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An Economic and Life Cycle Analysis of Regional Land Use and Transportation Plans

MTI Report 11-25

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REPORT 11-25

AN ECONOMIC AND LIFE CYCLE ANALYSIS OF REGIONAL LAND USE AND TRANSPORTATION PLANS

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16. Abstract

Travel and emissions models are commonly applied to evaluate the change in passenger and commercial travel and associated greenhouse gas (GHG) emissions from land use and transportation plans. Analyses conducted by the Sacramento Area Council of Governments predict a decline in such travel and emissions from their land use and transportation plan (the "Preferred Blueprint" or PRB scenario) relative to a "Business-As-Usual" scenario (BAU). However, the lifecycle GHG effects due to changes in production and consumption associated with transportation and land use plans are rarely, if ever, conducted. An earlier study conducted by the authors, applied a spatial economic model (Sacramento PECAS) to the PRB plan and found that lower labor, transport, and rental costs increased producer and consumer surplus and production and consumption relative to the BAU. As a result, lifecycle GHG emissions from these upstream economic activities may increase. At the same time, lifecycle GHG emissions associated with the manufacture of construction materials for housing may decline due to a shift in the plan from larger luxury homes to smaller multi-family homes in the plan. To explore the net impact of these opposing GHG impacts, the current study used the economic production and consumption data from the PRB and BAU scenarios as simulated with the Sacramento PECAS model as inputs to estimate the change in lifecycle GHG emissions. The economic input-output lifecycle assessment model is applied to evaluate effects related to changes in economic production and consumption as well as housing construction.

This study also builds on the findings from two previous studies, which suggest potential economic incentives for jurisdictional non-compliance with Sustainable Communities Strategies (SCSs) under Senate Bill 375 (also known as the "anti-sprawl" bill). SB 375 does not require local governments to adopt general plans that are consistent with the land use plans included in SCSs, and thus such incentives could jeopardize implementation of SCSs and achievement of GHG goals. In this study, a set of scenarios is simulated with the Sacramento PECAS model, in which multiple jurisdictions partially pursue the BAU at differing rates. The PRB is treated as a straw or example SCS. The scenarios are evaluated to understand how non-conformity may influence the supply of housing by type, and holding other factors constant, the geographic and income distribution of rents, wages, commute costs, and consumer surplus.

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EXECUTIVE SUMMARY

California led the nation by passing the first global warming legislation in the U.S. (AB 32: The Global Warming Solutions Act). California is now tasked with reducing greenhouse gas (GHG) emissions to 1990 levels by 2020 and 80 percent below 1990 levels by 2050. California Senate Bill 375 (SB 375) – commonly known as "California's anti-sprawl bill" – mandates regional GHG targets linked to land use and transportation plans (called Sustainable Community Strategies or SCSs).

This publication is the third in a series of studies funded by the Mineta Transportation Institute that applies a new form of spatial economic model to examine questions surrounding the economic effects, the distribution of those effects, and their implications for AB 32 and SB 375 implementation. The Sacramento PECAS land use model is used to simulate the Sacramento region's land use and transportation plan (also known as the "Preferred Blueprint" or PRB) and "Business-as-Usual" scenario (BAU). For study purposes, the PRB is treated as a proxy SCS.

The first publication[1] explores the AB 32 requirement that economic and equity effects of mechanisms (land use and transportation plans under SB 375) used to achieve GHG targets be evaluated prior to implementation. The second publication[2] investigates how a local government's decision to not comply with the SCS could change the geographic distribution of economic benefits and under what circumstances this change may be an incentive or disincentive for SCS implementation. The current publication builds on the second by exploring how changes in housing supply can drive local economic incentives or disincentives for compliance. The current study also includes an analysis of the life cycle GHG effects due to changes in production and consumption associated with the transportation and land use plans in the Sacramento region. This executive summary and report include findings from both the current and previous two publications. Taken as a whole, the results of these studies provide new and expanded policy insights.

ECONOMIC AND EQUITY EFFECTS

Advanced aggregate travel models and activity-based travel models have been applied in equity studies in the U.S. to evaluate the distribution of travel time and cost effects of land use and transportation policies across different socio-economic groups. However, new forms of spatial economic models represent the interactions between the transportation system and the broader economic system. These enable equity evaluations that encompass a wider range of impacts such as employment, wages, rents, as well as consumer and producer surplus by household types and industry sectors.

In the first publication, the results of the simulation of PRB and BAU scenarios with the Sacramento PECAS model suggest that a more compact urban form designed around transit stations (in the PRB scenario) can reduce private travel costs and rents. This may lead to overall net economic benefits (consumer and producer surpluses) for the region, even when the total size of the economy is held constant. Increased accessibility tends to benefit industry directly and indirectly (through reduced labor costs). Low-income households tend to benefit from a greater supply of lower rent, multi-family housing and improved travel conditions. The reduced supply and higher cost of large, luxury single-family housing units tend to result in consumer surplus losses for the higher income groups in the region.

The Sacramento PECAS model was largely developed with data collected before 2007 that indicate a general consumer preference for larger single-family homes. However, a number of recent studies[3] report a possible shift in consumer preferences toward smaller homes in smart growth communities resulting from factors other than the 2008 economic downturn, for example, strong consumer interest in "green" homes with lower energy costs. The size of a home makes a significant contribution to the energy it consumes. A change in consumer preferences could mitigate losses to higher income groups that result from a reduced supply of larger, luxury single-family housing units.

INCENTIVES AND DISINCENTIVES FOR IMPLEMENTATION

The second[4] and current publications address implementation questions surrounding SCSs under SB 375 to meet GHG goals. SB 375 does not require local governments to adopt general plans that are consistent with the land use plans included in SCSs. Instead, SB 375 strengthens and places emphasis on "bottom up" public participation processes to enable the development of and support for plans that meet GHG goals. The bill also relies on incentives for implementation that include transportation funding and California Environmental Quality Act streamlining.

The spatial economic framework of the Sacramento PECAS model allows for an analysis of the economic incentives and disincentives faced by jurisdictions charged with implementing the regional land use plans. Such jurisdictions may face significant pressures from developers, if as the first study indicates, the supply of luxury single-family housing falls significantly short of the demand.

In the second study, the application of the Sacramento PECAS model is expanded to explore conditions under which some jurisdictions may benefit from non-conformity with the PRB and how such a decision may affect the economic welfare of other jurisdictions as well as the region as a whole. In general, the results of the study suggest that if non-conformity leads to further decentralization of the region, then the region as a whole – and, to a greater or lesser extent, the non-conforming jurisdictions – would suffer economic losses due to higher costs for business operations. The exception is when non-conformity enables the production of more, large, luxury single-family housing at a cost that offsets higher private transportation costs required to access the outlying area.

In the current study, a different set of non-compliance scenarios are developed in which multiple jurisdictions partially pursue the BAU at differing rates. The focus is on how non-conformity may influence the supply of housing by type, and holding other factors constant, the geographic and income distribution of rents, wages, commute costs, and consumer surplus. On average, when non-conformity increases the supply of larger, luxury single-family homes in non-complying jurisdictions, the average household in those jurisdictions experiences increased economic benefits, while the average household elsewhere experiences economic losses. The total net benefits in the non-complying jurisdictions are large enough to offset the losses in complying jurisdictions to produce net benefits for the average regional household. However, when non-conformity increases in both luxury and standard single-family housing, then economic benefits decline for the average household in all jurisdictions. At this point, the more heavily weighted gains of the higher income households are not great enough to offset the less heavily weighted losses of the lower income classes.

LIFE CYCLE GREENHOUSE GAS EFFECTS

Travel and emissions models are commonly applied to evaluate the change in passenger and commercial travel and associated GHG emissions from land use and transportation plans. Analyses conducted by the Sacramento Area Council of Governments (SACOG)[5] predict a decline in such travel and emissions in the PRB relative to the BAU scenario. However, the life cycle GHG effects due to changes in production and consumption associated with transportation and land use plans are rarely, if ever, conducted.

As described above, lower labor, transport, and rental costs in the PRB scenario increase producer and consumer surpluses, and production and consumption relative to the BAU. As a result, life cycle GHG emissions from these upstream economic activities may increase. At the same time, life cycle GHG emissions associated with the manufacture of construction materials for housing may decline due to a shift from larger luxury homes to smaller multi-family homes. The net impact of these opposing GHG impacts is not well understood.

To explore this issue, the current study uses the economic production and consumption data from the PRB and BAU scenarios, as simulated with the Sacramento PECAS model, as inputs to estimate the change in life cycle GHG emissions. The Economic Input-Output Life Cycle Assessment model (EIOLCA) is applied to evaluate effects related to changes in economic production and consumption as well as housing construction.[6] The EIOLCA model is a publicly available lifecycle assessment model of upstream emissions impacts resulting from economic activity within a particular sector. The model is produced and maintained by Carnegie Mellon University's Green Design Institute.

The results indicate that total CO_2e (carbon dioxide equivalent) would increase by 1,037,864 metric tons from upstream economic activities derived from consumption in the PRB scenario relative to the BAU over 25 years. However, a commensurate shift in construction from larger luxury to smaller single- and multi-family homes causes a reduction in upstream emissions that is estimated at a larger 2,165,959 metric tons. Changes in economic activities may be underestimated in the PRB scenario because of the assumption of constant total economic size. However, to put the relative impacts in perspective, the difference between economic activities (from the BAU to the PRB) would have to at least double to offset the reductions in GHG emissions from housing construction.

It is important to note that the analysis of life cycle GHG emissions includes production, but not the use of goods and services demanded by consumers or purchasers in each scenario. GHG emissions from the distribution and use of the transportation system is estimated to decline in the PRB relative to the BAU, as discussed above; however, it is unclear how use of products and services might impact the results of this study.

KEY FINDINGS, IMPLICATIONS, AND POLICY RECOMMENDATIONS

- Coordinated land use and transportation plans, such as those envisioned by SB 375, may reduce housing, transport, and labor costs and increase net economic benefits.

- A shift in the supply of larger, luxury single-family to multi-family housing in land use and transportation plans may benefit all but the highest income household (assuming consumer preferences remain constant from the year 2000 model estimation and calibration year).

- The overall reduction in home size from this shift in housing supply may more than offset increases in life cycle GHG emissions due to greater economic production that may result from the plan.

- If the consumer preference for larger homes returns to levels observed prior to 2007, developers and jurisdictions may face significant economic incentives to increase the supply of luxury single-family homes over and above that recommended in the regional land use and transportation plan. If this is at the expense of multi-family housing units, then low-income households may face significant economic losses.

- If, however, the early evidence that consumer preferences are shifting in favor of smaller homes coupled with high quality local and regional accessibility, then the land use and transportation plans envisioned under SB 375 are more likely to match market demand and be implemented.

- More research is needed to understand the market preferences for housing in regional land use and transportation plans under SB 375 to realize their potential to improve the economy, equity, and GHG reductions.

- Implementation of SB 375, as well as the regional supply of multi-family housing, should be carefully monitored. Decision makers may find the results of monitoring very useful as they contemplate the need for future revisions to SB 375 over time.

I. INTRODUCTION

Travel and emissions models are commonly applied to evaluate the change in passenger and commercial travel and associated greenhouse gas (GHG) emissions from land use and transportation plans. Analyses conducted by the Sacramento Area Council of Governments (SACOG)[7] predict a decline in such travel and emissions from their land use and transportation plan (the “Preferred Blueprint” or PRB scenario) relative to a “Business-as-Usual” scenario (BAU). However, the life cycle GHG effects due to changes in production and consumption associated with transportation and land use plans are rarely, if ever, conducted.

In an earlier study conducted by the authors,[8] a spatial economic model (Sacramento PECAS) simulated the PRB plan and found that lower labor, transport, and rental costs increased producer and consumer surplus and production and consumption relative to the BAU. As a result, life cycle GHG emissions from these upstream economic activities may increase. At the same time, life cycle GHG emissions associated with the manufacture of construction materials for housing may decline due to a shift in the plan from larger, luxury single-family homes to smaller multi-family homes in the plan. The net impact of these opposing GHG impacts is not well understood.

To explore this issue, the current study uses the economic production and consumption data from the PRB and BAU scenarios, as simulated with the Sacramento PECAS model, as inputs to estimate the change in life cycle GHG emissions. The Economic Input-Output Life Cycle Assessment model (EIOLCA), which is a publicly available model of upstream emissions impacts resulting from economic activity produced and maintained by Carnegie Mellon University’s Green Design Institute, is applied to evaluate effects related to changes in economic production and consumption as well as housing construction.

