact the GHG intensity of building-related transportation, water and waste over the coming years. The GHG abatement potential of the strategies will be established through synthesis and updating of extensive previous work performed by the members of this research team (UC-Berkeley Center for Resource Efficient Communities, Fehr and Peers Associates, and the Horvath lab at the UC-Berkeley College of Engineering), the results of previous ARB-sponsored research efforts (especially Salon 2014 and the briefing memos collectively entitled *Research on Impacts of Transportation and Land-Use Related Policies*), and other major sources.

The project will consist of four technical tasks:

Task 1: Zero carbon building strategy inventory, in which the research team will define multiple tiers of zero carbon construction, identify the specific building types to be studied, and assemble an inventory of the pertinent transportation, water and waste strategies (including their demonstrated and potential GHG abatement efficacy, any construction or installation cost premiums, and payback periods associated with those premiums).

Task 2: Zero carbon building feasibility analysis, in which the research team will establish future building performance baselines in transportation, water and waste for each building type, and then perform the wedge analyses to assess how the strategies (including the potential use of offsets or in-lieu contributions) can combine to displace all of the GHG emissions under each baseline emissions curve by selected target dates.

Task 3: Discussion of zero carbon retrofit potential for existing buildings, in which the research team will identify which of the strategies used in the Task 2 wedge analysis are applicable to existing buildings in the various building types, what their collective GHG abatement potential is relative to future performance of existing buildings, and what are feasible goals for existing building retrofits to near-zero carbon status.

Task 4: Setting targets and appropriate policy framework, in which the research team will make recommendations to ARB on appropriate targets for zero carbon building (utilizing the three tiers of zero carbon building established in Task 1 and the results of the wedge analyses in Task 2) and will assess the GHG benefits and cost-effectiveness of zero carbon buildings over and above both the 2013 CalGreen standards and the ZNE building standards.

The proposal also describes the robust body of recent and ongoing research that this project will draw upon, the research team's qualifications to perform this work, the project management plan, and the data management plan. The proposed project term is 21 months (15 months for research and 6 months for review and revision of the final report).

Introduction

The State of California passed AB 32 – a.k.a. the "Global Warming Solutions Act" – in 2006 to bring the state's greenhouse gas (GHG) emissions levels down to 1990 levels by 2020. At roughly the same time, then-Gov. Schwarzenegger issued Executive Order S-3-05 that established an official state goal to reduce GHG emissions to 80% below 1990 levels by 2050. While the state is on track to meet the 2020 targets codified in AB 32, significant work remains to be done to meet the much more rigorous 2050 target.

The Air Resources Board (ARB), from the first AB 32 Scoping Plan (2008) onwards, has identified green buildings as a component of any effective GHG reduction plan. Green building strategies affect not only the operational energy use of the buildings but also the water usage, waste disposal rates, and transportation patterns of the buildings and their occupants. In the initial Scoping Plan to strategize GHG reductions to 2020, green buildings were included as a supplementary, cross-cutting strategy whose potential GHG reduction benefits were quantified at 26 MMT CO2e/year based on analysis from the Climate Action Team (CAT 2008). This estimate did not even include potential GHG reductions associated with building-related transportation, which for some building types are larger than operational energy, water and waste-related GHGs combined (Mozingo and Arens 2014). By including this strategy, ARB recognized the fact that buildings collectively are among the largest end-users of energy in the state and that major improvements to their overall efficiency will be necessary even as electricity and fuel stocks are gradually de-carbonized.

The First Update to the Scoping Plan (ARB 2014) began identifying post-2020 strategies that would be needed to put the state on a trajectory to meet the 2050 emission goal. The First Update makes reference to the existing policy goals promulgated by the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) that all new residential buildings constructed in California be Zero Net Energy (ZNE) by 2020 and all new commercial construction be ZNE by 2030. However, even if these standards are achieved, two important issues would remain unaddressed in the absence of other policy action. First, building-related emissions from transportation, water and waste would remain at levels incompatible with achievement of the 2050 GHG emissions goals. Second, buildings constructed before these threshold dates (which will still comprise a sizable fraction of the buildings standing in 2050) would still trigger substantial GHG emissions through their routine operations.

For these reasons, the First Update identifies the need for an assessment of the feasibility of Zero Carbon Buildings (ZCBs) that generate no, or nearly no, GHGs from transportation, water, and waste in addition to operational energy. This is a much more ambitious undertaking than ZNE. Transportation behavior, in particular, is very GHG-intense and is shaped by many factors other than building design and operations, including factors ranging from the individual (e.g. what trips to what locations a particular building occupant needs to take each day) to the regional (e.g. how extensive a mass transit network exists) to the global (e.g. gas prices). Nonetheless, there are many strategies that building designers and operators can implement that affect the transportation choices of the occupants, most importantly the choice of where to locate the building in the first place.

Previous research by the participants in this proposal has shown that deep reductions in GHG emissions are indeed possible through design strategies related to transportation, water and

waste. PI Louise Mozingo and lead researcher Dr. William Eisenstein recently completed a study for ARB (Mozingo and Arens 2014) on the GHG emission reductions in transportation, water and waste achieved by certified green office buildings in California, finding that office buildings using the LEED-EBOM system were able to reduce their GHG emissions from water use by 50% relative to conventional office buildings, emissions from solid waste by 48%, and from transportation by 5%. Buildings seeking extra performance credits on water and waste were able to reduce their emissions by 69% and 62%, respectively, relative to conventional office buildings. Transportation emissions reductions, though much smaller on a percentage basis, were much larger on an absolute basis because the GHG intensity per building square foot of transportation activity is over 90 times higher than that of water usage, and over 170 times higher than that of solid waste generation, for commercial office buildings in California. (These ratios will vary, perhaps substantially, for other building types.)

There is good reason to believe that much greater reductions are possible than those reflected in that study. The LEED-EBOM system that certified the buildings under examination did not require the implementation of specific strategies to manage transportation, water and waste, only that the buildings meet certain performance thresholds. Thus, the study did not offer insight into the *maximum* reductions achievable from full implementation of a wide range of strategies. Moreover, because LEED-EBOM applies to existing buildings, some strategies that are more economical to implement in new construction (such as double-plumbing to permit internal water re-use, or limitation of parking) were likely not prevalent among the buildings in the dataset.

Fehr and Peers Associates, a proposed sub-contractor on this research team, has conducted groundbreaking research on the efficacy of GHG-abatement strategies in transportation at both the project and plan scales. At the project (building) level, they quantified the GHG-abatement efficacy of various transportation strategies for CAPCOA (2010), now a standard reference for methods on documenting project-level GHG emissions reductions for purposes of CEQA review. Fehr and Peers has also created validated project and strategy evaluation tools for the U.S. EPA, the Bay Area Air Quality Management District (BAAQMD), the Southern California Association of Governments (SCAG), and the San Diego Association of Governments (SANDAG) that are directly pertinent to this research. In addition, research team member Jerry Walters is a co-author of *Growing Cooler* (Ewing et al 2008), a landmark synthesis of the research quantifying the connections between urban land use patterns and GHG emissions.

Prof. Arpad Horvath and Dr. Jennifer Stokes have conducted extensive prior research since 2001 on the energy use and GHG emissions associated with water and wastewater systems in California at physical scales ranging from the building to entire utilities. This has included detailed life-cycle assessments (LCAs) of four water utilities, two wastewater systems, and a building-scale recycled water system (Stokes and Horvath 2006, 2009, 2010, and 2011; Shehabi, Stokes and Horvath 2012). As part of this line of research, they have developed the Water-Energy Sustainability Tool (WEST) and the Wastewater-Energy Sustainability Tool (WWEST), both of which are Excel-based decision support tools designed to assist industry professionals, regulators, and policymakers in quantifying the energy and GHG effects of water and wastewater design, investment and management decisions (see http://west.berkeley.edu). The Horvath/Stokes team has also developed a GHG abatement cost curve for selected water management technologies (Stokes, Hendrickson and Horvath 2014). Their current research includes developing a GIS-based estimate of embedded energy and GHG emissions in water

supplied to each of the ten hydrologic regions in California, and assessing the potential costs and benefits of neighborhood-scale off-the-grid wastewater treatment and water reuse technologies, both of which will supply information directly useful to the current proposal.

Objectives

The purpose of this research is to explore the technical feasibility of zero carbon residential and commercial new buildings to support the development of state targets and policy frameworks on zero-carbon building. This involves accomplishing four objectives:

- Assess the efficacy of existing and anticipated building-level strategies used to manage transportation, water and waste in reducing GHG emissions for multiple types of residential and commercial buildings, and identify construction cost premiums (if any) and payback period for each strategy

- For each building type, project the potential performance of those strategies, individually and collectively, in reducing GHG emissions of new construction from anticipated future baseline levels (as derived from the California Green Building Standards and other important state laws and policies) to zero by a specified time horizon

- Discuss the applicability and effectiveness of the strategies in achieving near-zero carbon status on existing residential and commercial buildings

- Identification of appropriate zero-carbon building construction targets by specified "milepost" years, and of an appropriate policy framework needed to support and incentivize achievement of these targets

The four technical tasks described below align directly with these four objectives. Two additional tasks are devoted to effective final reporting and project administration.

Technical plan

The following sections will describe each of the six tasks (four technical tasks and two administrative tasks) in detail, including descriptions of the research methods and data sources to be employed in the research.

Task 1. Zero-carbon building strategy inventory

The objectives of this task will be (a) to define the scope of the term "zero carbon" as it pertains to transportation, water and waste strategies; (b) to identify the building types to be studied in the subsequent tasks; and (c) to assemble an inventory of the transportation, water and waste strategies to be used in subsequent tasks.

For subtask (a), the researchers will define the scope of zero carbon building by distinguishing between multiple tiers of zero carbon achievement in each of the three resource areas. Given the ambitiousness of achieving zero carbon buildings, these tiers will be desirable to facilitate the setting of intermediate state goals and policies on a path to zero carbon building. In

transportation, this will involve identifying the following three tiers, all of which will be subject to analysis in this study:

- Tier 1: Zero GHG emissions from fleet vehicles and building-originated trips
- Tier 2: Zero GHG emissions from commutes to buildings
- Tier 3: Zero GHG emissions from customer and visitor trips to buildings

(A potential fourth tier, zero GHG emissions from the transportation lifecycle, is beyond the scope of this study, as stated explicitly in the RFP.)

Tier 1 zero carbon status would involve three key components:

- Optimizing GHG efficiency of building-based fleet composition
- Reducing the number of building-based vehicle trips and vehicle miles travelled (VMT) via strategies that provide opportunities for mode shift, trip consolidation, optimal sizing of vehicles to purpose, least-distance and least-congestion routing and sourcing locations, and shifting of travel to non-peak times.
- Shifting dependence for certain trip purposes from privately owned to building-based fleet vehicles for delivery of goods and services, connecting intra-campus activities, commuters, and visitors.

Tiers 2 and 3 would be achieved through employment of a wide variety of building-related transportation strategies enumerated under subtask (c) below and quantified in Fehr and Peers' previous research for CAPCOA, several MPOs, and a number of individual businesses and developers.

With respect to water and waste, the research team will identify two tiers of zero carbon achievement:

- Tier 1: Zero GHG emissions from in-building water and waste systems (including pumping, heating, and materials handling functions)
- Tier 2: Zero GHG emissions from delivery and disposal/treatment of water and waste

In these cases, Tier 1 refers to the processes directly under the control of building designers and operators, including water heating, internal water circulation, and solid waste handling. Tier 2 refers to the GHG emissions triggered in other phases of the life cycle of water and waste, including the delivery of water and materials to the building, wastewater treatment, landfilling and recycling. In the case of water delivery, this will involve accounting for regional variability in the energy intensity of water deliveries, drawing upon research performed in Mozingo and Arens (2014), CEC (2006) and Blanco et al (2012).

For subtask (b), the research team will then identify the building types to be studied, including both single- and multi-family residential and four types of commercial buildings. The commercial building types will be selected to reflect the diversity of the commercial building stock, which vary dramatically in their occupant density and resource use patterns. Office buildings, for example, have very high occupant densities and thus very high transportation impacts relative to many other types of commercial buildings, whereas restaurants and hotels

have very high water use per square foot and very different waste generation profiles relative to other building types. By selecting the commercial building types that represent the "bounding cases" at the extremes of these comparisons, the research will encompass the full range of conditions which state policy makers must consider in crafting zero carbon building policy.

For subtask (c), the research team will assemble the full inventory of strategies potentially useful in reducing GHG emissions from transportation, water and waste at the building level. For each strategy, the research team will review existing literature or current professional practice to identify:

- Typical and potential GHG abatement effectiveness
- Any existing cost premium in new construction
- The payback period for those cost premiums

For transportation, the strategies to be considered in this inventory include at least these:

- Location in transit-rich neighborhoods
- Location in other compactly developed, mixed-use areas
- Provision of alternative-fuel fleet vehicles
- Provision of on-site services
- Telecommuting and teleconferencing
- Technology- and incentive-assisted mode shift and trip-chaining for commuters, visitors, deliveries
- Employer or building-provided transit benefits/discounts
- Occupant education campaigns or other persuasion
- Parking management and pricing
- Parking preferences for alternative-fuel vehicles, carpools, and vanpools
- Provision of alternative fueling infrastructure
- Bicycle infrastructure, parking, and showers
- Carpooling/vanpooling (especially if alternative fuel)
- Private buses (especially if alternative fuel)
- Autonomous vehicles (especially if alternative fuel)

The final list will be drawn from the more than 50 strategies documented by Fehr and Peers in CAPCOA (2010) as well as validated project and strategy evaluation tools developed previously by Fehr and Peers for US EPA, BAAQMD, SCAG and SANDAG. The research team will also consult the ARB-sponsored series of briefing memos entitled *Research on Impacts of Transportation and Land Use-Related Policies* (ARB 2013-14) for additional quantitative evidence of GHG reduction efficacy of various strategies. In addition, the research team will undertake new research as necessary on emerging strategies (such as autonomous vehicles) and growing experience with established programs.

The CAPCOA (2010) research identified transportation measures that could be applied at the building or development site level to reduce GHGs (see Figure 1 below), and the credible evidence on their individual efficacy, to create a framework for evaluating the effects of various combinations of measure in different regional settings. The methods take into account synergies and mutually exclusive tendencies among the individual measures, and the extent to

which different packages of measures combine for an overall effect relative to the maximum reported within the relevant regional context.

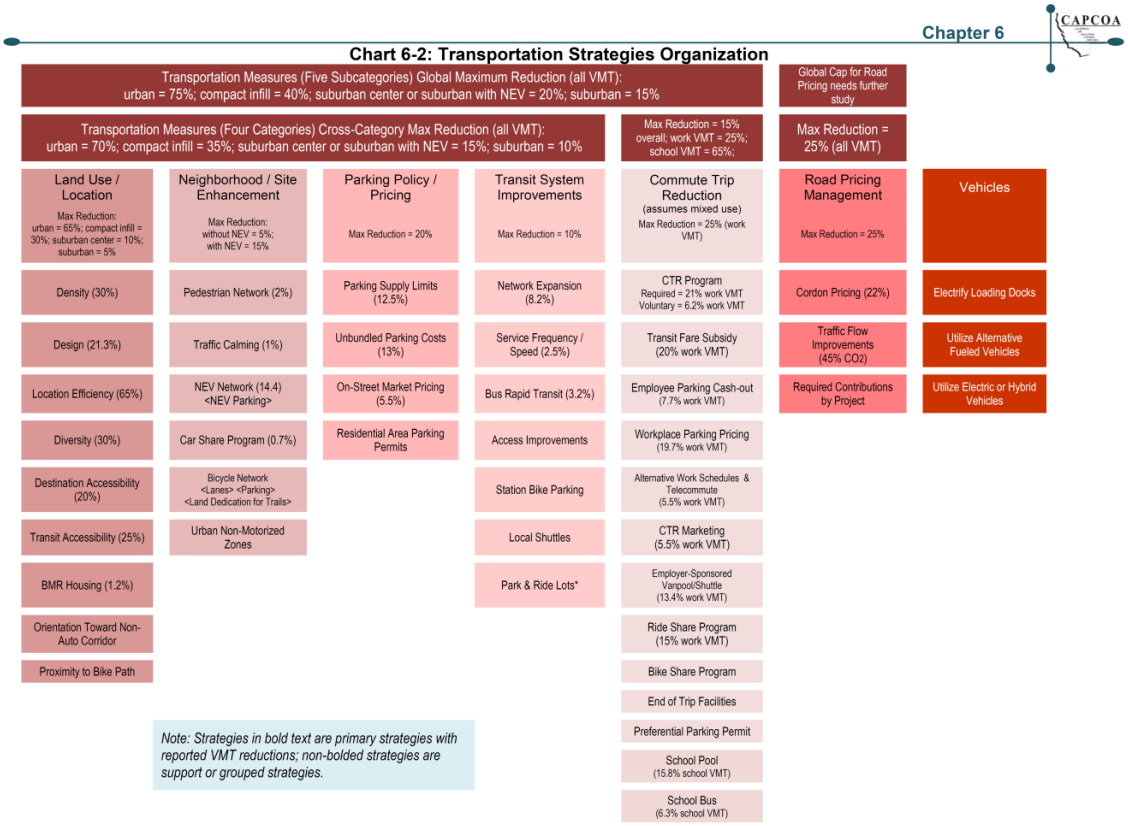

Figure 1. Transportation Strategies with Quantified GHG-Reduction Efficacy (CAPCOA 2010)

Estimates produced by the CAPCOA methods were validated against field data from active land use sites in northern California. The research team will update the CAPCOA research to include new data on travel reduction programs. Findings from Salon (2014) and ARB (2013-2014) will also be particularly useful for this purpose. Both the CAPCOA and Salon research quantify the effects of context and travel demand management measures individually for commute related and non-commute travel. This will enable the research team to differentiate the effects of prospective GHG reduction measures on commuter trips (i.e. achievement of Tier 2 zero-carbon building) from the effects on customer, visitor, shopping and school trips (i.e. achievement of Tier 3 zero-carbon building). This will also allow targeting of strategies in a manner that is responsive to different levels of respective activities by building and context type.

For each of these strategies, the research team will quantify the GHG abatement effectiveness related to building operations, commuter and visitor travel generation and VMT. The team will then differentiate the effectiveness estimates by building location, using a primary distinction between locations within or outside a central, compact, transit-rich area versus those located outside such areas as defined in the SB 375 Sustainable Communities Strategies created by California's Metropolitan Planning Organizations (MPOs). For example, in the Bay Area the

distinction will be based on the building's location within or outside a Priority Development Area. The research team will also identify the maximum aggressively achievable effectiveness of each strategy, and will identify which strategies rely upon the continuing incentives and/or monitoring for their effectiveness (as opposed to being one-time changes whose effects persist without continuing effort on the part of building managers and occupants).

For water, the strategies to be considered in this inventory include at least these:

- Demand reduction
- Xeriscaping (landscaping with drought-tolerant native plants)
- Occupant education campaigns and other persuasion
- Ultra low-flow, dual-flush, waterless and composting toilets and urinals
- High-efficiency indoor fixtures and fittings (e.g. low-flow showerheads and faucet aerators)
- High-efficiency appliances (e.g. dishwashers and washing machines)
- High-efficiency irrigation fixtures and management systems (e.g. timers and sensors)
- High-efficiency pumps
- Solar water heating
- Tankless water heating (both electric and gas)
- Small-scale potable or non-potable water re-use (e.g. membrane bioreactors, UV disinfection)
- Rainwater/stormwater collection for on-site re-use

This work will leverage extensive knowledge and prior research done at UC Berkeley related to the energy and GHG emissions associated with water and wastewater provision in California, including Stokes and Horvath (2006, 2009, 2010, and 2011) and Mozingo and Arens (2014), as well as CAPCOA (2010), CEC (2006), NRDC (2004) and Gleick et al (2003). The project team is currently developing, for another project, a GIS-based estimate of embedded energy in water for each of the ten hydrologic regions in California, as well as a more detailed, county-based assessment of selected urban areas. This information will be available for use to provide location-specific analysis of the water-related energy and GHG emissions of buildings.

Projecting the GHG emissions effects of water conservation will also require projecting the GHG intensity of electricity within California. In previous work for ARB, Mozingo and Arens (2013) combined information from E3 (2010) and the Statewide Energy Efficiency Collaborative (n.d.) to project emissions factors for major electricity utilities in California. These factors will be reviewed and, if feasible, updated to reflect the new target of 50% renewable energy generation by 2030 recently announced by Gov. Brown.

For solid waste management, the strategies in the inventory will include at least these:

- Source reduction (reduction of materials use)
- Occupant education campaigns and other persuasion
- Three-bin collection system throughout building (trash, recyclables, compostables)
- Central collection, sorting and handling
- Alternative-fuel waste hauling vehicles

The research team will assess the effectiveness of these solid waste strategies in reducing the GHG emissions embedded in materials handling and in disposal techniques, including landfilling, recycling and composting. We will consult and expand upon GHG quantification methods used in CAPCOA (2010) and the Landfill Emissions Tool v 1.3 as applied in Mozingo and Arens (2014).

Task 2. Zero-carbon new building feasibility analysis

The objectives of this task will be (a) to establish future building performance baselines and, for each building type, express those baselines as curves of anticipated building-related emissions from each resource area over time; and (b) to perform a wedge analysis of how the strategies identified in Task 1 can displace the area under the anticipated emissions curve for each resource area in each building type to achieve zero carbon new construction.

First, for subtask (a) the research team will establish anticipated future building performance baselines for each building type. This will involve quantifying the transportation, water and waste-related GHG emissions associated with building performance anticipated under the 2013 version of the California Green Building Standards code (CalGreen 2013), including both mandatory and voluntary standards. Underlying performance data for these baselines will come from a variety of sources, all of which the research team has used in previous studies.

For transportation, the research team will assemble trip generation data from the Institute for Transportation Engineers *Trip Generation Manual* (2012), and other sources, for each building type and apply appropriate trip length estimates based on the building's regional location category to estimate VMT generation by building type and location. The research team will also assemble data from ARB and other sources on GHG intensity by travel mode, including anticipated intensities for forthcoming alternative fuel vehicles. For water, the research team will model water use for each building type using the same method used in Mozingo and Arens (2014) – a combination of current CalGreen standards, International Plumbing Code standards, and Department of Water Resources methods for estimating irrigation demand – combined with information on the GHG intensity of water assembled in Task 1. For waste, the research team will assemble data on waste diversion rates in various building types from the most recent Statewide Waste Characterization Reports with pertinent data, from StopWaste.org survey results, and potentially from other sources, combined with information on the GHG intensity of waste disposal and recycling assembled in Task 1.

These initial baselines will incorporate the effects of CalGreen and thus will enable subsequent analysis in Task 4 of the degree to which zero-carbon building goals exceed current CalGreen standards. To these initial baselines, the research team will then incorporate the effects on anticipated GHG emissions from transportation, water and waste of other relevant state standards and goals already on the books, including:

- Targets of ARB's Advanced Clean Cars Initiative and the Low Carbon Fuel Standard
- Targets of the Renewable Portfolio Standards and Gov. Brown's 50% by 2030 renewables goal
- Legislative mandate to reduce per-capita urban water use by 20% by 2020 (a.k.a. "20 by 2020")
- AB 341 municipal solid waste management goals
- Other relevant AB 32-related targets to be identified in consultation with ARB

These baselines will be expressed, for each building type, as a set of three curves showing the trend of building-related GHG emissions intensity from transportation, water and waste over time. These will be further differentiated by region if regional differences in the GHG abatement effectiveness of strategies are found to be significant enough to warrant it. The ultimate time horizon will be selected to encompass the full length of time deemed necessary to achieve zero carbon buildings. Unlike other examples of wedge analysis in which the "business-as-usual" GHG emissions rise (see the topline of Figure 2 for an example), these baseline curves will slope downward over time as the state targets identified above are met. The challenge for this wedge analysis is to discover how to accelerate and complete the downward trend of the curves all the way to the x-axis (e.g. zero carbon status).

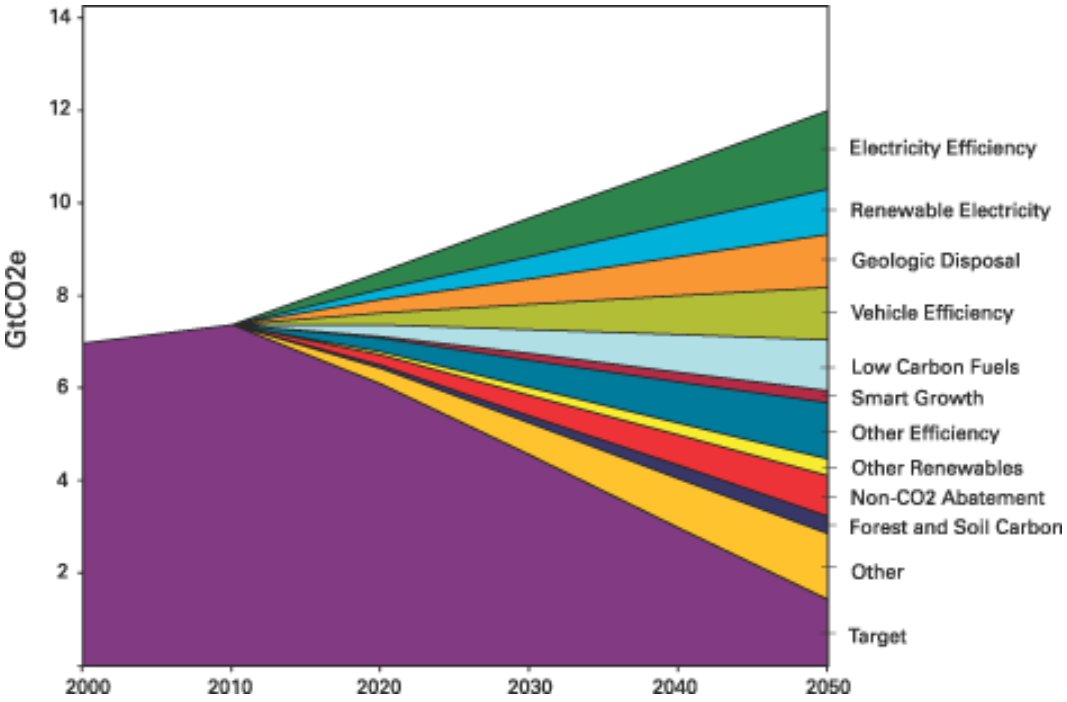

Figure 2. Example of graphical output of a wedge analysis showing potential to reduce GHG emissions by a target date (http://www.nrdc.org/globalwarming/blueprint/methodology.asp as of February 18, 2015)

Second, for subtask (b) the research team will then perform wedge analyses for each building type to show how the strategies inventoried in Task 1 can be used collectively to displace the GHG emissions remaining under the baseline curves. For transportation, we will determine the size of the wedge that can be attained from each strategy under the baseline curves for a time horizon consistent with the SB 375 longest-range target year used in the most recent Regional Transportation Plans and Sustainable Communities Strategies. Effectiveness estimates will be prepared for best practice and emerging demand-side and supply-side GHG reduction strategies. They will also account for strategies' increasing or declining effectiveness over time and provide data and analytics to underpin ARB's regulatory programs or upcoming policy decisions. If a strategy's effectiveness gain over time is non-linear, we will approximate the shape of the wedge effectiveness curve within the long-range forecast horizon.