This study also builds on the findings from two previous studies,[9] which suggest potential economic incentives for jurisdictional non-compliance. In this study, the analysis is expanded by simulating a set of scenarios (using the Sacramento PECAS model) in which multiple jurisdictions partially pursue the BAU, instead of the PRB, at differing rates. Because SB 375 does not require local governments to adopt general plans that are consistent with the land use plans included in Sustainable Community Strategies (SCSs), such incentives could jeopardize implementation of SCSs and achievement of GHG goals. The scenarios are evaluated to understand how non-conformity may influence the supply of housing by type, and holding other factors constant, the geographic and income distribution of rents, wages, commute costs, and consumer surplus.

The study begins with background on the project, including relevant legislation, a description of the Sacramento region land use and transportation scenarios, and a review of the relevant literature. Next, the Sacramento PECAS model is described, as well as the simulation of the base BAU and PRB scenarios. This is followed by a discussion of the methods and results for both the life cycle and non-compliance analyses. The study ends with a discussion of the major conclusions of the study and key recommendations.

II. BACKGROUND

LEGISLATIVE

In 2006, California Governor Arnold Schwarzenegger signed California Assembly Bill 32, also known as the Global Warming Solutions Act (AB 32), into law. As the first global warming legislation in the U.S., the law tasked the California Air Resources Board (ARB) to develop a plan for reducing California's GHG to 1990 levels by 2020. Executive Order S-3-05 signed by the governor specified additional GHG emissions reductions: 80 percent below 1990 levels by 2050. In its AB 32 Climate Change Scoping Plan, ARB recommended a three-pronged approach for reducing GHG emissions from personal vehicles, identifying vehicle technology, fuel GHG intensity, and travel behavior as key components contributing to overall passenger vehicle GHG emissions.

California's legislative answer to the necessity of changing travel behavior to meet AB 32 goals came in 2008 with the passage of California Senate Bill 375 (SB 375), or California's "anti-sprawl bill." The bill directs ARB to set regional targets to reduce GHG emissions, which are to be achieved through regional land use and transportation policies. According to ARB's AB 32 Scoping Plan, changes in land use and transportation planning should result in an annual reduction of five million metric tons in carbon dioxide equivalents by 2020 from reduced vehicle miles traveled (VMT).

SB 375 requires Metropolitan Planning Organizations (MPOs) to include a Sustainable Communities Strategy (SCS) in their regional transportation plan that demonstrates how the region will meet the greenhouse gas emission targets. Although the bill requires such a strategy, it does not compel local governments to conform to this strategy. Because their general plans do not have to be consistent with the regional plan and they retain authority over development decisions in their jurisdiction, local governments have the final word over how the provisions of SB 375 are ultimately implemented.

SACRAMENTO REGION

In its 2004 Blueprint Project, SACOG established the basic participatory planning process that was later codified by SB 375. This public participation planning process resulted in the creation of a common land use and transportation vision for the Sacramento region. Over 5,000 residents contributed to the effort to develop a plan to cope with an estimated doubling of the regional population by 2050 and the increasing air pollution that would result from current land use patterns, transportation funding levels, and transportation investment priorities.

The outcome of this effort, the "Preferred Blueprint" (PRB), articulates levels and locations of redevelopment and new transit-oriented development linked to a list of preferred transportation projects. This was contrasted with the "Business-as-Usual" (BAU) plan that continues past land use and transportation trends, and leads to a larger area of urban coverage and lower densities of urban development relative to the PRB. The U.S. Environmental Protection Agency (EPA) permitted SACOG to use land use and transportation components of the PRB plan in their official regional transportation plan as part of their air quality conformity process.

The location and intensity of household and employment is illustrated in Figure 1 for both the BAU and the PRB scenarios. In the BAU scenario, transportation investments continue to focus on highway expansion, and land development persists in low-density, auto-dependent patterns. In the PRB scenario, transportation investment emphasizes improvement in transit, sidewalks, and bicycle lanes over highway expansion. Significant housing development is located near existing employment centers near downtown Sacramento, Rancho Cordova (east of Sacramento on US Route 50), and Roseville (northeast of Sacramento on Interstate 80) to improve the overall jobs-to-housing balance and concentrate growth near high quality transit service. There is a relatively large increase in multi-family homes (10.9 percent) and decrease in luxury single-family homes (6.3 percent); however, total single-family homes decline by only 1.9 percent. The PRB scenario assumes that local jurisdictions honor their Blueprint Plan commitments through local land use controls.

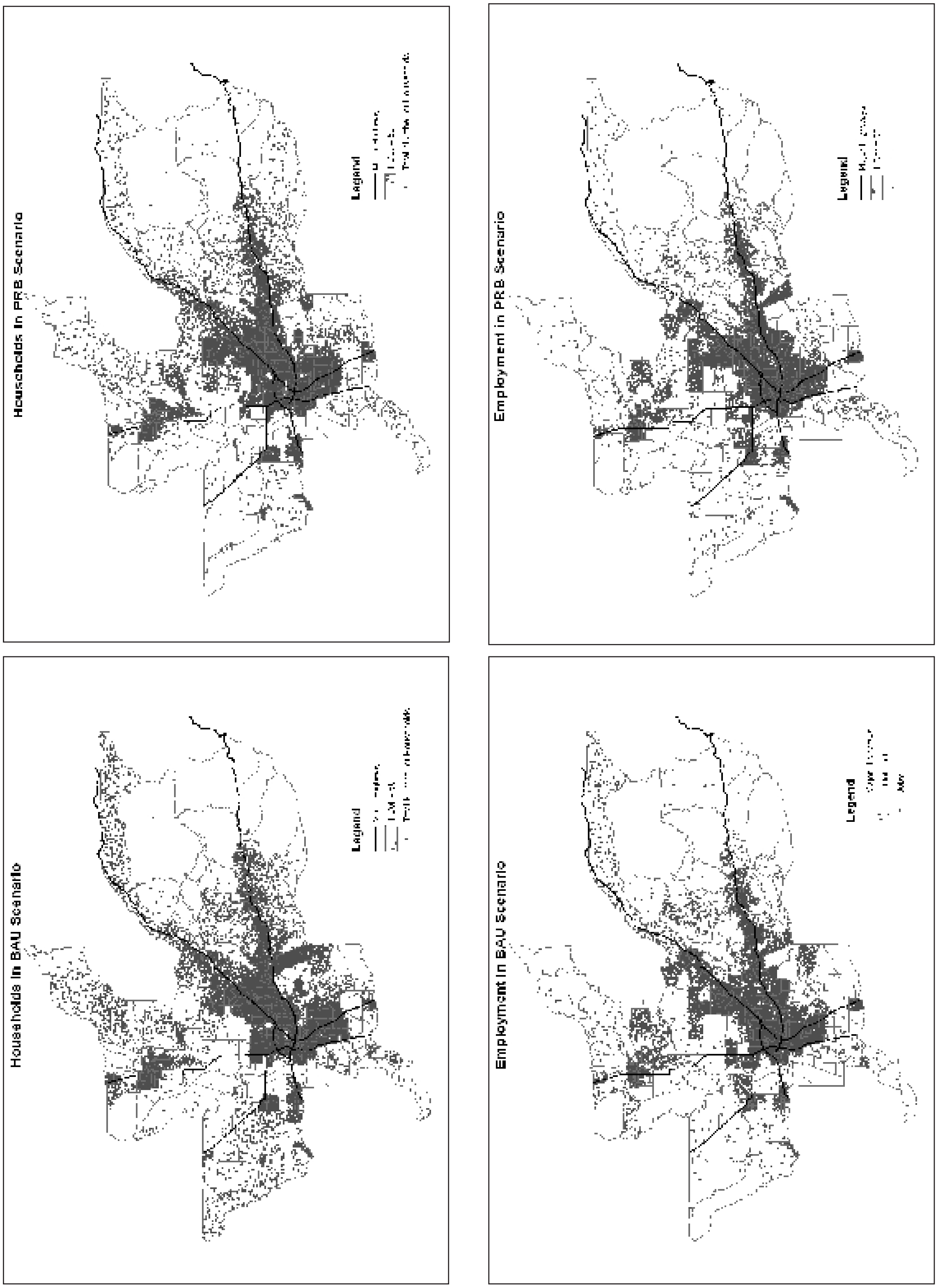

Figure 1. Household and Employment Location in the 2035 BAU and the PRB Scenarios

LITERATURE REVIEW

Economic and Equity Effects

A number of studies in the U.S. use either aggregate travel demand models or, more recently, disaggregate activity-based travel models for regions and/or cities to examine the economic and equity effects of transportation and land use policies on the travel time and cost of travel for population segments by available modes, origin and destination locations, and trip purposes. Several studies use an aggregate travel demand model to measures total consumer welfare and consumer welfare by household income classes for transit, land use, and pricing scenarios in the Sacramento region[10] and for gas tax policy scenarios in the Washington, DC area.[11] Activity-based models can calculate the distribution of travel time and cost effects across a broader range of household and individual socio-demographic characteristics. Deakin and Harvey[12] developed an early activity-based model that is used to evaluate the distributional effects of auto-pricing policies in the major regions of California. More recent versions of the STEP model were applied in equity studies in Baltimore, MD and Las Vegas, NV.[13] Most recently, the San Francisco activity-based travel model[14] was used to evaluate the distribution of travel time savings from a proposed transportation plan among specific communities of concern.

Other studies use aggregate land use and transportation models, which allow a partial representation of the spatial economy and an aggregate treatment of space use and development, to simulate the economic and equity effects of land use and transportation policies. Through linkages with a travel model, these models can represent the effect of changes in the transportation system on the allocation of activities and development in the built environment, which can then influence travel behavior. Economic and equity measures from these models typically include the travel time and cost effects of policies as do those from travel models. However, the travel time and cost effects are more inclusive in these studies because they include the trade-off between location decisions and travel time and cost. In the U.S., such studies use the MEPLAN framework in Sacramento[15] and the LUSTRE model in Washington, DC.[16] Internationally, such models are used for analyses in regions and cities in the UK[17] and in Europe.[18]

Both activity-based models and aggregate land use models can be used to calculate the distributions of travel time and cost impacts. But calculating the distributions of wider impacts on the economy – including wages, rents, productivity and/or changes in consumer and producer surplus – require models that include explicit representation of the transportation system and the rest of the spatial economic system.[19] The integration of activity-based models and recent generations of land use models, such as PECAS, allow analysts to answer a broader range of questions about the economic and equity effects of transportation and land use plans and policies. These include demand for goods, services, labor, and space; cost of producing and purchasing goods and services; industry and labor transportation costs; wages by employment type; rents and values for housing and employment space by type; and consumer (household by household income class) and producer surplus measures.

The current study is the last in a series of three studies for the Mineta Transportation Institute, in which the wider range of economic and equity measures available from such a spatial economic model is illustrated through the partial implementation of the Sacramento PECAS model. In the first study,[20] the 2035 land uses for the PRB and BAU scenarios generated from the Blueprint visioning process were input into the activity allocation module of the PECAS model along with network travel time and cost inputs generated from the Sacramento activity-based travel model (SACSIM) for each scenario. The results of this study indicate that both producers and consumers benefit from the changes in land use planning and transportation investment in the PRB scenario relative to the BAU. From an equity perspective, the PRB scenario shows the benefit to low-income residents due to decreased cost of living expenses. These results demonstrates that a more compact urban form designed around transit stations could reduce travel costs, wages, and housing costs by increasing accessibility. These decreased costs can benefit industry categories and lower income households while potentially reducing the welfare of higher income households.

The Sacramento PECAS model was largely developed with data collected before 2007 that indicate a general consumer preference for larger single-family homes. However, a number of recent studies[21] report a possible shift in consumer preferences toward smaller homes in smart growth communities resulting from factors other than the 2008 economic downturn, for example, strong consumer interest in “green” homes with lower energy costs. The size of a home makes a significant contribution to the energy it consumes. A change in consumer preferences could mitigate losses to higher income groups that result from a reduced supply of larger luxury single-family homes.

Two studies were conducted that employed the UrbanSim model, which is an advanced micro-simulation land use model that captures the behavior of individual agents and at fine levels of geographic resolutions, to investigate localized employment decentralization in Amsterdam and Tel Aviv;[22] however, the economic effects were largely confined to change in land values.

Incentives and Disincentives for Implementation

In the second study,[23] the application of the Sacramento PECAS model and the PRB and BAU scenarios was expanded to consider the possible economic and equity effects of non-conformity by an individual jurisdiction on the region as a whole and on other jurisdictions that do conform. The study developed “jurisdictional scenarios” in which all but one jurisdiction adhered to the PRB plan, while the one exception jurisdiction developed according to the BAU plan. These scenarios were grouped into four categories based on whether housing and/or employment is centralized or decentralized in the region (relative to the PRB) by the jurisdiction’s behavior. The modeling results of these scenarios indicate that a jurisdiction’s decision to develop according to the BAU scenario may increase regional and jurisdictional consumer surplus, only if this action further centralizes housing and employment in the region. The authors were unable to find other published literature or reports that included similar economic and equity measures related to localized decisions to violate a regional land us plan.

III. THE SACRAMENTO PECAS MODEL

In this study, the activity allocation module of the PECAS model for the Sacramento region is used to explore the distributions of impacts from the PRB scenario relative to the BAU scenario for the year 2035. PECAS is a generalized approach for simulating spatial economic systems. It is designed to provide a simulation of the land use component of land use transportation interactive modeling systems.

PECAS stands for Production, Exchange, and Consumption Allocation System. Overall, it uses an aggregate, equilibrium structure with separate flows of exchanges (including goods, services, labor, and space) going from production to consumption, based on variable technical coefficients and market clearing with exchange prices. It provides an integrated representation of spatially distinct markets for the full range of exchanges, with the transportation system and the development of space represented in more detail with specific treatments.

Flows of exchanges from production to exchange zones and from exchange zones to consumption are allocated using nested logit models according to exchange prices and transportation generalized costs (expressed as transportation utilities with negative signs). These flows are converted to transportation demands that are loaded on to transportation networks in order to determine congested travel utilities. Exchange prices determined for space types inform the calculation of changes in space attractiveness, thereby simulating developer actions. Developer actions are represented at the level of individual land parcels or grid cells using a microsimulation treatment. The system is run for each year being simulated, with the travel utilities and changes in space for one year influencing the flows of exchanges in the next year.

BASIC MODEL SYSTEM MODULES

PECAS includes two basic modules that are linked together with two other basic modules to provide a representation of the complete spatial economic system. The set of four basic modules are:

- **Space Development Module (SD module):** This is one of the two PECAS modules. It represents the actions of developers in the provision of different types of developed space where activities can locate, including the new development, demolition, and re-development that occurs from one point in time to the next. This developed space is typically floor space of various types and is called “space” in the PECAS framework.

- **Activity Allocation Module (AA module):** This is the other of the two PECAS modules. It represents how activities locate within the space provided by developers and how these activities interact with each other at a given point in time.

- **Transport Model (TR module):** This is one of the “non-PECAS” modules. It represents the transportation system connecting locations, including at a minimum a transportation network, the transportation demands that load onto this network (as a result of the economic interactions represented in the AA module), and the congested times and costs for interactions between locations arising from the loading of these demands.

- **Economic Demographic Aggregate Forecasting Model (ED module):** This is the other of the “non-PECAS” modules. This is the method used to develop aggregate economic forecasts for the study area being modeled.

The four basic modules listed above are linked together with information flows as shown in Figure 2. This linked system works through time in a series of discrete, fixed steps from one point in time to the next, with the AA module running at each point in time and the SD module considering the period from each point in time to the next. In general, the fixed steps can be of any duration, but one-year time steps are recommended since they allow an appropriately quick response of land developers in the SD module to the space prices established in the AA module.

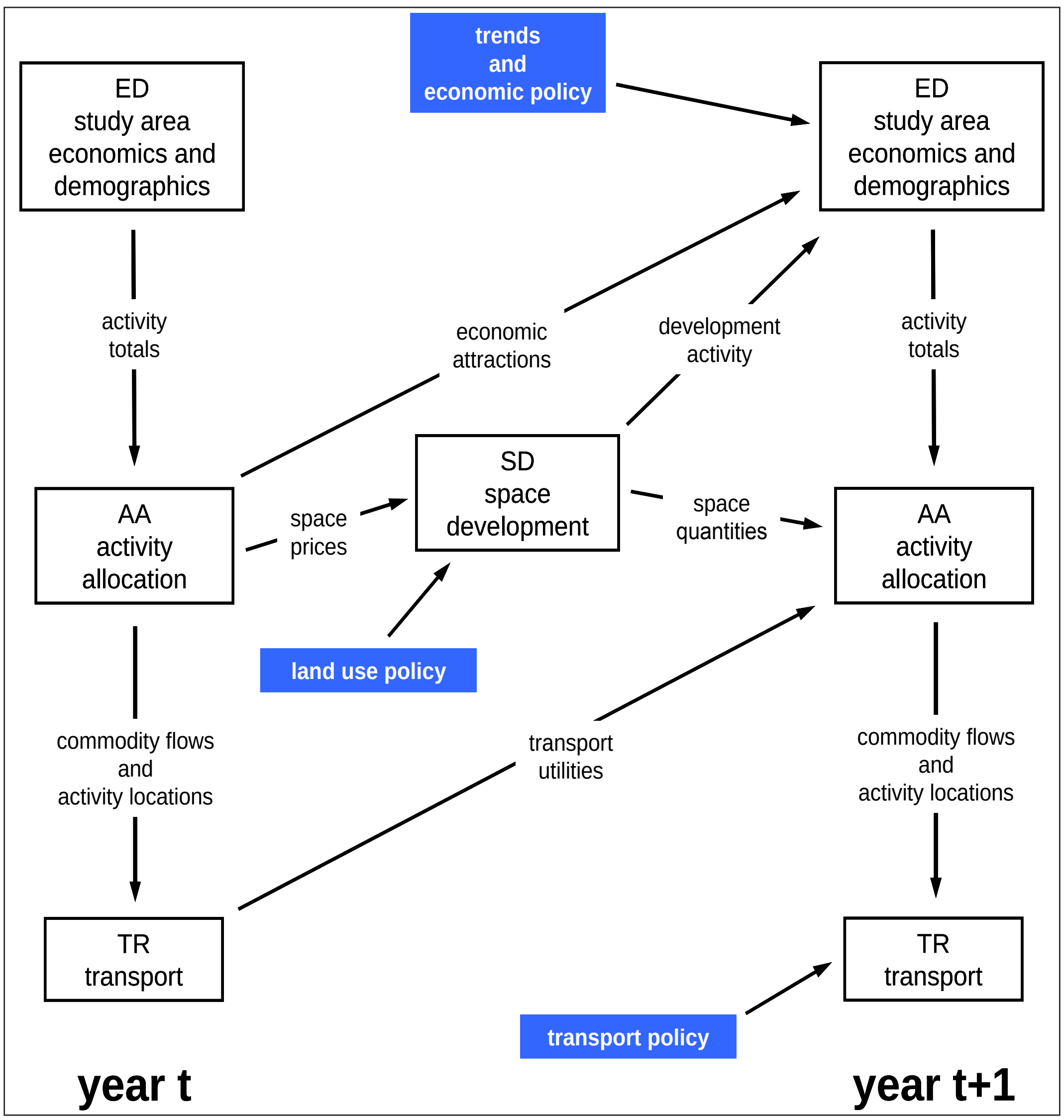

Figure 2. Modules and Information Flows Simulating Temporal Dynamics

Ideally, the transportation model (TR module), used to calculate the congested travel times and associated transportation utilities, is run for each year, after the AA module has been run for that year. If the overall model run-time is too long and travel conditions are relatively stable, the TR module can be run less often to save computation time.

The study area is organized into a set of land use zones (LUZs). In the AA module, activities locate in these zones and commodities flow between them. Ideally, these zones match the transportation zones (TAZs) used in the TR module or are aggregations of whole numbers of adjacent TAZs. The connectivity among the LUZs is based on the representation provided by the TR module, where the TR module establishes congested network times and costs, and associated transportation utilities that the AA module uses in its consideration of the interactions between the LUZs in the next time period.

The land in each LUZ is further partitioned into smaller cells or parcels. The parcels can correspond to actual legal parcels or portions of legal parcels. The cells can be formed by superimposing a grid pattern over the land. The term “parcel” is used to refer to both cells and parcels in the descriptions below. In the microsimulation version of the SD module, developed space (called “space”) is located on these parcels, with only one type of space on a given parcel, and the total quantity of each type of space in the LUZs is the sum of the quantities on the parcels in that LUZs.

When an activity in the AA module is located in a LUZ, it consumes space in the LUZ at rates consistent with the production technology or technologies used in the LUZ. Land is used in the provision of the space in the zone as an input to the development process, as represented in the SD module.

Activity Allocation Module

The AA module is an aggregate representation. It concerns quantities of activities, flows of commodities and markets with aggregate demands and supplies and exchange prices. Activities are located in LUZs. Activities produce commodities, and then transport and sell these commodities; they also consume commodities after buying them and transporting them. There are different types of activities, including industrial sectors, government, and households. Activity quantities can be measured in values (e.g., dollars of business repair or industrial activity) or numbers (e.g., number of households with high income and two or less persons). The AA module allocates the study-area-wide quantity of each activity among the LUZs as part of its allocation process.

Commodities flow, at specific rates, from where they are produced to where they are exchanged (from seller to buyer), and then flow from where they are exchanged to where they are consumed. Commodities are grouped into categories, including different types of goods and services, labor, and space. Commodities other than space in general flow across zone boundaries. Space is restricted in that it is “non-transportable” and must be exchanged and consumed in the LUZ where it is produced – which means that the space commodity categories receive some special additional treatments in PECAS as described further below.

Commodity flows are measured in values per unit time (e.g., dollars of management services per year) or numbers per unit time (e.g., tons of coal per month). The movement of these flows of commodities from where they are produced to where they are consumed is the economic basis for travel and transportation in the modeling system. It is the travel conditions – the distances, costs, times, and associated (dis)utilities by mode – for the movement of these commodities that results in the influence of the transportation system on the interactions among activities and the attractiveness of locations for activities. As part of its allocation process, the AA module allocates the flows of commodities from production location LUZ to exchange location LUZ, and then from exchange location LUZ to consumption location LUZ, and finds the corresponding set of prices at the exchange location LUZ that clears all markets.

Activities produce commodities and consume commodities in the production process according to the technology they use. More specifically, an activity quantity in a given LUZ produces commodities at specific rates per unit of activity and consumes commodities at specific rates per unit of activity according to the technology being used by the activity. One or more “technology option” alternatives are defined for a given activity. Each of these technology options is a specific vector of production and consumption rates for different commodities per unit of the activity, representing a particular technology option for the production process available to the activity. The AA module allocates the quantity of the activity in each LUZ among these technology options as part of its allocation process.

The allocation process in the AA module uses a three-level nested logit model with a nesting structure as shown in Figure 3.

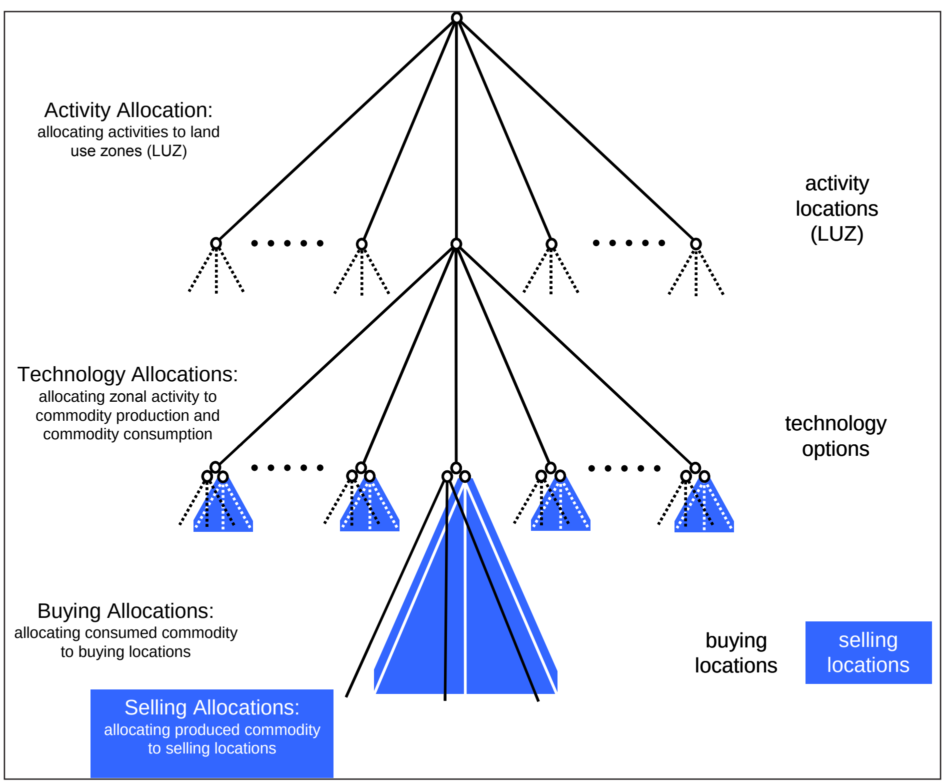

Figure 3. Three-Level Nesting Structure Used in Activity Allocation Module

At the highest level of the nesting structure, the study-area total quantity of each activity is allocated among the LUZs. At the middle level, the quantity of each activity in each LUZ is allocated among the available technology options. At the lowest level, there are two logit allocations for each commodity in each LUZ. The first is an allocation of the produced quantities among the various exchange locations where they are sold to other activities. The second is an allocation of the consumed quantities among the various exchange locations where they are bought by other activities.