For water and waste, the research team will determine the size of the displacement wedge attainable from each strategy assessed in Task 1 by identifying aggressive but feasible implementation rates consistent with the literature on each strategy and high-performance building experience in California. As with transportation, this analysis will account for strategies' potential to increase or decrease in effectiveness over time. The wedge analysis will also account for the regional variation in the GHG intensity of water around the state, either by creating a composite value to represent the state's building-related water usage as a whole, or by creating regionally distinct wedge analyses for the water sector.

This research approach implicitly assumes achievement of the state's targets for zero net energy residential and commercial construction, since these will be the basis for forthcoming updates to Title 24, Part 6 building energy codes. The curves thus focus only on the additional components of zero carbon building, namely transportation, water and waste. However, certain strategies may include energy generation, including solar water heating and provision of electricity charging capacity for electric cars. Assessments of the potential effectiveness of these strategies will include consideration of whether, and how, this additional generating demand can be accommodated within the context of ZNE buildings, or if it must be generated from the grid.

In addition, it may prove to be the case that building-level strategies alone, for certain building types, are insufficient to displace the entire quantity of emissions needed to achieve zero carbon status. In these cases, the remaining emissions abatement may need to be achieved through offsets. These could take a variety of forms, including requiring buildings to make use of existing GHG offset protocols in California (e.g. forest planting, etc), or requiring buildings to pay proportional in-lieu fees to finance systemic infrastructure upgrades that would reduce the GHG footprint of transportation, water and waste systems as a whole. Such upgrades might include improving regional mass transit infrastructure, developing zero-net-energy wastewater treatment plants, or financing improved methane capture technology on landfills, to cite only three possible examples. Thus it is possible that offsets and/or in-lieu fees, in some form, may constitute an abatement wedge for some or all of the building types.

This wedge analysis approach also focuses on the outcomes of strategy implementation across a large stock of buildings of a given type (or a "typical" building of each type), rather than simulation of specific buildings. This approach is chosen because it offers a more panoramic view for policymakers concerned with the whole stock of California building construction, and because it is less captive to the particular assumptions about location, climate, and occupancy required to create meaningful building performance simulations. Moreover, based on previous findings (Mozingo and Arens 2014), GHG emissions associated with transportation will dwarf those associated with water and waste for most (if not all) building types, and transportation is not effectively simulated at an individual building scale. Use of individual project assessment software such as CalEEMod to generate performance simulations would subject the researchers to unwanted limitations on estimating the efficacy of novel building performance strategies within the software environment, particularly under future conditions not reflected in CalEEMod's underlying calculations.

Unlike many other deployments of the abatement wedge concept, our approach does not require that each wedge be scoped to be equivalent in "size" (i.e. in emissions abatement

potential), but rather that each abatement strategy's wedge be scaled according to its potential contribution to the zero carbon goal. Policymakers will thus receive a concise and easily interpretable portrait of the relative importance of each strategy for each building type, and can focus policymaking and standard-setting accordingly. The transportation, water and waste sectors for each building type will be presented as different curves for ease of viewing and interpretation, but because the emissions associated with each are overwhelmingly non-overlapping and additive, they can be compiled into a composite curve and wedge analysis for each building type.

Because the state's ZNE building targets are not until 2020 (for residential) and 2030 (for commercial), targets for zero carbon buildings cannot precede these dates. The time horizons used in the baseline curves and the wedge analysis will likely range from 2020 to 2040 or 2050, depending upon the quality of evidence for projecting to the latter date. Interim targets for zero carbon construction standards before these latter dates, particularly those pertaining to the Tier 1 definitions of zero carbon buildings identified in Task 1, will also be identified in Task 4 based on these analyses.

Task 3 Discussion of zero carbon retrofit potential for existing buildings

In this task, we will identify and discuss the potential for retrofit of existing buildings to the various tiers of zero carbon status. This analysis will begin with the results of Task 2 as a starting point, and will then assess which components of the wedge analysis can usefully be applied to existing buildings. For each building type, the research team will sort the GHG abatement strategies (i.e. the wedges) into three groups:

- Group 1: Strategies that can be implemented individually without a major property renovation
- Group 2: Strategies that can only be implemented as part of a major property renovation
- Group 3: Strategies that have prohibitive installation costs in existing buildings

The potential to retrofit existing buildings to zero carbon, or near zero-carbon, status is a product of the first two groups of strategies. For strategies in group 2, the research team will gather data from the Construction Industry Research Board and BuildFax to estimate the frequency of major renovations in the various building types, and hence the proportion of the existing building stock within each building type that can be expected to be renovated within the time periods of interest. Based on these findings and the GHG abatement potential of the strategies in group 1, the research team will identify appropriate ranges for the proportion of existing buildings within each building type that could be retrofitted to zero carbon, or near-zero carbon, status. This is not as simple as just reading the results of Group 1 and 2 strategies off the wedge analyses, for two reasons. First, existing buildings, even when substantially renovated, are not yet subject to CalGreen provisions (though other components of the baseline analysis, such as the Renewable Portfolio Standard, affect new and existing buildings equally by changing the GHG intensity of electricity) and hence will have higher future baseline emissions. Second, while AB 758 is aimed at substantially improving the operational energy efficiency of existing buildings, the state's ZNE building goals apply only to new construction and it is unlikely that AB 758 implementation efforts will reach similar levels of efficiency. Hence, the research

team will not be able to assume net-zero operational energy in assessing the potential for exiting buildings to reach zero carbon status.

Importantly, however, the use of the Task 2 wedge analysis results in this manner will enable the research team to estimate the GHG abatement gains that could be made even in situations where potential renovations fall well short of near-zero status. For example, the research team will identify what GHG abatement gains could be made in each building type using only the group 1 strategies, in order to inform policymakers of how far abatement efforts in existing buildings can go using only the "low hanging fruit" of these more easily implemented strategies. The cost information attached to each strategy in Task 1 will also enable the research team and policymakers to assess the role of offsets (likely necessary given the absence of ZNE standards for operational energy in existing buildings) in setting targets for existing building retrofits.

Task 4. Setting targets and appropriate policy framework

Finally, based on the findings from Tasks 2 and 3, the research team will make recommendations to ARB on appropriate targets for zero carbon building, both new and retrofit. The recommendations will make use of the distinction between Tier 1 (zero carbon from in-building operations and building-originated trips), Tier 2 (zero carbon from commuter trips and delivery and disposal of water and waste) and Tier 3 (zero carbon from customer and visitor trips) buildings introduced in Task 1 by recommending targets for achievement of Tier 1 zero carbon buildings as an interim step to achievement of the more rigorous Tier 2 and Tier 3 definitions. The results of the wedge analysis in Task 2 will be used to define aggressive but achievable targets for the proportion of buildings able to obtain these various zero carbon statuses by identified threshold dates, likely ranging from 2030 to 2050.

This task will also include assessment, based on the wedge analysis in Task 2, of the GHG benefits and cost-effectiveness of zero carbon buildings over and above both the latest CalGreen standards and the ZNE building standards. The cost information attached to each strategy in Task 1 will enable the research team to assess the comparative cost-effectiveness of GHG abatement using zero carbon building strategies, as compared to the cost of selected well-established GHG abatement strategies. This analysis will include points of comparison such as the costs of these selected well-established GHG abatement strategies, the cost of carbon on the cap-and-trade market, and the approximate cost of offsets, including both existing offset protocols and in-lieu contributions to systemic upgrades to transportation, water and waste handling systems.

Task 5: Final report preparation and revision

This task will consist of the authorship of a draft final report that follows ARB's required format, and revision of that draft into a final report based on feedback from ARB staff, peer reviewers, and the Research Screening Committee.

Task 6: Project administration

This task will consist of internal coordination of management of the research team, including holding meetings of the project team at least twice monthly, and preparation of quarterly reports to ARB.

Project management plan

The research will be led out of the Center for Resource Efficient Communities at UC-Berkeley, a center devoted to supporting the State of California's climate change and resource efficiency goals through interdisciplinary research, public communication and professional outreach. The CREC has previously completed two successful research contracts for ARB, and the same leadership (PI Louise Mozingo, and Lead Researcher Bill Eisenstein) will manage this project and coordinate the activities of the research team. Prof. Mozingo and Dr. Eisenstein have collaborated previously with Prof. Arpad Horvath and Dr. Jennifer Stokes through their mutual participation in a National Science Foundation-funded Engineering Research Center called Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt). Fehr and Peers Associates, in particular principal Jerry Walters, has a long record of successful collaboration with other research institutions to produce leading analyses and research syntheses intended for use by policymakers (e.g. CAPCOA 2010 and Ewing et al 2008).

Fehr and Peers Associates will be primarily responsible for the transportation-related components of Tasks 1, 2 and 3. Prof. Horvath, Dr. Stokes and a postdoctoral research under their direction will be primarily responsible for the water-related components of Tasks 1, 2 and 3. Dr. Eisenstein will be primarily responsible for overall coordination of the sub-components of the study, the waste-related components of Tasks 1, 2 and 3, assembling cost and payback period information for all strategies in Task 1, and for Tasks 4, 5 and 6. Prof. Mozingo will be responsible for overall project supervision, quality control and administration. Because the research team involves only three entities (the CREC, the Horvath lab, and Fehr and Peers) and each entity has multiple points of contact, coordination challenges within the project team should be minimal. In addition, the majority of the data to be compiled and analyzed in this study are already either publicly available or within the possession of the research team. While significant effort will be required to compile data from diverse sources, the research team will not have to rely upon any third party to deliver any major dataset in order to execute the research.

Data management plan

The primary dataset to be used in the study will be a database of building-based GHG abatement strategies identified in Task 1, along with the best information available from previous research and professional practice about their existing and potential GHG abatement effectiveness, any construction or installation cost premium associated with them, and anticipated payback periods for those increased first costs. Compilation of this dataset will not require any equipment or instrumentation beyond ordinary office computers. The GHG efficacy of many strategies, particularly with respect to transportation, has been validated in previous research, and those validations will be reported when available. Because this research project is a feasibility study that attempts to assess the potential scope of building-based GHG abatement efforts, it will involve projections of future implementation and performance of strategies. Such projections, by definition, cannot be empirically validated and will involve invoking the professional judgment of the researchers. The quality of the data and conclusions drawn from it will therefore be assured by the collective academic and professional experience of the research team, as well as routine consultation with ARB in Task 6.

Given the nature of the data to be compiled in this study and the methods used to analyze it, there should be no need for review by the UC-Berkeley Committee for the Protection of Human Subjects or any other institutional review board.

Context of related research

This study will synthesize a burgeoning body of research on the GHG impacts of buildings, transportation, water and waste. Indeed, it will rely and expand upon previous major syntheses, especially the project-level GHG quantification guidance issued by CAPCOA (2010), the series of briefing memos prepared primarily by Handy and Boarnet for ARB (2013-2014) entitled *Research on Impacts of Transportation and Land Use-Related Policies*, and the major book-length summary of the evidence linking urban land use patterns and climate change entitled *Growing Cooler* (Ewing et al 2008), co-authored by research team member Jerry Walters. Each of these syntheses drew upon dozens of previous studies quantifying the efficacy of various building and land use strategies in reducing GHG emissions and/or vehicle miles traveled.

In addition, with respect to transportation particularly, the research will consult national-level synthesis of potential GHG abatement effectiveness of various transportation strategies conducted by Cambridge Systematics in the volume entitled *Moving Cooler* (2009), and Salon's (2014) important California-focused work for ARB entitled *Quantifying the Effect of Local Government Actions on VMT*. Studies by Feigon et al (2003), and Pyke et al (2011) will also be of use for specific insights about climate impacts of building-related transportation patterns. Other basic data sources will include the Institute for Transportation Engineers' *Trip Generation Manual* (2012), and a variety of public data resources such as the American Community Survey.

With respect to water and waste, the CAPCOA (2010) guidance will provide some insight into the anticipated GHG abatement effectiveness of various strategies. Previous work conducted by members of this research team in Mozingo and Arens (2014) improved upon some aspects of the CAPCOA quantification of water-related GHGs by consulting the work of Blanco (2012) as an update to the previously standard CEC (2006). Studies by Dziegielewski et al (2000), NRDC (2004) and Gleick (2003) contain important information for setting baselines. The Department of Water Resources' *Water Budget Workbook* (DWR 2010) is also of use for calculating irrigation demand in various portions of California. In addition, for residential buildings, the Green Point Rated Climate Calculator, and work done under ARB sponsorship to improve it (Kammen et al 2012) will provide additional insight. For waste, the periodic Waste Characterization Studies issued by CalRecycle will be consulted, as well as the GHG quantification formula that underlies version 1.3 of the Landfill Emissions Model.