At the lowest level, the utility of each exchange location alternative is influenced by the price at that exchange location and the characteristics for transporting the commodity to or from that exchange location. The composite utility values from these two lowest-level logit models are called the "buying utility" and the "selling utility" for the commodity in the LUZs. They are used as the transport-related inputs in the middle level for allocating the activities in the LUZs among the relevant technology options. The composite utility value for the range of technology options considered at the middle level for an activity in a LUZ is part of the location utilities used at the highest level.

The spatial aspects of the AA module allocation process are illustrated in Figure 4. Buying and selling allocations link through the exchange locations to establish commodity flows from production to consumption locations in the LUZs.

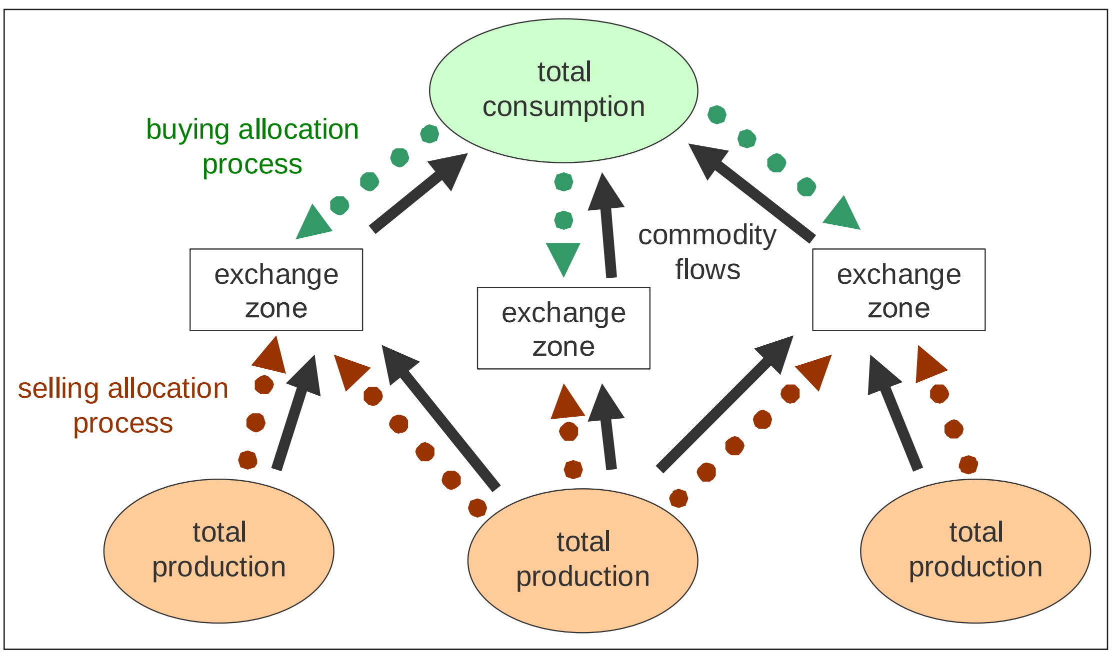

Figure 4. Buying and Selling Allocations Resulting in Commodity Flows from Production Zone to Consumption Zone via Exchange Location

The exchange locations are location-specific markets for commodities, where sellers sell commodities to buyers. Prices are established at exchange locations so that the quantity bought equals the quantity sold – thus, the spatial allocation procedure in the AA module assumes short-run market equilibrium in commodities.

Activity Allocation Utility Equation

Since AA is based on random utility theory, it is based on a "utility function" describing the attractiveness of each option implied in Figure 4. For one unit of activity type a∈A, where A consists of the full set of types of activity under consideration (including households, business establishments, and other institutions), consider the joint choice of:

- **Location**: $l \in L$, that is, the home location for the unit; being a residential location for households, or establishment location for business establishments and other institutions (the top level of Figure 4);

- **Technology Option:** $p \in P^a$, described by a set of technical coefficients $\alpha_p = \{\alpha_{p1}, \alpha_{p2}, \ldots \alpha_{pn}, \ldots, \alpha_{pN_p}\}$ and a corresponding list of commodities $c_p = \{c_{p1}, c_{p2}, \ldots c_{pn}, \ldots, c_{pN_p}\}$, each $c_{pn} \in C$. Each α_{pn} describes how much of commodity c_{pn} is produced (or consumed, if α_{pn} is negative) per unit of activity *a*, with indices *n* from 1 through N_p. P^a is the set of allowed Technology Option alternatives for activity *a* (the middle level of Figure 4); and

- **Exchange Location**: $e_n \subset E_c$, for each commodity c_{pn} produced or consumed, being the choice of where to purchase, sell (or otherwise exchange, as is the case for unpriced commodities) the quantity $|\alpha_{pn}|$ (the bottom level of Figure 4).

The utility of this joint choice is given by:

$$U^a_{lpe_1e_2\ldots e_n} = V^a_l + \varepsilon^a_l + V_p + \varepsilon_{lp} + \sum_{n=1\cdots N} |\alpha_{pn}| s_{pn} \left(V_{e_n l} + \varepsilon_{e_n lp}\right) \qquad (1)$$

where:

V^a_l = the measurable component of utility associated with location *l* and activity *a;*
ε^a_l = a random component of utility associated with location *l* and activity *a*;
V_p = the measurable component of utility associated with technology option *p*;
ε_{lp} = a random component of utility associated with technology option *p* and location *l*;
α_{pn} = the technical coefficients associated with technology option *p* as described above;
s_{pn} = scaling adjusting associated with technical coefficient α_{pn} (non-negative and usually 1.0);
$V_{e_n l}$ = the measurable component of utility associated with exchanging the commodity c_{pn} associated with α_{pn} in exchange location e_n given location *l* and technology option *p*;
$\varepsilon_{e_n lp}$ = a random component of utility associated with exchanging commodity c_{pn} at exchange location e_n given activity location *l* and technology option *p.*

The terms V_p and V_l^a are normally established in calibration and do not change between years or between scenarios. Thus core policy-sensitivity of the model is in the $V_{e_n l}$ terms. Each of the $V_{e_n l}$ terms contains three subterms:

- the cost of transporting commodities to or from the exchange zone,
- the prices of commodities in the exchange zone, and
- the relative size of the exchange zone.

Since prices are determined endogenously to clear the spatial markets, the dominant policy-related inputs to AA involve transportation costs and measures of zone size (normally quantities of space from SD), and the total quantity of each activity specified as a policy control total, to be allocated according to equation (1) and Figure 4.

See Hunt and Abraham[24] and Abraham and Hunt[25] for complete documentation of the theoretical formation and calibration methods of the PECAS model.

IMPLICATIONS

The intention of this study was not to forecast built form and land use patterns, but rather to use the AA module of PECAS to evaluate patterns of built form. Since the AA module is based on rigorous application of nested and additive logit theory, the top level expected maximum utility measure (the “logsum”) at the top of Figure 4 is a representation of the full composite utility (the consumer surplus in the case of household activities) of all the choices of where to locate; the quantity of interactions to undertake; and the transportation costs, prices, and opportunities for each of these interactions. Equation (1) is the utility of one particular option in the model regarding the choice of location, technology, and exchange locations. The expected maximum utility of choosing from amongst all the options of location, technology, and exchange location options provided by the built form and transportation system is calculated by the activity allocation module and is available as an output benefit measure for each activity in the model.

In particular, for households in the Sacramento model, the top level expected maximum utility takes into account the transportation costs for all of the households’ interactions; the relative prices for every category of good, service, labor, and housing; as well as the willingness and ability of households to shift their location, their housing type, their occupation, and the destination of all of their trips. Benefits of increased opportunities are considered and compared against transportation costs and other costs in this output measure from PECAS; if a policy or scenario reduces opportunities at any level of Figure 4, costs may be reduced (because opportunities to spend money or travel time have been reduced) but benefits will also be reduced. Benefit calculation with transportation models alone, or with transportation models with land use models which are less rigorously consistent, can fail in this aspect; for instance, closing down congested roads. The PECAS model allows this type of consistent rigorous analysis using random utility theory applied consistently to spatial choices for both supply and demand of goods, services, labor, and space in a complex economy.

This study uses the PECAS AA module to evaluate built form scenarios and transportation scenarios. A transportation demand model was used to forecast transportation level of service. The SD module was not used in this study – as a result, the input to the scenario is not a set of policies designed to shape future built form and land use, but rather a specific future configuration of built form. AA was used to allocate quantities of industry and households into the assumed space, with AA generating prices for space in each LUZ along with prices for every other commodity in each LUZ.

CALIBRATION OF THE PECAS ACTIVITY ALLOCATION MODULE

Calibration of the PECAS model has been ongoing as part of SACOG's model improvement program.[26] However, further calibration is always possible given additional data and additional resources, especially in the case of PECAS, because its scope is very deep, covering the whole of the spatial economy.

For this study, additional calibration efforts were performed that were specific to the benefit analysis. Transportation cost functions, which translate travel model zone-pair travel attributes into disutility measures for each commodity in PECAS, were refined using improved data from the travel models, wage data by occupation, and from goods movement studies. The commodity flow distances were calibrated to trip length information, to establish the logit dispersion parameter in the models of buying or selling for each commodity. These dispersion parameters control the random term in the flow allocation (they are inversely related to the standard deviations of the $\varepsilon_{e_n lp}$ terms in equation (1)). It is important to establish these parameters before undertaking benefit analysis, because they establish the value associated with variety in each commodity (recall that the other terms at this level of the model reflect price, transportation cost/disutility, and zone size). In the case of commodities with low dispersion parameters, additional opportunities for interaction are very valuable, even if they are poorly priced or a long distance away.

The choice model of household lifestyle (the middle level of Figure 4, for household activities) was calibrated based on observed patterns of behavior from the U.S. Census Public Use Microsample (PUMS). This established the tendency of certain types of household to use certain types of housing and make certain types of labor, and the willingness (and/or the ability) to shift occupation and housing depending on conditions. Dispersion parameters for the higher level choices in Figure 4 were refined with the help of the additive logit theory in Abraham and Hunt,[27] which was not available when the Sacramento PECAS model was first developed.

Other elements of the model that were further calibrated include the treatment of imports and exports (more explicit in quantity and direction than in Abraham et al.[28]), and the floorspace short-term supply function (which allows large vacancy rates if space demand in any zone is uncharacteristically low).

See Abraham et al.[29] for a description of the Sacramento PECAS model, its initial calibration, and its planned ongoing calibration. It describes how the make and use coefficients (the αpn in equation (1)) were established for the various activity-commodity combinations from economic "input-output" relationships and Census data, the classification systems applied to determine the categories of activities, commodities, and LUZs; the strategies for establishing both alternative specific constants for particular production options (p in equation (1)) and location options (l in equation (1)); and strategies for calibrating the parameters controlling the size of the random components in equation (1).

Abraham et al.[30] also describes the development and calibration of the SD module, which would be used if land use policy over time were being used as an input to the model. (In this study land use patterns were being evaluated, not land use policy.)

IV. LAND USE AND TRANSPORTATION SCENARIOS

SACOG provided employment, household, and land inputs for the BAU and PRB scenarios in the year 2035 that were used in their SACSIM simulations. Employment and household locations were not used directly by PECAS – since one of PECAS's functions is to allocate employment and households. Rather, the expectations regarding employment and household locations from the two scenarios were used to develop the inputs on built form (or floorspace) that would normally be provided by PECAS's space development module. A full version of PECAS, with both the space development and activity allocation models, would predict both the location of employment and households, and the location of built form, with policy variables (such as zoning regulations) as inputs. A travel model, on the other hand, requires employment locations, household locations, and built form as inputs. In this work, a middle road was taken, with built form as an input, while employment and household locations are determined by the activity allocation model and thus output floor space varied from input floor space.

Zone-to-zone travel times and costs (generalized transportation costs or logsums) for all modes by trip purpose were obtained from SACSIM and were consistent with input floorspace for each scenario. Zone-to-zone travel times and costs were aggregated to PECAS zones using an approach that weighted values by trip frequency. Total economic growth by activity category was assumed to remain constant for both scenarios simulated with the PECAS AA module. Zone-to-zone travel times, but not distance traveled, were held constant in the transportation costs. As a result, travel costs may be underestimated somewhat if the land use changes in the scenarios increased congestion, or overestimated if the land use changes reduced congestion. However, given the relatively small changes simulated in the scenarios, the magnitude of this possible error is likely very small and not likely to change the order of magnitude and direction of change in the simulated results.