Overall, this research builds squarely upon previous ARB-sponsored research on buildings and sustainable communities, and will represent an important new synthesis of the GHG abatement effectiveness of building-level strategies.

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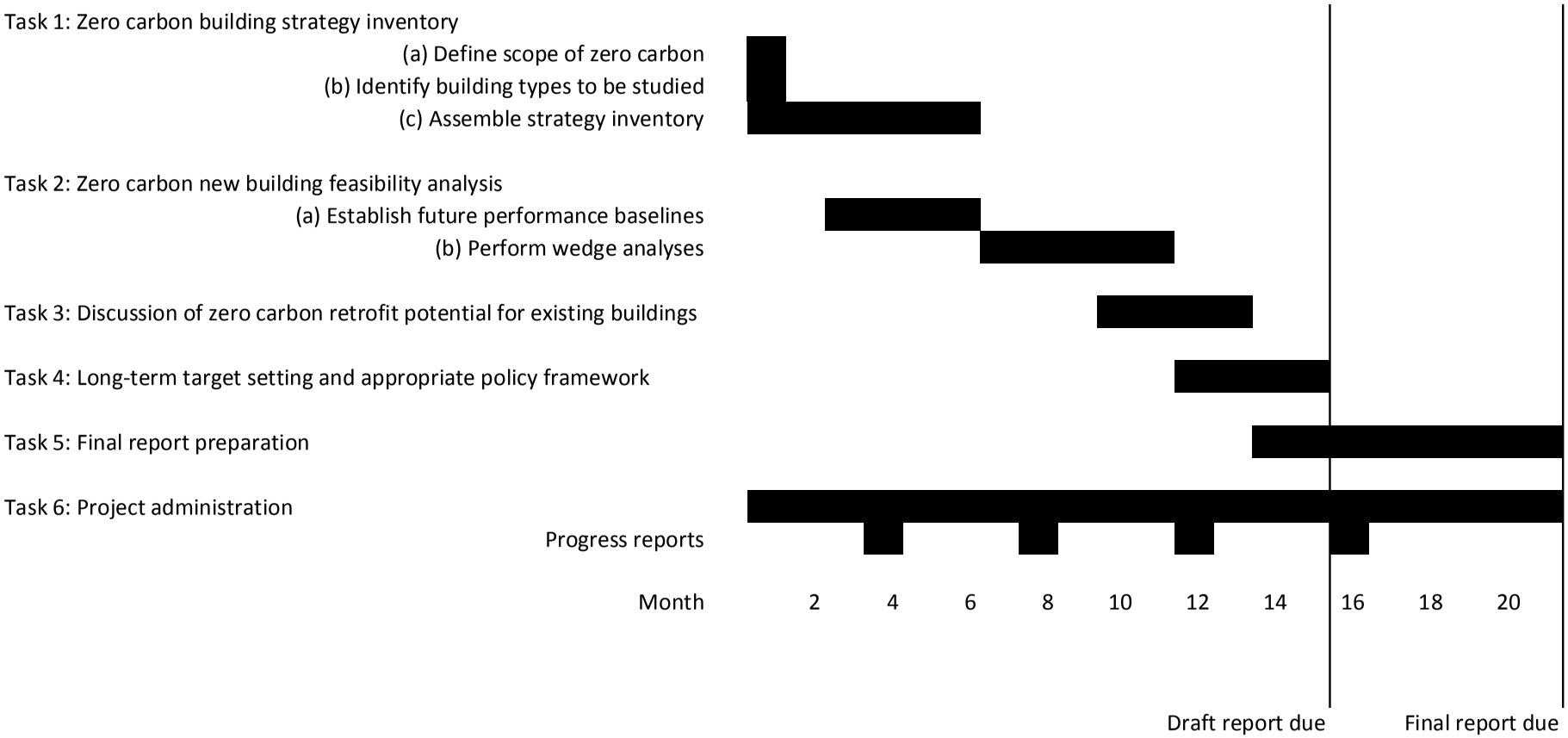
Project schedule



ARB draft proposal
California Air Resources Board
PI Louise Mozingo

Task	Mozingo Salary	Horvath Salary	Eisenstein Salary	Stokes Salary	Postdoc Salary	Benefits (inc. GAEL)	Subaward Fehr & Peers	Printing	Overhead	Total
1	$ 1,680	$ 1,896	$ 6,120	$ 5,624	$ 22,271	$ 9,873	$ 52,150	$ -	$ 7,246	$ 106,859
2	$ 1,680	$ 1,896	$ 6,120	$ 5,624	$ 22,271	$ 9,873	$ 52,150	$ -	$ 4,746	$ 104,359
3	$ 2,240	$ 542	$ 8,160	$ 1,607	$ 6,363	$ 5,455	$ 14,900	$ -	$ 2,437	$ 41,703
4	$ 2,240	$ 542	$ 8,160	$ 1,607	$ 6,363	$ 5,455	$ 14,900	$ -	$ 2,437	$ 41,703
5	$ 2,240	$ 271	$ 8,160	$ 803	$ 3,182	$ 4,404	$ 7,450	$ 1,500	$ 2,056	$ 30,066
6	$ 1,120	$ 271	$ 4,080	$ 803	$ 3,182	$ 2,728	$ 7,450	$ -	$ 1,218	$ 20,852
	$ 11,200	$ 5,416	$ 40,800	$ 16,068	$ 63,630	$ 37,788	$ 149,000	$ 1,500	$ 20,140	$ 345,542

Curriculum Vitae

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EXPERIENCE

Chair 2014-present **Professor** 2011-present
Associate Professor 2000-2011 **Assistant Professor** 1993-2000
Department of Landscape Architecture and Environmental Planning
University of California, Berkeley
Urban Design Graduate Group
College of Environmental Design

Director 2011-2014 **and Faculty** 2002-present
American Studies
Undergraduate Interdisciplinary Studies
College of Letters and Sciences

Affiliated Faculty
Center for Environmental Design Research
Institute of Urban and Regional Development
Global Metropolitan Studies

RESEARCH ACTIVITIES

Founding Director, **Center for Resource Efficient Communities**, College of Environmental Design, University of California, Berkeley, 2009-present

A center devoted to interdisciplinary research regarding the environmental planning and design of resource efficient urban environments. www.crec.berkeley.edu

Co-principal investigator with faculty from Center for the Built Environment (Building Science), Computer Science and Electrical Engineering

Research Collaboration with Fisher Center for Urban and Real Estate Economics, Haas Business School, and Center for Law Energy and the Environment, Berkeley Law School

Recent publications, available http://www.crec.berkeley.edu/research.html include:

Leveraging a New Law: Reducing Greenhouse Gas Emissions Under SB 375

Hedonic Valuation of Residential Resource Efficiency Variables

Evaluating the Performance of Pedestrian-Oriented Developments

Moving Beyond Prevailing Street Design Standards

Building Energy Efficient Communities: A Research Agenda for California

Affiliated Faculty, Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt)
National Science Foundation funded Engineering Research Center (ERC) in collaboration with Stanford University, Colorado School of Mines, and New Mexico State University, 2013-present

Co-director, collaborative program, Thai Public Policy Foundation, Chulalongkorn University, Bangkok, and University of California, Berkeley, Institute of Urban and Regional Development 2006-2010

GRANTS (all only principal investigator unless otherwise noted)

2013 California Energy Commission, *Local Benefits from Building Efficiency Standards*, Co-PI with Ed Arens, $200,000

2012 California Air Resources Board, *Residential Energy Use and GHG Emissions Impacts of Compact Land Use Types*, Co-PI with Ed Arens, $100,000

2012 California Energy Commission, through UC Los Angeles, California Center for Sustainable Communities Research, *SB 375 Policy Analysis And Implementation Support, Pilot Pedestrian Rating Tool, Legal Research in Support of Resource Efficient Street Design,* $400,000

2012 California Air Resources Board, *Quantifying the Comprehensive Greenhouse Gas Co-benefits of Green Buildings*, Co-PI with Ed Arens, $180,000

2012 Association of Bay Area Governments, *Using Land Use and Water Management Regulations to Improve Local Planning Processes and Develop Integrated Projects*, $12,000

2011 American Rivers, *Economic Benefits of Floodway Conservation*, $20,000

2011 Siemens Corporation, *Lifecycle Support for Sustainable Cities*, Co-PI with David Culler, $400,000

2010 California Energy Commission, through UC Los Angeles, *Urban Transportation Modes in California: Beyond VMTs and GHGs*, $98,988

2010 California Energy Commission, *Center for Resource and Energy Efficient Communities Research Plan Phase II* (Modeling Human Comfort for Transportation Improvements, Hedonic Evaluation of Residential Resource Efficiency Variables, Evaluation of Performance of Pedestrian Oriented Developments, Moving Beyond Prevailing Street Design Standards, Mobile technology for Pedestrian and Bicycle Research) $203,044

2009 California Energy Commission, *Center for Resource and Energy Efficient Communities Research Plan Phase I* (White Paper on Building Energy Efficient Communities, Pedestrian Comfort Model Interface and Validation, Survey Procedures for Pedestrian Comfort Model, Wireless Sensor Systems for Pedestrian Comfort, Community Resource Assessment Methods, Summary of Cool Communities Research), $401,786

PUBLICATIONS

Chapters, Articles, Reviews and Reports

Municipal Fiscal Impacts of Building Energy Research in California: A Guidebook for Local Officials. Center for Resource Efficient Communities, University of California, Berkeley. November 2014.

Valuing Central Valley Floodplains: A Framework for Floodplain Management Decisions. With William Eisenstein. Center for Resource Efficient Communities, University of California, Berkeley. May 2013.

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"The Glenn W. Daniel King Estate Park Master Plan." *Landscape Journal*. with Ann Baker, Jonathan London, Nicholas Ancel, Masato Dohi and Iris Cheng. Exhibit Catalogue *Eco-Revelatory Design: Nature Constructed/Nature Revealed*. Special Issue, 1998. pp. 12-14.

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"What are the Appropriate Historic Methods for Research in Landscape Architectural History?" with Robin Karson, Karen Madsen, and Kathryn Gleason. *What Do We Expect to Learn From Our History?: The First Symposium on History in Landscape Architecture*. Penn State University: The Center for Studies in Landscape History, 1996. pp. 117-118.

"Dorothea Lange: American Photographs." *Landscape Journal*. Vol. 14, No. 1, Spring, 1995. pp. 130-135.

"Ecologically Informed Designers: An Interview with Ian McHarg." *On the Ground*. Vol. 1, No. 2, Winter/Spring 1995. pp. 1-4.

"Public Space in the Balance." *Landscape Architecture*. Vol. 85, No. 2. February, 1995. pp. 42-47. Cover story of issue on *Urban Security*.

"Homelessness in Urban Parks: Is Exclusion the Solution?" *Landscape Architecture*. Vol. 84, No. 2, February, 1994. p.112.

"Women and Downtown Open Space." *Places*. Volume 6, Number 1, Fall 1989.

EDUCATION

Master of Landscape Architecture, May, 1984
University of California, Berkeley

Bachelor of Science, Biology and Art History, May, 1980
College of William and Mary, Williamsburg, Virginia

AWARDS

2014 Honor Award in Communications
American Society of Landscape Architects
for *Pastoral Capitalism: A History of Suburban Corporate Landscape*

2014 The Elizabeth Blair MacDougall Book Award
Society of Architectural Historians
for the most distinguished work of scholarship in the history of landscape architecture or garden design
for *Pastoral Capitalism: A History of Suburban Corporate Landscape*

2011 American Publishers Award for Professional and Scholarly Excellence (PROSE Award) in the Architecture and Urban Planning category
for *Pastoral Capitalism: A History of Suburban Corporate Landscapes*

2000 Award of Recognition
Council of Educators in Landscape Architecture
for *Excellence in Teaching, Writing, and Service*
2000 Chancellor's Award of Recognition for University and Community Partnerships
University of California, Berkeley

FELLOWSHIPS

Townsend Initiative Grant
The Doreen B. Townsend Center for the Humanities
University of California, Berkeley, 2005

Fellowship, Studies in Landscape Architecture, Dumbarton Oaks
Harvard University, 1996-97

Humanities Research Fellowship
University of California, Berkeley, 1996-97

Dr. William A. Eisenstein

EDUCATION

Ph.D	**University of California, Berkeley,** Environmental Planning, December 2005
M.C.P.	**University of California, Berkeley**, City and Regional Planning, December 2000
B.A.	**Oberlin College**, Phi Beta Kappa, Highest Honors, May 1994