V. LIFE CYCLE ANALYSIS

The GHG emissions from personal and commercial vehicle travel were evaluated for both the PRB and the BAU scenario as part of the Sacramento Region's Metropolitan Transportation Plan.[31] The results indicate that GHGs from vehicle travel could be reduced by implementing the PRB scenario. In this section, we expand the evaluation of GHG emission from these land use and transportation scenarios by applying a life cycle-analysis (LCA) model to evaluate GHGs from changes in economic consumption and housing construction in each scenario as available from the Sacramento PECAS simulations of the year 2035 BAU and PRB.

METHODS

Economic Input-Output Life Cycle Assessment Model

The Sacramento PECAS outputs include forecasts of consumption and production activity within a comprehensive set of economic sectors. These outputs are in units of production and consumption dollars, employees, floorspace, and housing units. The outputs of the Sacramento PECAS model can serve as inputs to a LCA model to evaluate the change in emissions that result from different planning scenarios evaluated by the PECAS model.

In this section, the integration of the Economic Input-Output Life Cycle Assessment Model (EIOLCA) with the outputs from the Sacramento PECAS model land use and transportation simulations, both separate and independent models, are described. The EIOLCA model was developed and made publicly available by the Green Design Institute of Carnegie Mellon University.[32]

Currently, there are generally three types of LCA practiced in industry and research. The first is a process-based LCA, which involves the modeling of a process or system from start to finish. The second is an economic input-output life cycle assessment (EIOLCA is an implementation of this), which uses information on economic relationships in the economy to estimate the energy and emissions associated with a dollar spent in the economy within a specific sector. A third form of LCA is a hybrid LCA, which begins with a process-based LCA, but models upstream elements of the supply chain using EIOLCA. The EIOLCA model is based on input-output tables that are published by the Bureau of Economic Analysis (BEA) within the Department of Commerce (DOC) on a semi-decadal basis (1997, 2002, and so on).[33] The release of input-output table data is currently subject to a considerable lag, in that input-output tables for 1997 were released in 2002 and input-output tables for 2002 were released in 2007. Currently, 2002 tables are the latest available. Hence, results from this analysis reflect the interrelationships of the 2002 economy. The EIOLCA model is also available in several forms and geographic regions. As of May 2012, there exist models for the United States, Canada, Germany and Spain. Within the U.S., there are a number of sub-models that apply to specific states, namely Pennsylvania and West Virginia. The nationwide model is available in two forms, the Producer Price model and the Purchaser Price model. The Producer Price model includes all processes up to and including the assembly of the product, while the Purchaser Price model consists of the impacts included in the Producer Price model as well as the distribution of products to the consumer. For this analysis, we apply the Purchaser Price model, because it includes the more comprehensive set of supply-chain impacts up to the consumer. The EIOLCA model takes U.S. dollars spent in a specific economic sector as the sole input.

Fundamentally, dollars spent within a specific economic sector (such as home construction) results in the producers of that sector spending a portion of their earned income to obtain critical inputs from other sectors (e.g., lumber, cement manufacturing, and pipe manufacturing) that supply its core value-added activity. These sectors in turn must spend on their inputs (e.g., oil, energy, and land) to produce inputs to the sector that they are supplying. The BEA input-output tables effectively map out this chain of activity to fully articulate how dollars spent within any given sector of the economy propagate through the rest of the economy. The resulting economic activity within each sector results in some quantity of energy expended, and hence emissions.

The EIOLCA ties the flow of dollars as defined from the BEA input-output tables to sector-specific emission factors. The ingenuity of the EIOLCA model is that it provides a mechanism to estimate the high-level emissions changes that result from changes in economic activity. As a result, as the Sacramento PECAS model estimates changes in the flow of dollars that result from different planning scenarios (i.e., BAU and PRB), it can be augmented with life cycle emissions as derived from EIOLCA. As the current EIOLCA model is derived from the BEA tables describing the entire U.S. economy, the emissions factors are based on national industry averages. Future analyses may be able to apply California or other state-specific factors.

Mapping PECAS Output and EIOLCA Inputs

The Sacramento PECAS model produces output by 22 economic activity sectors. These sectors are listed in Table 1.

Table 1. PECAS Economic Activity Sectors

• Agriculture (plus Mining)	• Finance Insurance Legal	• Other Education
• Construction	• Real Estate	• Personal Services
• Manufacturing	• Hotels	• Membership & Non-Profit Orgs.
• Transportation Services	• Business Services	• Professional Services
• Communications and Utilities	• Automotive Services	• Government Nonutility Enterprises
• Wholesale Trade	• Amusement Services	
• Retail Trade	• Health Services	• Military
• Restaurants	• Primary Education	

Source: PECAS Model.
Notes: These are the economic sectors into which consumption and production activity is categorized in PECAS.

The alignment of the Sacramento PECAS model output sectors is not entirely congruent with EIOLCA. Some sectors align precisely, while others align quite poorly. For example, Wholesale Trade is a unique category within both the Sacramento PECAS model and EIOLCA. Hence, the change in dollars spent in Wholesale Trade, as simulated and output by the Sacramento PECAS model, can be used directly as an input to the EIOLCA model within the economic sector of the same name. However, the Sacramento PECAS model also has an Automotive Services sector. This sector is covered by two EIOLCA sectors, the Automotive Repair and Maintenance, Except Car Washes sector and the Car Washes sector. The coverage of one PECAS sector by two sectors in EIOLCA introduces the problem of EIOLCA input dollar division. For example, if the PECAS output suggests in the modeled scenario that $1 million would be spent the Automotive Services sector, then how should that be allocated within EIOLCA? The two corresponding EIOCLA categories will have different emissions factors, and so assumptions regarding the division of the PECAS $1 million into the two automotive services-related EIOLCA categories will impact the results. By assumption, or by fact, some division of this output into EIOLCA is necessary to run the EIOLCA model. The analyst might assume that 100 percent of the $1 million is applied to the Automotive Repair and Maintenance, Except Car Washes economic sector, thus ignoring the emissions factors from car washes. Alternatively, some broad assumption (80 percent/20 percent) could be made dividing the PECAS output Automotive Services into the two EIOLCA sectors. Fortunately, there is an alternative approach that is grounded in data describing the relative share of economic activity that each EIOLCA sector has within a metropolitan region such as Sacramento. This data provides an empirically grounded breakdown to a relatively high level of detail.

The County Business Patterns (CBP), published by the Census Bureau, reports the annual payroll (in thousands of dollars) of businesses by industry, as classified by the North American Industry Classification System (NAICS) code (see Appendix A for tables detailing the CBP classifications).[34] This distribution of annual payroll is used as a proxy to determine the relative share of economic activity of any specific sector within the region of interest. The CBP is published for a number of different geographic resolutions, including the nation, state, county, metropolitan region, and zip code.[35] However, the more refined the geographic resolution, the more incomplete the information presented in the CBP. At more specific economic sectors, the Census Bureau suppresses information if the level of aggregation is not sufficient to reasonably occlude the business reporting the data. Hence, the more refined the regional resolution, the more likely the data are contributed by a single business and thus removed from subtotals. At the metropolitan level, for a region the size of Sacramento (the Sacramento--Arden-Arcade--Roseville, CA Metropolitan Statistical Area (MSA)), this problem is not too pervasive across sectors and can otherwise be overcome with simple assumptions.

The connection of the Sacramento PECAS output to EIOLCA data for any region thus requires the spanning of three data classifications. The output to any PECAS economic sector must be divided into subcategories of NAICS industry classifications that comprise the PECAS economic sector. The NAICS industry classifications can then be mapped to appropriate EIOLCA economic sectors. The shares of economic activity, as identified by the NAICS, inform how activity within the Sacramento PECAS model should be split within EIOLCA. The BEA publishes a mapping of the input-output (EIOLCA) sectors to NAICS industry codes.[36] This mapping is necessary to complete the linkage between EIOLCA and PECAS if local economic sectors are to be proportionally represented in accordance with the local economy.

Table 2 illustrates, conceptually, the linkage across each data set for the example sector Communications and Utilities. It shows how NAICS codes (managed by the U.S. Census Bureau) align rather well with Input-Output (IO) categories (managed by the BEA), and that many, but not all, NAICS codes map directly to unique IO codes. There are many more NAICS codes than IO codes (of which there are 491), and different levels of the NAICS hierarchy (represented by the number of digits in the NAICS code) are represented within the IO structure. Because of this, it is the IO structure that defines the baseline NAICS codes that are referenced as part of the mapping. Most of the IO codes map to 3- or 4-digit NAICS codes. But, as is evident in Table 2, a number of IO codes align with NAICS sectors at the 5-digit level.

Generally, there is a precise NAICS code for every IO code, and the digits of the IO code align with the corresponding NAICS code. There are cases in which more than one NAICS code maps to an IO code, as indicated by 5111A0 in Table 2. In these cases, the activity with the shared NAICS codes are simply distributed proportionally (or equally into halves, thirds, etc.) to represent the IO code.

Table 2. Example of PECAS to NAICS to IO Category Mapping

	U.S. Census Bureau		Bureau of Economic Analysis	
	NAICS Code	**Description**	**IO Code**	**Description**
PECAS Sector: Communications and Utilities	51111	Newspaper Publishers	511110	Newspaper Publishers
	51112	Periodical Publishers	511120	Periodical Publishers
	51113	Book Publishers	511130	Book Publishers
	51114	Directory and Mailing List Publishers	5111A0	Directory, Mailing List, and Other Publishers
	51119	Other Publishers		
	51121	Software Publishers	511200	Software Publishers
	5121	Motion Picture and Video Industries	512100	Motion Picture and Video Industries
	5122	Sound Recording Industries	512200	Sound Recording Industries
	5151	Radio and Television Broadcasting	515100	Radio and Television Broadcasting
	5152	Cable and Other Subscription Programming	515200	Cable and Other Subscription Programming
	516	Internet Publishing and Broadcasting	516110	Internet Publishing and Broadcasting
	517	Telecommunications	517000	Telecommunications
	5181	Internet Service Providers and Web Search Portals	518100	Internet Service Providers and Web Search Portals
	5182	Data Processing, Hosting, and Related Services	518200	Data Processing, Hosting, and Related Services
	519	Other Information Services	519100	Other Information Services
	2211	Electric Power Generation, Transmission, and Distribution	221100	Electric Power Generation, Transmission, and Distribution
	2212	Natural Gas Distribution	221200	Natural Gas Distribution
	2213	Water, Sewage, and Other Systems	221300	Water, Sewage, and Other Systems

Source: North American Industry Classification System (NAICS) Codes, http://www.census.gov/eos/www/naics/; Bureau of Economic Analysis Benchmark Input-Output Data, http://www.bea.gov/industry/io_benchmark.htm.

To map the CBP data, the annual payroll of each NAICS sector is identified with the CBP for the Sacramento region. The share of this payroll among the total payroll of the NAICS sectors within a PECAS classification defines the share of input that the IO sector receives as an input to the EIOLCA model. The mapping is verified to be complete and comprehensive when the sum of payroll expenses of all mapped NAICS sectors is equal to the high-level (2-digit) NAICS sector. Broadly, this methodology allows for the EIOLCA model to better reflect the true mix of economic activity for the region in which the PECAS (or other land use model) was developed and deployed. It allows the appropriate mix of EIOLCA categories to more representatively reflect the change that would occur within the PECAS sector. For this project, a Visual Basic (VBA) program was written to convert the BEA-IO-to-NAICS mapping into a database format useable for future research efforts.

The annual payroll of each NAICS sector that is aligned with an EIOLCA category is then used to construct a “custom product” within the EIOLCA model. The custom product permits the addition of specific sectors to an EIOLCA model run. Each EIOLCA sector is assigned a dollar amount representing the sector’s share in the custom product. In this case, the dollar amount is the payroll for the NAICS-EIOLCA sectors in Sacramento in millions of dollars. The model is run when all of the EIOLCA sectors within the corresponding PECAS sector are added to include their payrolls. A new custom product is created for each PECAS model sector. Table 3 shows how the NAICS-EIOLCA sectors are assigned payroll values as derived from the 2009 CBP for the PECAS Communications and Utilities sector. The list of sectors in Table 3 is shorter than Table 2 because not all sectors are active in the Sacramento MSA.