EXPERIENCE

1. **Executive Director**, Center for Resource Efficient Communities, UC-Berkeley, July 2009 – present. Founding executive director of research center studying links between community design and energy, water, and carbon efficiency. In charge of all research, fundraising, organizational development, and strategic planning functions. See "Contracts and Grants below" for brief project descriptions. Led CREC as founding partner of California Center for Sustainable Communities Research. Also serves as Urban Systems and Integration Thrust Leader for Renewing the Nation's Urban Water Infrastructure (ReNUWIt), an NSF-funded Engineering Research Center.
2. **Appointed member**, Research Screening Committee, California Air Resources Board, September 2013 – present. Member of 11-member statewide committee to oversee research in support of ARB's implementation of California's greenhouse gas regulations.
3. **Principal**, Eisenstein Consulting LLC, November 2008 – present. Projects include Sacramento – San Joaquin Delta Conservancy Strategic Plan, Delta National Heritage Area Feasibility Study Phase I, and Central Valley Flood Protection Plan (CVFPP)
4. **Independent Consultant,** October 2007 – December 2008. Projects included State of California Delta Vision Process, Cumulative Effects of Urbanization on the California Delta Study Scoping
5. **Director, Delta Initiative**, UC-Berkeley, June 2006 – Sept. 2007. Projects included the Delta Vision Charrette, The Great Delta Charrette, and *ReEnvisioning the Delta*
6. **Independent Consultant**, January 2001 – December 2005. Projects included *Greenbelt At Risk*, Caspar, CA Area Plan, and *Environmentalism and Smart Growth: Forging a New Consensus*

CONTRACTS AND GRANTS (written or overseen as Executive Director of CREC with principal investigator Prof. Louise Mozingo, unless otherwise noted)

1. **California Energy Commission,** $400,000 from May 2012 to December 2014 for development of a pedestrian rating system, analysis of SB 375 implementation, and preparation of a guidebook on street design for California city attorneys
2. **California Air Resources Board**, $120,000 from June 2012 to December 2014 for project entitled "Quantifying the Comprehensive Greenhouse Gas Co-Benefits of Green Buildings" (CREC share of $180,000 research agreement; Profs. Ed Arens and Louise Mozingo, co-principal investigators)
3. **California Energy Commission,** $200,000 from February 2013 to June 2014 for project entitled "Local Government Benefits from Building Energy Efficiency Standards"

4. **Siemens, Inc.**, $67,000 from September 2012 to September 2013 for assessment of prototype of CLM software tool (CREC share of $200,000 research agreement; Profs. David Culler and Louise Mozingo, co-principal investigators)
5. **Siemens, Inc.**, $67,000 from September 2011 to September 2012 for assessment of data needs for better pedestrian planning (CREC share of $200,000 research agreement; Profs. David Culler and Louise Mozingo, co-principal investigators)
6. **American Rivers**, $20,000 from July 2011 to July 2013 for report on economic and ecological valuation of Central Valley floodplains
7. **California Air Resources Board**, $100,000 from May 2011 to November 2013 for project entitled "Residential Energy Use and GHG Emissions Impacts of Compact Land Use Types"
8. **California Energy Commission**, $100,000 from June 2010 to October 2012 for analysis of policy options to incorporate life-cycle assessment into transportation planning and policy (Profs. Ed Arens and Louise Mozingo, co-principal investigators)
9. **California Energy Commission**, $203,000 from April 2010 to December 2010 for field testing of a pedestrian thermal comfort model, analysis of methods in the assessment of pedestrian-oriented developments, assessment of use of wireless devices in pedestrian surveys, identification of legal barriers to sustainable street design, and analysis of property value impacts of cool community designs

PUBLICATIONS

Peer-reviewed journals

1. Eisenstein, W., M. Chester, and S. Pincetl. 2013. "Policy options for incorporating life-cycle environmental assessment into transportation planning." *Transportation Research Record* 2397: 30-37.
2. Chester, M., S. Pincetl, Z. Elizabeth, W. Eisenstein, and J. Matute. 2013. "Infrastructure and automobile shifts: Positioning transit to reduce life-cycle environmental impacts for urban sustainability goals." Environmental Research Letters 8 015041 doi:10.1088/1748-9326/8/1/015041
3. "That Others May Simply Live: Ecological Design as Environmental Justice," *Landscape Review* 9(1): 107-110. Proceedings of CELA conference, Lincoln University, Christchurch, New Zealand, June 25-29, 2004.
4. "Ecological Design and Culture: Toward a Research Agenda," CELA Conference Selected Papers, SUNY College of Environmental Science and Forestry, Syracuse, New York, September 25-28, 2002. Published 2003. [Papers peer reviewed independently.]
5. "Urban Infrastructure for Ecological Humanism," MESH Landscape Architecture Conference Proceedings, RMIT University, Melbourne, Australia, July 9-11, 2001. Published as CD-ROM insert in *kerb: Journal of Landscape Architecture* 10 (2001). [Papers peer reviewed independently.]
6. Review of *Human Settlements and Planning for Ecological Sustainability: The Case of Mexico City*, by Keith Pezzoli, *Berkeley Planning Journal* 13 (1999): 129-132.

Books

1. *Eco-Revelatory Design and the Values of the Residential Landscape.* Saarbrucken: Scholar's Press, 2013.

Research reports for professional audiences

1. Quantifying the Comprehensive Greenhouse Gas Co-Benefits of Green Buildings, Report to the California Air Resources Board, In Review as of July 2014
2. Municipal Fiscal Impacts of Building Energy Efficiency, Report to the California Energy Commission, In Review as of July 2014
3. Siemens – UC Berkeley CKI Project: Year 1 Final Report, Center for Resource Efficient Communities, Center for the Built Environment, and i4Energy, December 2012
4. Residential Energy Use and Greenhouse Gas Emissions Impacts of Compact Land Use Types, Report to the California Air Resources Board, November 2013.
5. *Valuing Central Valley Floodplains: Insights from Ecological Economics*, Report to American Rivers, May 2013
6. *Greener Miles: Incorporating Life Cycle Assessment into Transportation Planning*, Report to California Energy Commission and UCLA Institute of the Environment, January 2012
7. *Life Cycle Assessment of Community Design Changes: Energy and Environmental Assessment of the Los Angeles Metro's Orange and Gold Lines* (secondary author), Report to the California Energy Commission and UCLA Institute of the Environment, January 2012
8. *Building Energy Efficiency Communities: A Research Agenda for California*, Report to California Energy Commission, March 2010
9. *The Great Delta Charrette*, Report to the California Department of Water Resources, May 2007
10. *ReEnvisioning the Delta*, Report on March 2006 UC-Berkeley symposium on the Sacramento-San Joaquin Delta.

Research reports supervised

1. Siemens – UC Berkeley CKI Project: Year 2 Report on CLM Evaluation, Center for Resource Efficient Communities, Center for the Built Environment, and i4Energy, August 2013
2. *Leveraging a New Law: Reducing Greenhouse Gas Emissions Under Senate Bill 375*, by Eliot Rose, Center for Resource Efficient Communities, UC-Berkeley, March 2011
3. *Hedonic Valuation of Residential Resource Efficiency Variables*, by Cynthia Kroll and Adam Cray, Center for Resource Efficient Communities, UC-Berkeley, December 2010
4. *Moving Beyond Prevailing Street Design Standards: Assessing Legal and Liability Barriers to More Efficient Street Design and Function*, by Steve Weissman, Meredith Wilensky and John Urgo, Center for Resource Efficient Communities, UC-Berkeley, December 2010
5. *Evaluating the Performance of Pedestrian-Oriented Developments: Summary of Site Visits and Research Design Options*, Center for Resource Efficient Communities, UC-Berkeley, December 2010

Articles for public audiences

1. "Planning California's Waterscape," *Access Magazine*, UC Transportation Center, Winter 2009 (with Matt Kondolf).
2. "The ReEnvisionists: Questioning Urbanization in the Delta," *Frameworks*, Fall 2006: 30-33 (with Matt Kondolf).
3. "The Unseen Apocalypse," *SPUR* [San Francisco Planning and Urban Research Association] *Newsletter*, May 2002: 8-9, 12.
4. "The Invisible Fortress," *Urban Ecology*, Spring 2002: 25-28.

5. "The Unbuilt City: Parks and Successful Urban Design" [Review of *The Great Remembering* by Peter Forbes, *Inside City Parks* by Peter Harnik, and *Great City Parks* by Alan Tate], *Urban Ecology*, Winter 2001-2002: 31-32. Also excerpted in *Land and People* 14 (Spring 2002): 4.
6. "Ecological Design, Urban Places, and the Culture of Sustainability," *SPUR Newsletter*, September 2001: 1, 3-7.
7. "Federation Square, Melbourne, Australia," *Urban Ecology*, Autumn 2001: 11.
8. Review of *The Bulldozer in the Countryside: Suburban Sprawl and the Rise of American Environmentalism* by Adam Rome, *Urban Ecology*, Autumn 2001: 33.
9. "Is the 'Death Tax' Death on Farmland?" *Urban Ecology*, Summer 2001: 24-27.
10. "The Open Waters of Kyoto," *Urban Ecology*, Summer 2001: 11.
11. "Sustainable Redevelopment for San Francisco," *SPUR Newsletter*, June 2001: 18, 20-21.
12. "Energy and City Form," *Urban Ecology*, Spring 2001: 23-26.
13. "Bike Lanes of Paris," *Urban Ecology*, Spring 2001: 11.

TEACHING

The Process of Environmental Planning, UC-Berkeley, Spring 2012
Introduction to Environmental Design, UC-Berkeley, Spring 2007, Fall 2004
Sustainability in the Built Environment, UC-Berkeley Extension, Fall 2006
Sustainable Urban Design in Stockton, UC-Davis, Spring 2006.
Environmental Planning Studio, UC-Berkeley, Spring 2004
Introduction to Environmental Science, UC-Berkeley, Fall 2003
Master's Thesis and Professional Project Seminar, Department of Landscape Architecture and Environmental Planning, UC-Berkeley, Fall 2003.
Introduction to Environmental Design, UC-Berkeley, Fall 2002

PEER REVIEWER

CA Air Resources Board Research Screening Committee, October 2013 - present
International Journal of Sustainable Transportation, June 2014
U.S. Environmental Protection Agency, Collaborative Science and Technology Network for Sustainability: Communities and the Built Environment grant program, 2006
Landscape Journal, July 2004.
The Future Metropolitan Landscape, Special Issue of *Places*, Fall 2006

Arpad Horvath
Professor
Department of Civil and Environmental Engineering, 215 McLaughlin Hall
Leader, Energy, Civil Infrastructure and Climate Graduate Program
Director, "Engineering and Business for Sustainability" Certificate Program
Director, Consortium on Green Design and Manufacturing
University of California, Berkeley, CA 94720-1712
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http://www.ce.berkeley.edu/~horvath
http://sustainable-engineering.berkeley.edu

EDUCATION

Technical University of Budapest (Hungary), Civil Engineering, M.S., 1993
Carnegie Mellon University, Pittsburgh, PA, Civil and Environmental Engineering, M.S., 1995
Carnegie Mellon University, Pittsburgh, PA, Civil and Environmental Engineering, Ph.D., 1997

MAJOR APPOINTMENTS

- Courses taught recently (first three include lectures on sustainability of water systems and buildings): CE 268E Civil Systems and the Environment, CE 292A Technologies for Sustainable Societies, CE 11 Engineered Systems and Sustainability, CE 166 Construction Engineering, CE 167 Project Management
- August 2013 – present: **Member**, Committee on Beneficial Reuse of Graywater and Stormwater, National Research Council, The National Academies
- Chair*, 2011 Conference of the International Society for Industrial Ecology* (Berkeley, June 2011)
- April 2014 – present: **Secretary**, Faculty of the College of Engineering, UC Berkeley\
- July 2010 – present: **Graduate Program Leader**, Energy, Civil Infrastructure and Climate Graduate Program, CEE, UC Berkeley
- January 2010 – present: **Member**, Editorial Advisory Board, *Environmental Science and Technology*
- October 2009 – present: **Member**, Science Advisory Board, Environmental Engineering Committee, U.S. Environmental Protection Agency
- July 2010 – present: **Professor**, UC Berkeley
- July 2005 – June 2010: **Associate Professor**, UC Berkeley
- May 2005 – present: **Editorial Board Member**, *J. of Industrial Ecology*
- May 2002 – present: **Associate Editor**, ASCE *J. of Infrastructure Systems*
- May 2000 – present: **Director**, Consortium on Green Design and Manufacturing, UC Berkeley
- July 1999 – June 2005: **Assistant Professor**, UC Berkeley
- January 1998 – June 1999: **Research Faculty**, Carnegie Mellon University
- July 1997 – December 1997: **Postdoctoral Researcher**, Carnegie Mellon University

HONORS AND AWARDS

- Chancellor's Sustainability Award, UC Berkeley (2013)
- Best Paper of 2012 – Policy Analysis, First Runner-up, *Environmental Science & Technology,* "Fuel Miles and the Blend Wall: Costs and Emissions from Ethanol Distribution in the United States."
- Excellence in Review Award, *Environmental Science & Technology* (2011)
- Best Paper of 2011 – Feature, Second Runner-up, *Environmental Science & Technology*, "Grand Challenges of Life-cycle Assessment of Biofuels"
- Best Paper of 2008 – Policy Analysis, Second Runner-up, *Environmental Science & Technology*, "Assessing the End-of-Life Impacts of Buildings"
- Walter L. Huber Civil Engineering Research Prize "for original and outstanding contributions to the life-cycle environmental modeling and assessment of infrastructure systems," American Society of

Civil Engineers (2008)
- Laudise Prize "for outstanding achievements in industrial ecology by a young scientist or engineer," International Society for Industrial Ecology (2005)
- AT&T Foundation Industrial Ecology Faculty Fellowship (1998, 2000, 2001, 2004)
- National Science Foundation CAREER award (2001-2006)

SYNERGISTIC ACTIVITIES
- 2011-2021: Project leader for life-cycle environmental and economic assessment of water and wastewater systems and carbon abatement cost curves within ReNUWIT, the NSF-funded Engineering Research Center
- 2010-11: Developed a new graduate program in Civil and Environmental Engineering: "Energy, Civil Infrastructure and Climate," which has as one of its main foci the sustainability of water systems and buildings.
- 2007: Developed the "Engineering and Business for Sustainability" certificate program at UC Berkeley (http://sustainable-engineering.berkeley.edu)
- 2003-2010: Principal Investigator of "Life-cycle Energy Assessment of Alternative Water Supply Systems in California," a project funded by the California Energy Commission, that has developed the Water-Energy Sustainability Tool (WEST) and the Wastewater-Energy Sustainability Tool (WWEST) (http://west.berkeley.edu)
- 2000 – present: Director of the Consortium on Green Design and Manufacturing, one of the oldest and most productive green engineering and management groups in the United States.
- 2000-2012: Developed and regular updates the course *CE 268E Civil Systems and the Environment*, which is the first and only course on campus dedicated to life-cycle environmental and economic analysis, and has lectures on water systems and buildings
- 1995 – present: Co-developed (with several others at CMU) the life-cycle assessment (LCA) model based on economic input-output analysis (EIO-LCA) and the first free web-based LCA software (www.eiolca.net).

RELEVANT RECENT PUBLICATIONS (from a total of more than 75 peer-reviewed papers)
- Hendrickson, T., Nguyen, M., Sukardi, M., Miot, A., Horvath, A., and Nelson, K. (2015), "Environmental Performance of a Building-Scale Wastewater Treatment and Non-potable Reuse System." Under review.
- Stokes, J. R., T. Hendrickson, and A. Horvath. (2014). "Save Water to Save Carbon and Money: Developing Abatement Costs for Expanded Greenhouse Gas Reduction Portfolios." *Environmental Science & Technology*. 48(23): 13583-13591
- Hendrickson, T. and Horvath, A. (2014), "A Perspective on Cost-Effectiveness of Greenhouse Gas Reduction Solutions in Water Distribution Systems." *Environmental Research Letters*, 9(1), 024017
- Stokes, J. R., A. Horvath, and R. Sturm. (2013). "Water Loss Control Using Pressure Management: Life-cycle Energy and Air Emission Effects." *Environmental Sci & Technol*. 47(19): 10771–10780
- Shehabi, A., J. R. Stokes, and A. Horvath. (2012). "Energy and Air Emission Implications of a Decentralized Wastewater System." *Environmental Research Letters* 7(2): 024007
- Stokes, J. and A. Horvath (2011). "Life-Cycle Assessment of Urban Water Provision: Tool and Case Study in California." *Journal of Infrastructure Systems* 17(1).
- Stokes J. and Horvath (2010). "Supply-chain Environmental Effects of Wastewater Utilities." *Environmental Research Letters* 5(1): 014015
- Stokes, J. R. and A. Horvath (2009). "Energy and Air Emission Effects of Water Supply." *Environmental Science & Technology* 43(8): 2680-2687.

Jennifer R. Stokes, Ph.D.
Research Engineer, Department of Civil and Environmental Engineering
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Research webpage: http://west.berkeley.edu

EDUCATION

Ph.D., Civil and Environmental Engineering, University of California, Berkeley, 2004
Master of Science, Civil and Environmental Engineering, University of California, Berkeley, 1999
Bachelor of Science, Civil and Environmental Engineering, Georgia Institute of Technology, 1998

RESEARCH AND TEACHING EXPERIENCE

University of California; Berkeley, California; October 2008 – present
Assistant Research Engineer, Consortium on Green Design and Manufacturing and ReNUWIT Engineering Research Center
Created and updated the Water-Energy Sustainability Tool (WEST), the Wastewater-Energy Sustainability Tool (WWEST) and streamlined online tool; analyzed case studies of urban water and wastewater utilities in California; Developed WEST/WWEST training sessions for industry professionals; Conducted analysis of energy and environmental benefits of pressure management in urban water distribution; Developed a greenhouse gas abatement cost curve for urban water utilities in California; Currently developing a GIS-based estimate of life-cycle energy consumption and greenhouse gas emissions for each of the ten California hydrologic regions; authored a guidance document for using Cost-Benefit Analysis to comply with California's Green Chemistry rule; mentored and managed undergraduate and graduate research projects
University of California; Berkeley, California; June 2004 – April 2005; October 2006 – Oct. 2008
Post-doctoral Researcher, Consortium on Green Design and Manufacturing
Continued to research environmental effects of water infrastructure and life-cycle assessment of wastewater systems; improved WEST
University of California; Berkeley, California; January 2004 – May 2004
Graduate Student Instructor, CE 268E Civil System and the Environment
University of California; Berkeley, California; September 2003 – May 2004
Graduate Student Researcher, Consortium on Green Design and Manufacturing
Conducted life-cycle assessment of water supply systems; analyzed imported, desalinated, and recycled water systems at two water utilities in California; created decision-support tool to facilitate future studies
University of California; Berkeley, California; September 2001 – June 2002
Graduate Student Researcher, Consortium on Green Design and Manufacturing
Conducted life-cycle assessment for alternative construction practices to excavate soil
University of California; Berkeley, California; June 1999 - August 1999
Graduate Student Researcher, Berkeley Environmental Restoration Center
Assisted Steam-Enhanced Extraction research project
University of California; Berkeley, California; August 1998 - December 1998
Graduate Student Instructor, CE 173 Groundwater and Seepage
Recent Guest Lectures: University of California Berkeley; E11: Engineered Systems and Sustainability (Spring 2014); CE268E: Civil Systems and the Environment (Fall 2013); San Diego State University-CONE420: Environmentally Conscious Construction (Spring 2010)

HONORS AND AWARDS

2003 – 2005 University of California Toxic Substances Research and Training Program Fellow
1998 National Science Foundation Graduate Research Fellow, Georgia Tech Helen E. Grenga Outstanding Woman Engineer Award, Alvin M. Ferst Leadership and Entrepreneurship Scholarship
1997 Georgia Tech Techcellence Award – *given by Dean of Students for academics and leadership*

PROFESSIONAL EXPERIENCE

Geomatrix Consultants; Oakland, California; August 1999-July 2001; July 2005 – October 2006

Project Engineer, Engineering Systems Department

Developed remediation strategies for brownfield sites; Designed groundwater and soil vapor treatment systems; Designed slurry, sheetpile, and soil-cement groundwater barrier systems; Coordinated maintenance and regulatory reporting for groundwater treatment facilities; Provided construction oversight, prepared bid documents and processed construction documentation for remediation projects

SELECTED PUBLICATIONS

Stokes, J. R., T. Hendrickson, and A. Horvath. (2014). "Save Water to Save Carbon and Money: Developing Abatement Costs for Expanded Greenhouse Gas Reduction Portfolios." *Environmental Science &* Technology. 48 (23): 13583-13591.

Miller-Robbie, L., B. Ulrich, D. Ramey, S. Herzog, T. Cath, J. Stokes, and C. Higgins. (2014). "Life-cycle energy and greenhouse gas assessment of the co-production biosolids and biochar for land application." *J. of Cleaner Production*, published online 2014. DOI:10.1016/j.jclepro.2014.12.050

Stokes, J. R., A. Horvath, and R. Sturm. (2013). "Water Loss Control Using Pressure Management: Life-cycle Energy and Air Emission Effects." *Environmental Science &* Technology. 47 (19): 10771–10780.

Shehabi, A., J. R. Stokes, and A. Horvath. (2012). "Energy and air emission implications of a decentralized wastewater system." *Environmental Research Letters* 7(2): 024007.

Stokes, J. and A. Horvath (2011). "Life-Cycle Assessment of Urban Water Provision: Tool and Case Study in California." *Journal of Infrastructure Systems* 17(1).

Stokes J. and Horvath (2010). "Supply-chain environmental effects of wastewater utilities." *Environmental Research Letters* 5(1): 014015

Stokes, J. R. and A. Horvath (2009). "Energy and Air Emission Effects of Water Supply." *Environmental Science & Technology* 43(8): 2680-2687.

SELECTED PRESENTATIONS

American Water Works Association, Bay Area Chapter Meeting. "Using Life-cycle Assessment to Inform Urban Water Decisions" Fremont, California, February 21, 2013.

World Café for Managing Water-Related Energy Use in Cities: Opportunities, needs, and barriers. "Life-cycle Assessment and Urban Water Systems." Lawrence Berkeley National Laboratory, Berkeley, California, April 29, 2011.

American Society of Civil Engineers- San Francisco Water Resources Group Meeting. "Quantifying the Life-cycle Environmental Effects of Water Systems." San Francisco, California, February 8, 2011

WateReuse Association California Section Annual Conference. "A Cradle-to-Cradle Assessment of Energy and Climate Change Impacts of Recycled Water." San Francisco, California, March 23, 2009

American Water Works Association, California-Nevada Section Conference. "Energy Use and Greenhouse Gas Emissions of Water & Wastewater Services: A Life-cycle View." Hollywood, California. April 24, 2008.

American Water Works Association, Peninsula Chapter Meeting. "The Life-cycle Climate Change Contributions of Water Systems" Cupertino, California, December 5. 2007.

Society of Environmental Toxicology and Chemistry- North America Conference. "Life-Cycle Environmental Evaluation of California Water Supply" Milwaukee, Wisconsin, November 12, 2007.

PROFESSIONAL SERVICE

Technical Advisory Committee, PIER Regional Energy Baselines project, Stephanie Pincetl, University of California, Los Angeles, Principal Investigator. November 2011- December 2013 (expected).

Technical Session Committee, WateReuse California Section Annual Conference, San Francisco, California, March 22-24, 2009.

Gerard Walters

Principal/Chief Technical Officer

about

Jerry Walters is Fehr & Peers' Chief Technical Officer and leader of the firm's sustainable transportation planning practices. He has over thirty years' experience in transportation planning, engineering and travel forecasting. Jerry has led regional, State and Federal research and capacity-building efforts for Transportation Research Board Strategic Highway Research Program (SHRP), US EPA and State DOT's and Metropolitan Planning Organizations.

Jerry led nationwide studies for US EPA and General Services Administration developing nationally-applicable methods for predicting local vehicle miles travelled (VMT) based on accessibility and land use measures included in the US EPA Smart Location Database. He also developed nationally consistent methods for transportation and land use policy analysis by State DOTs and MPOs in SHRP2 C16: *The Effect of Smart Growth Policies on Travel Demand.* Jerry also contributed to *Methodologies and Data and Modeling Needs for Estimating GHG Emissions for Incorporation in the Transportation Planning Process* Handbook for FHWA, and *Estimating Demand for Non-Motorized Travel* (NCHRP 8-78). He served on the American Public Transit Association (APTA) working group on national guidelines for estimating climate change impacts of transit. He also developed project evaluation methods and metrics for the US EPA including the national guide *Mixed-use Development and Vehicle Trips: Improving the Standard Estimation Methodology* peer reviewed by the American Society of Civil Engineers and published by the American Planning Association. He co-authored *Growing Cooler – the Evidence on Urban Development and Climate Change* published by the Urban Land Institute.

He was principal author on performance measurement for the California Smart Mobility Framework and is assisting the Oregon Department of Transportation in preparation of its Statewide Transportation Strategy and impact measurement tools for regional and local governments. He served on Regional Targets Advisory Committee to the Air Resources Board on implementing California's landmark transportation/ land use and climate law SB 375, and the on the California Transportation Commission working group on travel modeling guidelines for Regional Transportation Plans under law AB32. He also led development of Caltrans inter-regionally consistent, locally tailored travel forecasting tools for scenario planning by all California MPOs

Jerry also served on the advisory committees for Caltrans' *"Assessment of Local Models and Tools for Analyzing Smart-Growth Strategies,"* and on the California Department of Housing and Community Development assessment *"The Effect of Housing Near Transit Stations on Vehicle Trip Rates and Transit Trip Generation"*,

education

Master of Engineering in Transportation Engineering, Rensselaer Polytechnic Institute, 1974

Bachelor of Science in Engineering Science, Rensselaer Polytechnic Institute, 1971

affiliations

Institute of Transportation Engineers (ITE)

registrations

Licensed Traffic Engineer, State of California (#1467)