Table 3. Payroll for Communications and Utilities within Sacramento MSA for NAICS-EIOLCA Sectors

NAICS Code	IO Code	Description as Defined in EIOLCA	Annual Payroll ($ millions)	Proportion of Comm. & Util. Local Economy (%)
51111	511110	Newspaper Publishers	80.783	5
51112	511120	Periodical Publishers	29.449	2
51113	511130	Book Publishers	0.773	0
51114, 51119	5111A0	Directory, Mailing List, and Other Publishers	20.366	1
51121	511200	Software Publishers	170.164	11
5121	512100	Motion Picture and Video Industries	17.608	1
5122	512200	Sound Recording Industries	1.946	0
5151	515100	Radio and Television Broadcasting	107.779	7
5152	515200	Cable and Other Subscription Programming	1.536	0
517	517000	Telecommunications	718.253	45
5182	518200	Data Processing, Hosting, and Related Services	181.340	11
519	519100	Other Information Services	40.829	3
2211	221100	Electric Power Generation, Transmission, and Distribution	139.090	9
2212	221200	Natural Gas Distribution	85.033	5
2213	221300	Water, Sewage and Other Systems	10.256	1
		TOTAL	**1,605.205**	**100**

Source: North American Industry Classification System (NAICS) Codes, http://www.census.gov/eos/www/naics/;
Bureau of Economic Analysis Benchmark Input-Output Data, http://www.bea.gov/industry/io_benchmark.htm.;
US Census, County Business Patterns, 2009. Sacramento--Arden-Arcade--Roseville, CA Metropolitan Statistical Area. http://www.census.gov/econ/cbp/.

The EIOLCA output provides estimates for a number of metrics. In using the 2002 EIOLCA Purchaser model with the Custom Product interface, we report the change in total economic activity, total GHG emissions (in metric tons [t] CO_2e), total energy, toxic releases, and water withdrawals. The output of each metric is then scaled by the ratio of the change in “consumption of goods and services,” forecasted by the Sacramento PECAS model, to the total payroll in the corresponding sector. For example, Table 3 shows that the total payroll for the custom product defining the Communications and Utilities sector is $1,605.205

million.[37] The Sacramento PECAS model in this study estimates that the consumption of goods and services in this sector falls by $2 million under the PRB. The EIOLCA outputs generally scale linearly (e.g., $5 million in activity generates five times the emissions as $1 million). The scaling factor of (2/1,605.205) is multiplied by the environmental outputs produced at $1,605.205 million of custom product output. This adjusted output is the estimated LCA impact metric of interest for the Sacramento PECAS model for a single year. There is one detail about the PECAS output that is relevant for calculating the total impact of economic shifts. The PECAS output from which differences in consumption are calculated comprise annual consumption values of the final forecasted year of the model (year 2035, in this case). But the economic impact occurs every year for the duration of the forecast period. Hence, the emissions calculated from the shifts in economic activity must be scaled to match the entire forecasted period. In this case, the period is from 2010 to 2035, or 25 years. It is, of course, likely that the differences in consumption observed at the end of the forecast period are not reflective of the interim year differences. Rather, this assumption applies an upper bound on the impact of changes in consumption on resulting emissions. Other assumptions defining the evolution of the difference, such as linear growth to the values observed in the final forecast year, could be applied, as shifts in the economy are generally gradual. For simplicity, we assume that the values observed in the final year are representative of interim year differences.

Estimating Residential Housing LCA Impacts

The Sacramento PECAS model also provides an estimate of the change in distribution of households as a result of different land use policies. As discussed above, four categories of household types are represented in the Sacramento PECAS model: 1) luxury single-family (SF) homes, 2) standard SF homes, 3) owned multi-family (MF) homes, and 4) rented MF homes. The total number of homes built in the BAU and PRB is held constant; however, as described above, in the PRB scenario there is shift from luxury SF to MF and standard SFs relative to the BAU.

To estimate the change that results from the shift in the distribution of housing between the BAU and the PRB scenarios in EIOLCA, it is necessary to make an assumption regarding construction costs. Current estimates of construction costs in California suggest that home construction costs are about $100 per square foot (sq. ft.) (not including the cost of land, which is not needed for this estimation).[38] In addition, to compute the cost of a single home construction, a second assumption is required on the size of the home. These assumptions are quantified in the results. The dollars spent on construction, as defined by these assumptions, are passed into the EIOLCA Purchaser model for the IO sector entitled Residential Permanent Site Single- and Multi-Family Structures (IO Code: 230201). The output of the housing metrics, defined above, is combined with the estimated changes to determine the total net change for all metrics of measurement. The PECAS model does produce other outputs, but if these outputs do not change from BAU to PRB, then there is no change to measure with EIOLCA.

Limitations and Considerations

The methodology developed here is designed to link two models that have not been linked in previous research. There are a number of limitations and considerations that should be understood in interpreting the results. One important assumption made with this methodology is that the structure of the economy over the course of the forecasted land-use change is relatively constant. Inevitably, the economy will change in structure and size. The degree of change will certainly impact the degree to which a structure defined in the year of analysis is reflective of the economy in the future. Naturally, the economic structure established during the year of analysis is the best guess available. Given this information, analysts are certainly free to make their own estimations on how the economic structure might be different in the future and adjust values with justification.

For many Sacramento PECAS sectors, there are a fair number of EIOLCA sectors represented. For example, manufacturing has the most, with 74 separate EIOLCA sectors. Changes or even eliminations of specific sectors within the Sacramento PECAS sector model will have a relatively small impact on the aggregate results in isolation. Many changes would be required to significantly alter a sector, and these changes may correspond to a change in PECAS sector consumption, which the model itself estimates to be small. This would further dampen impacts of structural economic changes to the results.

The same problem of permanence exists for EIOLCA. The model used here is derived from the 2002 economy, which is already 10 years removed from the current year. Based on the existing BEA pace of IO sector release, any such analysis would be at best, five years removed. Even if EIOLCA factors represented the current year, the assumption remains that those environmental factors are constant over the course the period forecasted by PECAS. Naturally, this assumption is not likely to hold, but the degree to which it impacts the results is sector dependent. Some sectors change considerably over time, while others practice processes and efficiencies that have evolved little over time. Hence, the current assumption of constancy in the EIOLCA factors over a long time period is not ideal for reflecting the likely changes to occur within the economy. It is, however, the best available information on the complex interrelationships between economic sectors available to the public.

An additional consideration is that the linkage between the EIOLCA and PECAS is effectively one estimate mapped to another estimate. Both estimates are subject to uncertainty. They serve as a best estimate of the order of magnitude of impacts given the modeling capabilities and information available for analysis at this time. The utilization of the CBP to better represent a PECAS sector in EIOCLA for any given region provides a way for the local economic structure to be incorporated as weights on the factors applied by EIOLCA. The CBP information is the most precise of all the applied inputs. But overall, the output of the LCA analysis are still best estimates, given prevailing knowledge, and should be considered for their ability to approximate relative magnitudes of different types of impacts, given the forecasted changes of Sacramento PECAS and how EIOLCA would consider those changes as influencing energy and emissions using information currently available.

Finally, the scope of the LCA analysis is defined by that of EIOLCA. EIOLCA is very useful for understanding the implications of changes in spending, as defined by any model influencing environmental factors, for the economy upstream in the production cycle of the items consumed. The EIOLCA model does not include use of the product itself. For many items, this consideration is not significant. For example, the use (or consumption) of items, such as food or paper, do not result much in the way of additional emissions. For these common items, most of the impact is derived from upstream production and delivery processes, which are within the scope of EIOLCA. There are also downstream disposal impacts that are not captured. Other goods, specifically those that consume power (e.g., automobiles, electronics, etc.), exhibit an additional impact also not captured within the scope of this LCA. These considerations should be understood when interpreting the results, but also should be viewed as opportunities for future research to improve the factors, resolution of assumptions, and data informing both models and their linkages.

RESULTS

The study uses the AA module of PECAS to allocate employment and housing locations using built form from the PRB and the BAU plans and scenario specific transport costs from the region’s activity-based travel model. The results indicate that a more compact urban form, including a greater number of smaller housing units and fewer large, luxury housing units, designed around transit stations tend to reduce the cost of living and increase economic consumption in the region. The key sector changes for the EIOLCA analysis are the size of housing floorspace construction and economic consumption from each scenario as produced by the Sacramento PECAS model.

In general, the results indicate that that the upstream increases in GHGs from increased economic consumption in the PRB scenario are outweighed by reductions in upstream GHG emissions that result from the shift in construction from luxury to smaller single and multi-family homes. That is, the strongest impact on the aggregate results is not the change in economic activity, but the change in housing type distribution. This result pertains only to the upstream economic activity that is induced by the construction of new homes. It does not include the maintenance and operation of these homes. Similarly, the GHG impacts resulting from shifts in economic consumption are the resulting differences in upstream activity as defined by the two scenarios. The detailed analysis is described below.

The GHG effects of the housing size distribution are highly sensitive to assumptions about household size. As a lower bound, luxury SFs were considered to be 1,500 sq. ft., with a construction cost of $100 per sq. ft. As a baseline assumption, all homes were considered to have the same dollar per sq. ft. construction costs. In reality, the cost for producing standard SFs and MFs would be less than that of luxury SFs. Hence, keeping these production costs equal favors an increase in emissions because lower production costs of these smaller homes would result in lower emissions that result from their increased production. Table 4 shows the change in homes forecasted by PECAS, alongside the factors applied to those changes.

Table 4. Assumptions Applied to Housing Data in EIOLCA

Housing Type	Area (sq. ft.)	Construction Cost ($/sq. ft.)	Difference in Scenarios Forecasted by PECAS [PRB – BAU]	
			Number of Housing Units	Total Construction Cost ($ millions)
Luxury Single-Family	1,500	$100	-25,182	-3,777
Standard Single-Family	1,500	$100	4,442	666
Owned Multi-Family	1,200	$100	3,017	362
Rented Multi-Family	1,200	$100	17,724	2,127

Notes: The table shows the assumptions made for each housing type. The size and construction cost of the Luxury Single-Family home is assumed to be the same as that of the Standard Single-Family home. In reality, most luxury homes in this region are larger than 1,500 sq. ft. and more expensive to build. These conservative assumptions are made to illustrate that the aggregate results are not contingent on assumptions regarding the differences in cost and size of these homes.

While this $100 per sq. ft. cost factor is in line with existing estimates, the size of luxury homes in the Sacramento region are generally larger than 1,500 sq. ft. If the assumed size of luxury homes were increased in this model, the spending on luxury homes would rise and result in larger reductions in energy and emissions from the reduction in luxury home construction. Thus, the analysis demonstrate that even at these lower bounds, the reduction in luxury homes and the shift towards smaller homes still have the largest relative impact.

Table 5 illustrates a summary of the EIOLCA GHG impacts of the PRB. The table shows each PECAS sector with its consumption under both the BAU and PRB scenarios. The difference between these scenarios is shown as well as the payroll within the sector as derived from the CBP. The ratio (5^{th} column value / 6^{th} column value) that scales the EIOLCA results for the entire sector is then given. The total GHG emissions in t CO_2e is shown for each PECAS sector. Table 5 also provides breakdowns of the fossil CO_2e, CH_4, N_2O, and “other,” which include hydrocarbon matter among other subgroups.

Table 5 shows that overall the PRB causes emissions to increase due to increased economic activity in the PECAS sectors. In several sectors, such as communications and utilities, there is a reduction in activity, causing a reduction in emissions. The reduction, in this case, is driven by more compact land uses, resulting in reduced consumption of communication and utility services within the region. However, absent a shift in the corresponding housing stock, the EIOLCA model predicts total CO_2e would increase by 1,037,864 t from upstream economic activity resulting from an economy restructured by the PRB scenario. The overall reduction in CO_2e comes from the shift in housing stock. This reduces CO_2e emissions by a much larger 2,165,959 t. The net effect is a reduction of 1,128,095 t CO_2e, as a result changes in economic activity upstream of consumption and housing construction due to implementation of the PRB.