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Gerard Walters

Principal/Chief Technical Officer

expertise

- Sustainability and Climate Change
- Transportation Performance Metrics
- Infrastructure Prioritization and Funding Programs
- Integrated Land Use/Transportation Planning
- Travel Models and Demand Forecasting
- Transit and Station Area Planning
- Highway Planning and Traffic Operations
- Livable Streets
- Infrastructure Prioritization and Funding Programs

publications & presentations

- US Environmental Protection Agency. *Estimating Worker VMT using EPA Smart Location Database.* 2013.
- American Planning Association. *VMT: Its Uses and Misuses in Planning.* 2012.
- California Air Resources Regional Targets Advisory Committee to the Air Resources Board. *Implementing California's Landmark Transportation/ Land Use and Climate Law, SB 375.* 2012.
- California Strategic Growth Council. *Urban Footprint Scenario Evaluation Tool and Vision California Statewide Sustainability Evaluation.* 2012.
- Federal Highway Administration Handbook. *Methodologies and Data and Modeling Needs for Estimating GHG Emissions for Incorporation in the Transportation Planning Process.* 2012.
- Transportation Research Board Strategic Research Program. *The Effect of Smart Growth Policies on Travel Demand and Capacity Requirements.* 2012.
- American Society of Civil Engineers. *Traffic Generated by Mixed-Use Developments – A Six-Region Study Using Consistent Built Environmental Measures.* 2011.
- US Environmental Protection Agency. *Mixed-use Development and Vehicle Trips: Improving the Standard Estimation Methodology.* 2011.
- California Air Pollution Control Officers Association. *Methods for Quantifying Effectiveness of Greenhouse Gas Mitigations.* 2010.
- California Department of Transportation. *Smart Mobility Framework.* 2010.
- National Association of Environmental Professionals. *Measuring the Benefits of Compact Development on Vehicle Miles and Climate Change.* 2009.
- Rebuilding America's Infrastructure. *Trip Generation at Mixed-Use Developments.* 2009.
- Urban Land Institute. *Growing Cooler: the Evidence on Urban Development and Climate Change.* 2008.

selected project experience

Regional, State, Federal Transportation Planning and Evaluation Programs

- Task leader on performance metrics and capacity-building for State DOTs and Metropolitan Planning Organizations (MPOs) on the Transportation Research Board (TRB) Strategic Highway Research Program (SHRP2) C16 investigation on the effects of smart growth on highway system capacity.
- Project Manager of US Environmental Protection Agency (EPA) national study on the traffic generation impacts of mixed use development projects, leading to protocols adopted by a number of State and regional agencies.
- Principal author of State of California Smart Mobility Framework performance measurement on State highways for Caltrans, California Department of Housing and Community Development, and Governor's Office of Planning and Research.
- Member of California Transportation Commission working group on implementation Regional Transportation Plan (RTP) procedures for California AB32 and SB375.
- Assisting the Oregon Department of Transportation prepare a Statewide Sustainable Transportation Strategy under State law SB1059 and development of scenario planning guidelines and a planning and evaluation toolkit for MPOs.
- Developed protocols for California Air Pollution Control Officers Association (CAPCOA) to assess the climate and air quality effects of a comprehensive list of transportation demand management

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(TDM) measures and other Best Management Practices (BMP).
- Project manager on Caltrans support to MPOs statewide in development and implementation of integrated transportation/ land use planning tools.
- Member of American Public Transit Association (APTA) working group on climate change credits and standards.
- Co-author of Urban Land Institute 2008 book: *Growing Cooler – Evidence on Urban Development and Climate Change*.

Highway Planning and Traffic Operations

- Served as advisor to FHWA and Utah DOT in preparation of Supplemental EIS on Legacy Parkway, including examination of potential benefits of optimal integration of transit and highway projects in the corridor and re-evaluation of project purpose and need, alternatives and transportation impacts
- Directed numerous multi-jurisdictional transportation planning studies, such as the 15-jurisdiction I-5 Corridor Transportation Strategic Plan and the five-county Foothill/Valley Intermodal Transportation Study
- Managed highway planning, design and operations studies for the I-680 high-occupancy-vehicle lanes and numerous interchanges and corridor studies.

Context-Sensitive and Safe Streets

- Led transportation planning and conceptual design for Caltrans demonstration project on Context Sensitive Street Design on a 4-mile segment of urban State highway.
- Traffic design principles for award-winning Palm Drive redesign and the Campus Drive and Sand Hill Road corridor street improvements at Stanford University.
- Study Advisor on Santa Clara Valley Transportation Authority Best Development Practices study and development of multimodal transportation Level of Service standards.
- Principal-in-Charge for Aurora, Colorado street standards for urban centers and transit oriented development.

Modal Integration Studies

- Environmental studies and statewide impact assessment for California High Speed Rail system.
- Principal-in-Charge of an eight-MPO transportation model improvements plan under a grant from the California Strategic Growth Council.
- Directed development of direct demand ridership forecasting models for concept screening, alternatives analysis and transit access and TOD planning for rapid rail (BART), commuter rail (Caltrain), and light rail transit systems in Denver, Sacramento, Salt Lake City, San Diego and Portland.
- Advised on prospective streetcar improvements plans in Salt Lake City, Albuquerque, Oakland and Austin.

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Tien-Tien Chan, AICP

Senior Transportation Engineer/Planner

about

Tien-Tien Chan is a Senior Transportation Engineer and Planner. She is passionate about transportation demand management (TDM) and sustainability, and this is shown through her project work and volunteer endeavors. She conducted groundbreaking work for the California Air Pollution Control Officers Association to quantify trip reduction and greenhouse gas (GHG) emissions reduction benefits for a suite TDM strategies. This included extensive surveying of state-of-the-practice and rigorous literature screening of transit, bicycle and pedestrian travel incentives, and auto disincentives. She has also developed a TDM tool for the Bay Area Air Quality Management District to put this new work into practice. Her work at Fehr & Peers includes providing recommended strategies for project-level and city-wide TDM programs. She has authored TDM plans and conducted monitoring studies for numerous university and office campuses. Tien-Tien actively volunteers with and sits on the committees for Transportation Research Board (TRB)'s Committee on Transportation and Sustainability, the Institute of Transportation Engineer's Sustainability Task Force, and TRB's Committee on TDM.

education

M.S. in Management Science and Engineering – Energy and Environmental Policy (emphasis on Transportation), Stanford University, 2009

B.S. in Applied Mathematics, University of California Los Angeles, 2004

professional affiliations

Association for Commuter Transportation (ACT), Board Member of the Northern California Chapter

Institute of Transportation Engineers (ITE), Member of Sustainability Taskforce

Transportation Research Board (TRB), Member of the Committee on Transportation and Sustainability, Member of the Committee on Transportation Demand Management

publications and presentations

Sustainable Transportation: State of the Practice Review, (Report). Institute of Transportation Engineers. August 2013.

Quantifying Greenhouse Gas Mitigation Measures – A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures (Report). California Air Pollution Control Officers Association. August 2010.

Travel Forecast Modeling for Sustainable Communities: The Building Blocks of Climate Change Evaluation (Panel Session), 2012 California Association of Environmental Professionals Conference

Moving Forward: A Tool for Estimating VMT Reductions (Panel Session), 2011 CA American Planning Association Conference

Validating VMT Reductions from Transportation Measures (Panel Session), 2011 GHG in a Changing Climate Conference, Air and Waste Management Association

project experience

City of San Francisco TDM Framework for Growth

Tien-Tien is the lead planner on a project developing a comprehensive TDM strategy for new land use development projects in San

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Francisco with the goal of quantifying transportation impacts and identifying mitigations in a forward-thinking way. The team is working with the City to create a model that links TDM strategies to reductions in VMT with the goal of requiring VMT-reducing mitigations. Tien-Tien led an extensive data collection effort to quantify the impacts of parking supply on auto mode share, applying this to a tailored TDM interactive tool.

Alameda Point TDM Plan Implementation

Tien-Tien is the project manager for the implementation of the TDM plan for a new mixed-use, transit-oriented community on Alameda Island. The project includes implementing the initial steps of the TDM plan over the next two years before major development occurs. The project will focus on working with the existing community, as well as implementing strategies that will attract residents and employers. The project will include creating a funding mechanism for the plan, establishing a TMA, creating a monitoring and evaluation plan, and establishing initial programs and community website.

San Francisco County Transportation Authority TDM On-Call

Tien-Tien is part of a team supporting the City and County of San Francisco's TDM Partnership Project. The purpose of the project is to both enhance and streamline existing TDM efforts in San Francisco, expanding outreach and the level of engagement with public and private partners. The project will involve the following key aspects:

- TDM policy research, development and analysis
- TDM program facilitation and capacity building
- TDM program design and development
- TDM implementation support and evaluation

Elements of the Partnership Project will include development of a TDM program and TMA organization for the southwest sector of San Francisco, creation of a partners program to facilitate collaboration of private shuttle services and public transportation, and implementation of a parking cash-out program.

TDM Strategy Model, Bay Area Air Quality Management District

Tien-Tien developed a TDM strategy model and a technical memo/user's guide for measuring the effectiveness of individual and grouped TDM strategies in reducing GHG emissions. The Excel-based tool models the combined effects of TDM strategies based on the literature review performed for the CAPCOA study, specific to the Bay Area. The model draws on the individual effectiveness and grouped effectiveness of measures reported in the literature.

Burlingame Point TDM Program

Tien-Tien was the project manager for a Transportation Demand Management (TDM) program for the Burlingame Point development in Burlingame, California. The TDM program was prepared to reduce both the traffic generated by the development and the demand for parking spaces by a minimum of ten percent, provide multi-modal travel options for employees of the site, and increase the "green" marketability of the development. We prepared a comprehensive and context-relevant TDM program designed to achieve the target using our experience in preparing TDM programs for significant nearby developments (including Mission Bay, Candlestick Point-Hunters Point Shipyard, Gateway Business Park, Genentech and others). The final TDM program included strategies that are flexible to meet a phased project build-out.). The program was developed in parallel with the EIR work to ensure consistency.

Candlestick Point - Hunters Point Shipyard (CP-HPS) TDM Funding and Implementation Plan

Tien-Tien prepared a Transportation Demand Management (TDM) Program for the redevelopment of Candlestick Point and the Hunters Point Shipyard sites in southeast San Francisco. The project's land use, urban design, and transportation plans are all aimed at making this new development a model of sustainability. The TDM program included a comprehensive menu of complimentary strategies which focused on both "carrots" and "sticks" to incentivize multi-modal travel. Specific strategies were also provided focusing on the increased traffic at game days for the proposed football stadium. Tien-Tien also conducted a cost and funding analysis for each of the TDM strategies.

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Other Project Experience

- University of San Francisco Institutional Master Plan
- University of Texas Austin Mobility and TDM Program
- Numerous office developments and large office campus TDM plans
- TDM plans for Kaiser Medical, Children's Hospital, and University of California San Francisco (UCSF)
- TDM plan performance monitoring for City College San Francisco, Stanford University Medical Center, and various office parks

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Sarah Peters, AICP

Transportation Planner

about

Sarah joined Fehr & Peers in 2011, while completing her Master's in Urban and Regional Planning from University of California Los Angeles. Sarah has worked on transportation demand management plans and monitoring, bicycle/pedestrian plans and multi-modal transportation studies and has developed communication tools for bicycle and pedestrian assessment methods and Complete Streets implementation techniques. She has experience with an array of multi-modal Level of Service evaluation systems and software programs, including Traffix, Synchro/SimTraffic, Cube and Geographic Information Systems (GIS).

education

Masters of Urban and Regional Planning, University of California, Los Angeles, 2012

Bachelors of Art in Liberal Arts, St. John's College, Annapolis, 2002

affiliations

- American Planning Association
- Young Professionals in Transportation

publications

- Complete Enough for Complete Streets? Testing the Sensitivity of HCM 2010 Multimodal Level of Service Under Conditions of Change (co-author), *Transportation Research Record*, 2013

- Impact Fees for Complete Streets, UCLA Complete Streets Initiative, Lewis Center of the Luskin School of Public Affairs, 2012

selected project experience

Facebook TDM Monitoring (Menlo Park, California)

Sarah manages Fehr & Peers' work on TDM monitoring at Facebook's Menlo Park campus. She coordinates with Facebook's transportation team to gather internal information on program performance as well as conducting physical site surveys to evaluate Facebook's compliance with its trip cap.

Castilleja School Study (Palo Alto, California)

Sarah manages our ongoing TDM monitoring work for Castilleja School, evaluating student mode share and trip cap compliance using a combination of internal and external data.

Stanford University Transportation Strategies (Stanford, California)

Sarah evaluated the effectiveness of a range of TDM and capacity expansion strategies to accommodate Stanford's future growth. Recommendations from this study included the implementation of a TDM program at Stanford Research Park.

VTA TIA Guidelines Update (Santa Clara County, California)

Sarah provided staff support for the 2014 update to the VTA TIA Guidelines. She worked closely with VTA Planning staff to develop a comprehensive update to the Guidelines and provided guidance on the use of multi-modal LOS methodologies and specialized trip generation methodologies.

North 40 Transportation Impact Analysis (Los Gatos, California)

Sarah is managing this project after serving as project planner and engineer during the development of the EIR.