Table 5. EIOLCA Greenhouse Gas Impacts of the Sacramento Blueprint

Activity	BAU PECAS Sector Consumption ($ million)	PRB PECAS Sector Consumption ($ million)	Consumption Difference [PRB – BAU] ($ million)	Sector Payroll in 2009 ($ million)	Consumption Difference Divided by Sector Payroll [([PRB-BAU) / Payroll] (%)	Greenhouse Gas Emissions (over 25 years) (t CO_2e)				
						Total	Fossil	CH_4	N_2O	Other
Agriculture (plus Mining)	3,465	3,466	0.177	335	0.0529	10,481	4,063	3,414	2,726	273
Construction	12,113	12,113	-0.003	617	-0.0004	-41	-33	-2	-1	-5
Manufacturing	24,926	24,926	0.002	738	0.0003	38	27	2	2	7
Transportation Services	4,324	4,327	2.650	715	0.3708	72,591	65,638	5,016	214	1,743
Communications and Utilities	7,958	7,956	-2.081	1,605	-0.1297	-58,351	-51,868	-4,895	-418	-1,287
Wholesale Trade	20,652	20,652	-0.186	1,879	-0.0099	-891	-775	-68	-11	-35
Retail Trade	21,430	21,467	36.859	2,378	1.5498	244,095	216,586	17,474	2,786	7,296
Restaurants	2,870	2,882	12.102	883	1.3707	175,444	128,156	24,912	15,797	6,569
Finance Insurance Legal	11,657	11,681	24.330	2,573	0.9455	51,530	44,202	4,515	799	1,808
Real Estate	27,978	27,990	11.792	538	2.1917	78,352	63,558	11,506	1,216	2,191
Hotels	1,104	1,106	1.906	1,136	0.1678	5,957	5,160	566	111	122
Business Services	10,350	10,351	0.404	693	0.0582	1,717	1,513	130	22	57
Automotive Services	3,307	3,314	7.446	197	3.7887	64,976	52,852	5,437	820	5,835
Amusement Services	1,372	1,376	4.360	443	0.9851	47,038	36,941	5,369	2,931	1,758
Health Services	8,572	8,607	34.808	5,136	0.6777	232,105	184,667	27,277	8,962	11,402
Primary Education	213	215	1.841	217	0.8487	24,613	20,221	2,886	772	664
Other Education	1,261	1,264	2.690	140	1.9189	13,049	10,842	1,319	166	715
Personal Services	2,670	2,676	5.809	235	2.4734	40,625	34,318	3,531	541	2,232
Membership & Non-Profit Orgs.	946	950	3.900	622	0.6275	29,492	24,786	3,059	573	1,082
Professional Services	11,511	11,512	1.144	2,852	0.0401	4,832	4,080	417	100	236
Government Nonutility Enterprises	4,167	4,167	0.021	1,262	0.0017	213	102	101	3	7
Military	0	0	0.000	0	0.0000	0	0	0	0	0
PECAS Economic Sector Subtotal						**1,037,864**	**845,037**	**111,964**	**38,111**	**42,671**
Luxury Single-Family	391,854	366,672	-25,182	-3,777	-3.78	-2,489,234	-1,926,418	-143,159	-61,192	-357,860
Standard Single-Family	702,414	706,856	4,442	666	0.67	93,939	92,607	255	575	596
Owned Multi-Family	35,454	38,471	3,017	362	0.36	50,682	50,682	0	0	0
Rented Multi-Family	146,739	164,463	17,724	2,127	2.13	178,654	74,652	0	0	104,002
PECAS Housing Type Subtotal						**-2,165,959**	**-1,708,477**	**-142,905**	**-60,617**	**-253,263**

NET TOTAL	**-1,128,095**	**-863,441**	**-30,941**	**-22,506**	**-210,592**

Source: PECAS Model, EIOLCA Model, US Census 2009 County Business Patterns for Sacramento MSA.
BAU = Business-as-usual scenario.
PRB = Preferred Blueprint scenario.
t CO_2e = metric tons of carbon dioxide equivalent.

Table 5 presents a lot of information that illustrates the overall impact of the PRB in contrast to the BAU. The top section of the table shows the shifts in economic activity that result from the two scenarios. Each row illustrates the shift sector-by-sector, and the sixth column shows the percentage change. It is notable that many of the changes within sector are not significant at all. A total of 15 sectors exhibit changes less than one percent in terms of shifts in the annual consumption of goods and services. Other consumption shifts are also small in terms of percentages. Hence, the overall impact from upstream emissions resulting from shifts in economic activity is small. Furthermore, emissions tend to track together, particularly when energy use is reduced, and the results find that energy and other emissions also fall as a result of the dynamics of shifting housing stock and economic activity. Table 6 shows the projected change in energy use in terajoules (TJ) from the PECAS model simulation of the PRB.

Table 6. EIOLCA-Projected Change in Energy Use as a Result of PRB Relative to BAU

Activity	Energy Use (over 25 years) (TJ)					
	Total	Coal	Petroleum	Natural Gas	Biogenic or Waste	Non-Fossil Electricity
Agriculture (plus Mining)	68	13	32	14	1	9
Construction	-1	0	0	0	0	0
Manufacturing	1	0	0	0	0	0
Transportation Services	1,029	95	731	131	11	60
Communications And Utilities	-710	-412	-65	-182	-9	-40
Wholesale Trade	-14	-3	-5	-3	-1	-2
Retail Trade	3,797	1,352	740	821	98	787
Restaurants	2,244	737	452	593	91	370
Finance Insurance Legal	799	217	225	189	40	128
Real Estate	1,096	442	151	248	18	236
Hotels	94	32	14	24	3	21
Business Services	27	9	5	7	1	5
Automotive Services	947	314	187	268	32	152
Amusement Services	645	199	144	180	16	106
Health Services	3,270	956	796	849	153	515
Primary Education	361	89	65	152	8	47
Other Education	196	46	57	58	11	24
Personal Services	611	209	108	161	21	112
Membership & Non-Profit Orgs.	438	124	114	113	16	71
Professional Services	71	20	22	17	3	10
Government Nonutility Enterprises	2	0	1	0	0	0

Activity	Energy Use (over 25 years) (TJ)					
	Total	Coal	Petroleum	Natural Gas	Biogenic or Waste	Non-Fossil Electricity
Military	0	0	0	0	0	0
PECAS Economic Sector Subtotal	**14,970**	**4,438**	**3,774**	**3,641**	**515**	**2,610**
Luxury Single-Family	-33,656	-7,215	-13,107	-7,932	-2,036	-3,369
Standard Single-Family	1,506	0	1,253	167	0	87
Owned Multi-Family	623	453	22	132	0	15
Rented Multi-Family	1,034	623	166	54	95	96
PECAS Housing Type Subtotal	**-30,494**	**-6,139**	**-11,667**	**-7,579**	**-1,941**	**-3,172**
NET TOTAL	**-15,523**	**-1,701**	**-7,893**	**-3,938**	**-1,427**	**-562**

Source: PECAS Model, EIOLCA Model, US Census 2009 County Business Patterns for Sacramento MSA.
Notes: TJ = terajoule.

As with the change in GHG, the change in energy is driven by the change in luxury SF. To quantify the change in toxic releases from PECAS and EIOLCA, Table 7 illustrates the change across sectors, in which the broader trend and dynamic remains the same.

Table 7. EIOLCA-Projected Change in Toxic Releases as a Result of PRB

Activity	Toxic Releases (over 25 years)								
	Fugitive (kg)	Stack (kg)	Total Air (kg)	Surface Water (kg)	Underground Water (kg)	Land (kg)	Offsite (kg)	Publicly Owned Treatment Works Metal	Publicly Owned Treatment Works Nonmetal
Agriculture (plus Mining)	72	421	492	80	118	464	128	1	79
Construction	-1	-4	-5	-1	-1	-8	-3	0	-1
Manufacturing	2	8	9	1	1	11	5	0	2
Transportation Services	433	2,383	2,809	402	362	3,569	1,252	8	525
Communications and Utilities	-213	-6,613	-6,840	-208	-190	-5,641	-1,290	-4	-389
Wholesale Trade	-17	-100	-117	-12	-13	-151	-40	0	-22
Retail Trade	2,863	28,207	31,074	2,100	2,681	30,686	8,873	53	3,952
Restaurants	2,981	18,915	21,896	4,215	2,303	22,616	6,031	31	5,037
Finance Insurance Legal	1,005	6,193	7,186	690	688	8,509	2,033	13	1,267
Real Estate	524	7,726	8,274	482	1,293	26,683	3,326	9	833
Hotels	60	659	721	51	47	579	158	1	82
Business Services	25	207	231	20	21	298	70	0	41
Automotive Services	1,487	8,733	10,229	1,601	1,572	24,627	9,320	70	2,624
Amusement Services	517	4,384	4,901	493	983	27,829	1,645	8	692
Health Services	4,252	25,921	30,326	4,540	6,116	59,297	10,030	67	9,199
Primary Education	221	1,935	2,164	269	267	2,652	696	4	410
Other Education	271	1,449	1,722	233	504	15,687	907	4	406
Personal Services	829	5,707	6,554	668	1,107	20,838	2,993	17	1,422
Membership & Non-Profit Orgs.	422	3,075	3,498	344	449	7,232	1,145	6	558
Professional Services	91	551	642	76	88	1,173	252	1	147

Activity	Toxic Releases (over 25 years)								
	Fugitive (kg)	Stack (kg)	Total Air (kg)	Surface Water (kg)	Underground Water (kg)	Land (kg)	Offsite (kg)	Publicly Owned Treatment Works Metal	Publicly Owned Treatment Works Nonmetal
Government Nonutility Enterprises	2	12	14	2	8	65	19	0	4
Military	0	0	0	0	0	0	0	0	0
PECAS Economic Sector Subtotal	**15,827**	**109,765**	**125,781**	**16,047**	**18,403**	**247,018**	**47,548**	**290**	**26,869**
Luxury Single-Family	-52,882	-330,135	-381,506	-40,417	-47,216	-453,275	-174,889	-827	-64,214
Standard Single-Family	1,086	1,706	2,792	1,299	3,285	60	434	15	4,597
Owned Multi-Family	550	1,723	2,277	7	0	7	163	0	139
Rented Multi-Family	2,169	3,488	5,657	2,020	423	55	351	9	466
PECAS Housing Type Subtotal	**-49,076**	**-323,218**	**-370,780**	**-37,090**	**-43,508**	**-453,152**	**-173,941**	**-803**	**-59,012**
NET TOTAL	**-33,249**	**-213,453**	**-244,999**	**-21,044**	**-25,106**	**-206,134**	**-126,393**	**-513**	**-32,143**

Source: PECAS Model, EIOLCA Model, US Census 2009 County Business Patterns for Sacramento MSA.

Finally, EIOLCA also produces estimates of changes in water usage that result from economic activities in specific sectors. In addition, the flow of dollars that result from spending in each sector is indicated as a function of direct and indirect economic activity. These EIOLCA outputs are given in Table 8.

Table 8. EIOLCA-Projected Change in Water Use and Economic Activity as a Result of PRB

PECAS Sector	Water Withdrawals (over 25 years) (kGal)	Economic Activity (over 25 years)		
		Total Economic Activity ($ millions)	Direct Economic Activity ($ millions)	Indirect Economic Activity ($ millions)
Agriculture (plus Mining)	829,713	10	8	1
Construction	-428	0	0	0
Manufacturing	1,201	0	0	0
Transportation Services	354,149	123	97	7
Communications and Utilities	-1,351,809	-91	-75	-3
Wholesale Trade	-12,860	-7	-6	0
Retail Trade	4,920,654	1,414	1,217	33
Restaurants	5,756,745	579	442	26
Finance Insurance Legal	869,860	1,014	853	20
Real Estate	1,610,872	425	374	48
Hotels	129,617	18	15	3
Business Services	31,573	16	14	1
Automotive Services	1,146,080	344	266	73

PECAS Sector	Water Withdrawals (over 25 years) (kGal)	Economic Activity (over 25 years)		
		Total Economic Activity ($ millions)	Direct Economic Activity ($ millions)	Indirect Economic Activity ($ millions)
Amusement Services	1,482,569	187	153	20
Health Services	4,591,274	1,452	1,206	14
Primary Education	475,291	80	65	17
Other Education	191,413	112	94	40
Personal Services	834,766	232	194	52
Membership & Non-Profit Orgs.	553,765	196	157	13
Professional Services	81,910	45	38	1
Government Nonutility Enterprises	1,592	1	1	0
Military	0	0	0	0
PECAS Economic Sector Subtotal	**22,497,946**	**6,150**	**5,114**	**368**
Luxury Single-Family	-30,671,596	-8,121	-5,968	-278
Standard Single-Family	2,671,612	666	666	67
Owned Multi-Family	405,454	33	32	35
Rented Multi-Family	1,675,942	136	71	111
PECAS Housing Type Subtotal	***-25,918,588***	***-7,286***	***-5,199***	***-65***
NET TOTAL	**-3,420,643**	**-1,136**	**-85**	**303**

Source: PECAS Model, EIOLCA Model, US Census 2009 County Business Patterns for Sacramento MSA.

The estimation from the EIOLCA model suggests that the PRB would reduce life cycle energy and emissions of GHG, toxics, and water use from upstream economic activities. These results are broadly driven by the impact of the shift in housing stock as forecasted by the PECAS model. The model suggests that the shift in housing stock overwhelms the increase in economic consumption-related emissions as simulated by the Sacramento PECAS model. The results indicate, in part, that changes in consumption activity may not be a primary source of LCA impacts associated with improved land use and transportation planning. Other changes more directly related to reduced infrastructure construction appear more likely to dominate. The estimation of impacts from the shift in housing stock are conservatively low, assuming luxury homes the same size and cost as standard single-family homes. At the same time, the estimation of impacts from changes in consumption are conservatively high, as the differences in annual consumption observed by PECAS during the final year of the forecast (2035), are assumed to be constant over the 25 year simulation.