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Chris Gray, AICP

Principal

about

Christopher J. Gray, AICP, is a Principal with nearly 20 years of experience in transportation planning, sustainable transportation, Complete Streets, climate change studies, travel demand forecasting, parking studies, transit studies, and Smart Growth. Chris has worked extensively in California, other areas of the United States, and internationally. He has assisted several cities and agencies with climate change planning, including GHG reduction strategies, transportation planning for VMT reduction, and model development to quantify their effects.

education

Master of Science in Planning (Transportation), Florida State University, 1995

Bachelor of Arts in Political Science, University of Florida, 1992

affiliations

American Planning Association (APA)

- Programs Chair of the Inland Empire Section APA Board
- American Institute of Certified Planners

Association of Environmental Professionals

- Climate Change Committee member

The Congress for a New Urbanism

Urban Land Institute

professional registration

American Institute of Certified Planners, #108198

selected conference presentations

- El Camino Real Complete Street, 2003 National ITE
- Rail Ridership Forecasting Methodology, 2004 National ITE
- Local Government Climate Action Plans, 2009 International ESRI Conference
- Greenhouse Gas Reduction Plans, 2010 National ITE
- Irvine Climate Action Plan, 2010 Statewide AEP Conference
- Greenhouse Gas Reduction Strategies, 2010 Western District ITE
- Transit Oriented Development, 2010 Statewide APA
- Greenhouse Gas Inventories, 2011 Statewide AEP
- Greenhouse Gas Inventory Methodologies and Approach, 2011 Statewide APA
- San Diego Foundation, 2012 Smart Growth Partners
- Future of the Car, 2012 National APA
- Innovations in Active Transportation, 2012 Riverside County Public Health Department Presentation
- Health Tools and Environmental Documents, 2013 National AEP
- Responses to Climate Adaptation, 2013 National AEP
- Do's and Don'ts of Healthy Community Planning, 2013 Innovative Communities

teaching

- Innovations in Transportation Planning, 2012 APA National Conference
- Health and the Built Environment, 2012 University of California Riverside Extension
- Land Use Transportation Interaction (PL-58), 2014 UC Berkeley Tech Transfer
- Guest lecturer at UCLA, UCI, UCR, and Cal Poly Pomona

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Chris Gray, AICP
Principal

publications

- Sustainable Transportation Around the Pacific Rim: Challenges and Changes in Asia. *Planning Magazine*, July 2011.
- The Car in 2035: Mobility Planning for the Near Future, 2013

selected project experience

Irvine Climate Action Plan

Fehr & Peers was a member of a multi-disciplinary team tasked with preparing the Climate Action Plan for the City of Irvine. The purpose of this Climate Action Plan was to identify reductions in Greenhouse Gas Emissions (GHGs) in accordance with the requirements set out under AB 32. Fehr & Peers' role in this study was to provide data and analysis related to transportation aspects of GHG emissions. Specific tasks included a review of the inputs and outputs related to ITAM, sensitivity testing for ITAM, the development of future year vehicle miles traveled (VMT) estimates, and identification of VMT and GHG reductions strategies. Strategies considered by the Climate Action Plan included traffic signal retiming/coordination, increases in density and mixed-use, increased transit service, supplemental improvements related to bicycle and pedestrian travel, and other related items.

IBC Vision Plan EIR – Transportation Related Greenhouse Gas Emissions Support

Fehr & Peers assisted the City of Irvine with an update of the Irvine Business Center (IBC) Vision Plan Environmental Impact Report (EIR). In response to significant public comments, the City of Irvine is updating this EIR to include a significant component related to GHG emissions. Our work efforts include the quantification of Vehicle Miles Traveled (VMT) related to new development within the IBC, a review of emission reduction strategies, and assistance in preparing the EIR Chapter discussing GHG impacts. Chris Gray is serving as the Fehr & Peers project manager for this effort.

Santa Barbara County GHG Inventory

Chris Gray served as the Fehr & Peers Project Manager for a Greenhouse Gas Inventory in Santa Barbara County. Our role on the team included a review of transportation data and preparation of VMT estimates for County land. A key element of this study included the differentiation of VMT between incorporated areas of the County and the unincorporated areas through the use of the SBCAG travel demand model.

WRCOG Regional Climate Action Plan

Fehr & Peers contributed to the development of a groundbreaking Regional Climate Action Plan in the State of California for the Western Riverside Council of Governments (WRCOG). Fehr & Peers has been a key participant in the effort through the quantification of transportation emissions for 12 cities including the City of Riverside using the Riverside County Travel Demand Model (RIVTAM). Fehr & Peers also developed GHG mitigation measures for each of the participating cities and quantified each measure based on the anticipated level of participation.

San Gabriel Valley COG Greenhouse Gas Inventory and Energy Efficiency Plans

Fehr & Peers provided transportation support to the Project Team for the development of a Regional Greenhouse Gas Inventory for the San Gabriel Valley COG. Fehr & Peer is preparing vehicle miles traveled for each of the cities in with the SGVCOG using the SCAG Travel Model.

Other Climate Action Plans and Greenhouse Gas Studies

Chris has worked on a variety of municipal climate action plans and other Greenhouse Gas reduction studies throughout the United States and locations outside the US including:

- City of Santa Ana Climate Action Plan
- Goleta Climate Action Plan
- City of Pasadena GHG Inventory
- County of San Diego Climate Action Plan
- City of San Diego Climate Adaptation Plan
- City of Vista Climate Action Plan
- Monterey Park Climate Action Plan
- San Clemente Climate Action Plan
- National City General Plan & Climate Action Plan
- City of Coachella General Plan

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Chris Gray, AICP
Principal

- City of Bellflower Climate Action Plan
- City of El Segundo GHG Inventory
- City of South Gate GHG Inventory

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Mike Wallace

Principal
Director of Travel Behavior & Forecasting

about

Mike Wallace, a Principal in the Walnut Creek office, has been responsible for detailed travel behavior analysis, travel forecasting, and traffic operations analysis of local and regional transportation facilities, as well as transportation impact, circulation and parking studies for land use developments. With over ten years of experience in the traffic engineering and planning field, he has developed in-depth expertise in the application of all major transportation analysis techniques, with particular emphasis on travel demand software applications such as TransCAD, Cube/Voyager, and VISUM. As the Director of Travel Behavior & Forecasting, Mike evaluates, implements, and shares new techniques and tools throughout the company, attends and presents at professional organization meetings, trains and mentors junior staff, and helps ensure that projects provide innovative solutions that benefit communities.

Mike has served as project manager, technical advisor, or project engineer on numerous transportation planning and operations analysis projects developing, enhancing, and applying the SLOCOG, AMBAG, and SBCAG models. Recently Mike has utilized combinations of innovative data collection and analysis techniques on multiple projects, and he continues to evaluate opportunities to turn research into practical application.

While attending Cal Poly SLO for his Master Degree, Mike worked at Caltrans District 5 in Travel Forecasting and Modeling. Since then, Mike has been an active member of the Central Coast Model User Working Group, the SLOCOG and AMBAG Model Coordination Working Groups, was a member of the AMBAG and SBCAG Model Update Peer Review Panels, and is currently managing the Fehr & Peers team updating for the SLOCOG and AMBAG models.

Mike has extensive experience in developing and utilizing city and regional models in the San Joaquin Valley.
Recently Mike managed a multi-firm team for the San Joaquin Valley Model Improvement Plan which enhanced the tools for addressing Senate Bill 375. The project enhanced the trip based model for each of the eight MPOs in the valley, conducted a three-county origin-destination study, developed an integrated GIS, land use and transportation model, and developed a parcel and a TAZ activity based models. In addition to updating models and quick response tools, Mike assisted in coordinating with MPOs and Air Resources Board for target setting.

education

Master of Science in Civil and Environmental Engineering, California Polytechnic State University, San Luis Obispo, 2004
Bachelor of Science in Civil Engineering, California Polytechnic State University, San Luis Obispo, 2002

affiliations

Institute of Transportation Engineers: Member
American Planning Association: Member
TRB Committee on Emergency Evacuation: Member

registrations

Engineer in Training, State of California, #113343
Professional Transportation Planner (PTP), #150

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Mike Wallace

Principal/Director of Travel Behavior & Forecasting

selected publications & presentations

- *Thinking Like a Futurist: Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity*, AMPO Annual Meeting 2014
- *Using Cube Land in the San Joaquin Valley and Beyond*, Citlabs Mountain West User Group Meeting, 2014
- *San Joaquin Valley's Next Top Transportation Model: A Technical Discussion with a Policy Focus*, San Joaquin Valley Fall Policy Conference, 2014
- *Improving Regional Land Use, Transportation, Air Quality and Greenhouse Gas Forecasting in the San Joaquin Valley Through Inter-agency Coordination and Standardization of Data, Models and Software Tools*, AMPO Annual Meeting, 2012
- *The First Penguin Through the Data Ice Hole – The effect of Big Data on Transportation Planning and Engineering*, Urban Systems Collaborative, 2012
- *Turning Data into Knowledge – Innovations in Data Collection and Analysis*, Utah Big Data Summit, 2012
- *The Future of Valley Modeling – Innovation through Collaboration*, Citilabs Annual International User Conference, 2011
- *Planning without Borders – Developing Sustainable Communities for Eight MPOs* , AMPO Annual Meeting, 2011
- *Future of Valley Modeling*, San Joaquin Valley Policy Conference, 2011

selected project experience

Strategic Highway Research Program Project (Sacramento County, CA)

As technical advisor, Mike provided input and assistance relating to the Strategic Highway Research Program Project (SHRP 2) Project C 10. The goal of this project is to improve modeling and network processes and procedures in order to address policy and investment questions that cannot be well addressed now, and to facilitate further development, deployment, and application of these procedures. The primary objective of this project is to make operational in public agencies a dynamic integrated model – an integrated, advanced travel demand model with a fine-grained, time-dependent network (integrated activities and networks). The secondary objectives of this project are to: Produce a portable, transferable, product, process, and sample data set that can be adapted for use elsewhere or used for research; incorporate SHRP 2 Capacity products from projects C04 (pricing) and C05 (operations) into the model capabilities; incorporate travel time reliability into the modeling capabilities; demonstrate the application of outputs of the integrated model to estimate greenhouse gas emissions using EPA's MOVES Model; and demonstrate the dynamic integrated model set in a real-world environment on selected policies. Fehr & Peers worked closely with several other teaming partners like SACOG, University of Arizona and FHWA. Fehr & Peers assisted with the data assembly and collection and in the testing of alternatives with the new model in the Sacramento region.

AMBAG Model Update (Monterey, San Benito Counties, and Santa Cruz, CA)

As Travel Demand Modeling Task Manager, Mike coordinated with the Prime Consultant and the Fehr & Peers team to update the regional travel model for use on the Metropolitan Transportation Plan (MTP) and Sustainable Community Strategy (SCS) evaluation. Fehr & Peers conducted a dynamic validation test of the AMBAG model to determine the sensitivity of the model to land use and transportation policy inputs. A set of related tasks were undertaken to improve the AMBAG travel model sensitivity to what are known in transportation planning as "D" variables. The Ds are local land use variables that include **D**ensity, land use **D**iversity, pedestrian **D**esign, and access to regional **D**estinations. This sensitivity testing was used to accurately implement the Ds modifications to the updated AMBAG travel model and also included testing sensitivity to roadway and transit projects. For areas not included in the regional travel model or the model lacked sensitivity, we developed guidelines or post-processers to evaluate policies and projects.

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SJ Valley Model Improvement Program (San Joaquin Valley, CA)

As Technical Project Manager, Mike managed a multi-consultant team to update and improve each of the Eight San Joaquin Valley MPO traffic models to meet near term needs and address continued maintenance and improvements, as defined under SB 375. The $2.5 M contract was completed on schedule in 16 months, and included:

- Improvements to each MPO model as prescribed by the new RTP guidelines as well as improvements requested in our interviews with MPO Staff,
- A three-county O/D travel survey for San Joaquin, Stanislaus and Merced Counties,
- A new three-county activity-based model for San Joaquin, Stanislaus and Merced Counties,
- A parcel based activity-based model for Fresno County,
- An integrated-transportation land use allocation model for Kern County,
- Model sensitivities to 4D land use and Best Management Practices as described in SB 375,
- Static and dynamic model validation and air quality conformity checking,
- Updated interregional and truck trip models for the Valley, and other improvements.

San Luis Obispo Council of Governments Model Improvement Program (San Luis Obispo, CA)

As Project Manager, Mike provided consulting services to update and improve the San Luis Obispo Council of Governments travel demand model to meet or exceed near term needs and address continued maintenance and improvements, as defined under SB 375. Through his experiences as a leading innovator in model enhancements prescribed by the new state laws, the improvements included:

- Peak and off-peak GPS travel time runs to calibrate speeds on major facilities as requested by Caltrans,
- Collected vehicle classification count data that included speeds to calibrate speed-flow curves,
- Utilized cell phone data to determine Origin-Destination patterns and travel speeds for use in validation,
- Enhanced the Graphical User Interface and Master Network to implement an "any year, any scenario" alternative management system,
- Calibrated model sensitivities to local conditions related to the 4D land use and Best Management Practices as described in SB 375,
- Static and dynamic model validation and air quality conformity checking and
- Included truck trips generated by land use for more accurate speed and GHG reporting
- Added zonal detail, sensitivity to parking and other costs, transit system, congestion, additional analysis time periods, and other factors that more accurately reflect travel behavior
- Began intersection control database and ability to include junction delay during traffic assignment
- Documented the model process, results, and limitations of the model for both decision makers/public and technical staff levels
- Presented results to member agencies, Caltrans, and adjacent MPO staff

San Luis Obispo Council of Governments Modeling Support (San Luis Obispo, CA)

As Travel Demand Modeling Task Manager, Mike was responsible for providing on-going support to San Luis Obispo Council of Governments (SLOCOG), an MPO, in the application and refinement of their travel demand model. This included updating the land use, calibrating trip generation rates, and implementing application of the 4D's, where the effects of different land use scenarios developed through a Blueprint process were compared to estimate the trip reductions associated with smart growth patterns. A quick response post-processing tool was developed to enable the COG to quickly determine the influence of factors such as increasing transit service, parking cost, or other travel demand management

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measures. In addition, "web shadowing" was used to provide hands-on training over the internet.

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