Finally, it is important to understand that the analysis, as based on the EIOLCA model, shows the impacts on energy and emissions up to point of use of a product. Critically, it does not include the GHG emissions from the energy used to operate or use the goods and services introduced into the system. These activities can have important implications, but are outside of the modeling scope of EIOLCA and PECAS. Naturally, while the comparison here is important for understanding the relative impacts of the shift in housing stock and economic consumption, there is a broader scope of impacts that should be considered in future research. These include changes in automotive use, household heating, operational requirements, as well as other activities that produce direct emissions not measured in this analysis. The scope of this LCA analysis is the appropriate methodological approach and empirical results of the relative impacts of upstream emissions that from a change in consumption and housing stock. This serves as a foundation for future research to obtain a complete understanding of the emissions impact of land use planning.

VI. COMPLIANCE AND NON-COMPLIANCE

This section's study builds on the findings from two previous studies,[39] which suggest potential economic incentives for jurisdictional non-compliance, by simulating a set of scenarios with the Sacramento PECAS model, in which multiple jurisdictions partially pursue BAU as opposed to the PRB, and at differing rates. Because SB 375 does not require local governments to adopt general plans that are consistent with the land use plans included in SCSs, such incentives could jeopardize implementation of SCSs and achievement of GHG goals.

METHODS

In each scenario, each jurisdiction in the region is randomly designated as either "complying" or "non-complying." Within the non-complying jurisdictions, each land use type (e.g., retail space, luxury single-family housing) within each LUZ was randomly assigned a percentage for which it would develop according to the BAU scenario. The assigned percentages of non-compliance were limited to 5 percent, 10 percent, 15 percent, and 20 percent.

One hundred and fifty (150) randomly generated scenarios were created and simulated with the Sacramento PECAS model. In each scenario, total amount of industrial floorspace by sector and number of total housing units in the region is held constant at the levels established for the PRB scenario, while the number of housing units by type is allowed to vary based on demand. This scenario configuration is not a feature of the PECAS model, but was instead a choice made in the study design in order to keep the analysis more tractable. In order to hold the regional amount of different land uses at a constant level, the changes in land use in the non-complying jurisdictions are allocated to zones in the region's jurisdictions that complied with the PRB development plan. Because allocation is weighted by relative share of zonal housing units and industry by sector in the PRB plan, zones with the more total land use supply obtain a larger share of the change in supply resulting from the BAU development in the non-complying jurisdictions.

The results of the scenarios provide insight into how changes in the relative supply of the four housing types represented in the model (luxury single-family housing units, standard single-family housing units, owned multi-family housing units, and rented multi-family housing units), and holding other factors constant, might influence housing values, rents, wages, commute costs, and consumer surplus (total and by-income class) across the region, and in conforming and non-conforming jurisdictions.

RESULTS

The means and standard deviations of the main consumer-related variables compiled from the non-compliance scenarios are presented in Table 9. These results suggest that when non-compliance increases luxury single-family units and decreases standard single-family, as well as owned and rented multi-family units (all else being equal), then consumer surplus tends to increase at the regional level and in non-conformity jurisdictions, while it declines somewhat for complying jurisdictions. For both non-complying and complying jurisdictions, it appears that these surplus changes are caused by relative changes in living expenses (in terms of rent, housing value, and commute cost) and earning. Only in the case of non-complying jurisdictions do increased earnings outweigh increased expenses.

Table 9. Mean Change in Metrics for the PRB Relative to BAU

	Region		Non-Complying Jurisdictions		Complying Jurisdictions	
	Mean	SD	Mean	SD	Mean	SD
Luxury Single-Family Housing Units (%)	0.40	0.32	0.57	1.03	0.00	0.80
Standard Single-Family Housing Units (%)	-0.01	0.14	-0.12	0.84	-0.03	0.77
Owned Multi-Family Housing Units (%)	-0.52	0.33	-1.03	0.81	-0.07	0.80
Rented Multi-Family Housing Units (%)	-0.70	0.45	-1.26	0.73	-0.07	0.79
Total Housing Units (%)	0.00	0.00	-0.11	0.80	-0.03	0.77
Average Housing Value (%)	0.15	0.10	0.17	0.15	0.10	0.08
Average Rent (%)	0.41	0.22	0.94	0.26	0.26	0.14
Average Wages (%)	0.05	0.02	0.07	0.02	0.03	0.02
Average Commute Costs (%)	0.47	0.27	0.68	0.45	0.13	0.24
Average Consumer Surplus ($ thousands)	163	253	237	250	-72	42

Notes: Standard Deviation (SD). Consumer surplus measured in year 2000 U.S. Nominal Dollars.

While these average results provide some idea of the potential consequences of non-compliance, the standard deviation of many of these results is quite large due to the wide variation in how each scenario's non-complying jurisdictions alters their housing supplies. The probability density functions for the changes in each of the housing unit types, shown in Figure 5, provide a more complete picture of the variation in which random non-compliance can impact the supplies of these commodities in the region, non-complying jurisdictions, and complying jurisdictions. The wide distributions of values in non-complying and complying jurisdictions for the different housing unit types clarify the large standard deviations seen in Table 9.

Finally, the probability density function for average consumer surplus is presented in Figure 6. The graph shows that the distributions of consumer surplus for non-complying jurisdictions and the region are dispersed over a wide range of both positive and negative values, with peaks in the distribution from below -$100,000 to greater than $500,000. By contrast, the distribution for complying jurisdictions is highly concentrated around the mean, illustrating that these jurisdictions rarely benefit from the non-compliance of other jurisdictions in the region. The constant, low-magnitude decrease in consumer surplus for non-complying jurisdictions also suggests that, as hypothesized in the previous study on non-compliance, the average change within the non-complying jurisdictions is often in the same direction as the region overall. If non-complying jurisdictions benefit significantly from their actions, the region will likely benefit at a slightly lower magnitude. However, if the non-complying jurisdictions see significant decreases in surplus, one cannot expect the region's surplus to be balanced out by equivalent surplus gains in complying jurisdictions.

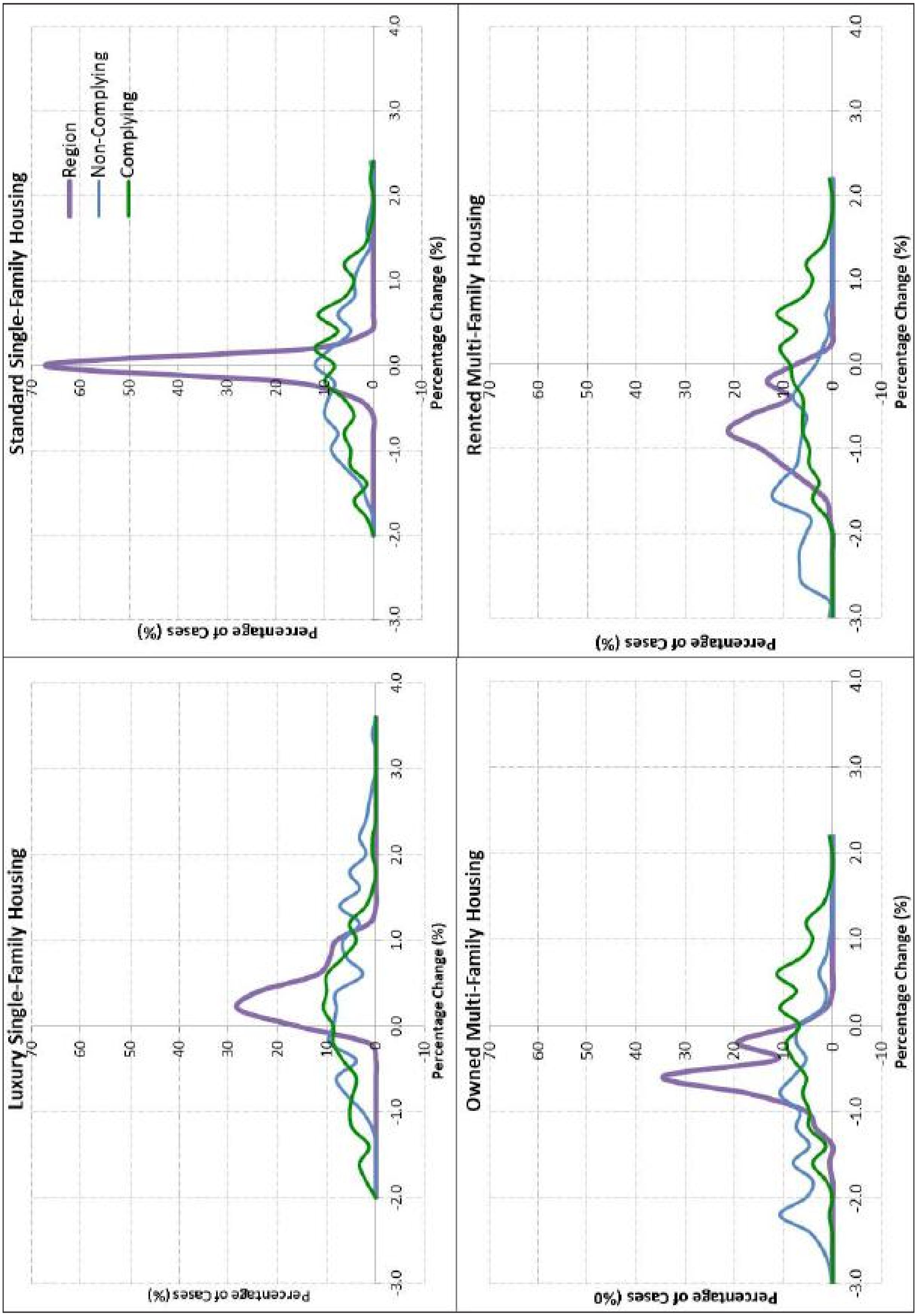

Figure 5. Probability Density Functions of the Quantity Changes for the Different Housing Types

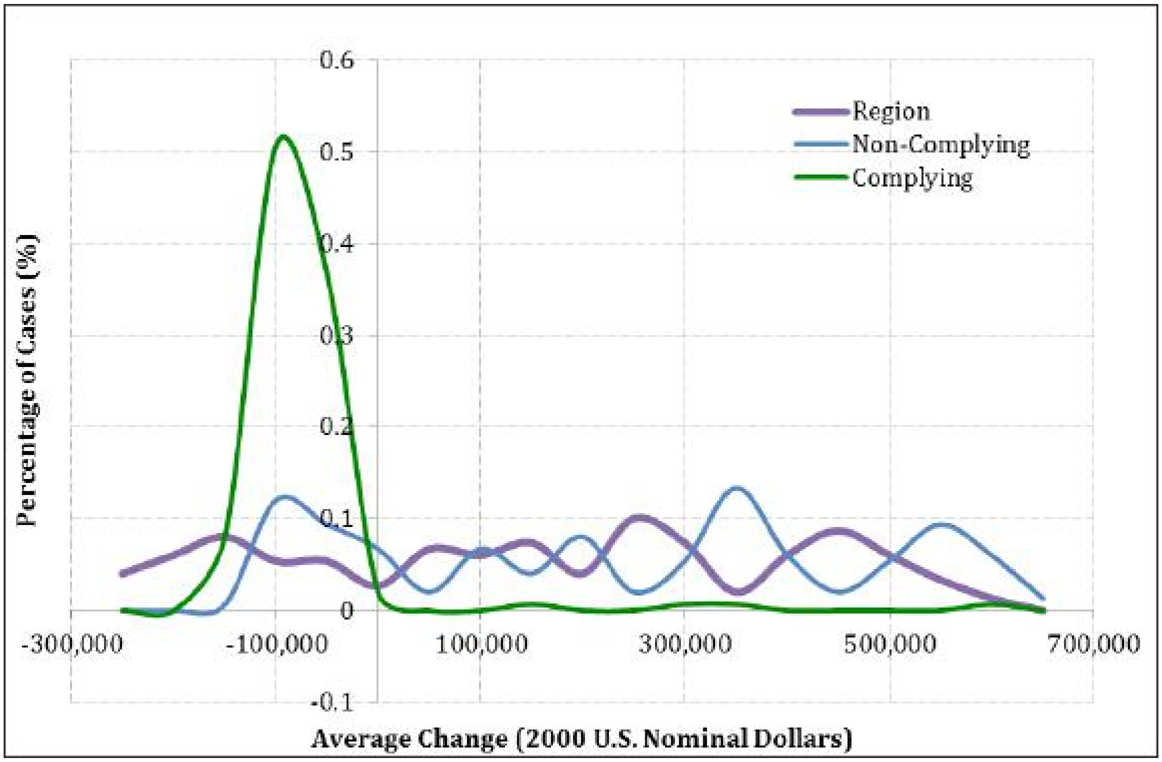

Figure 6. Probability Density Function of Average Consumer Surplus

In order to explore the relationships between regional consumer surplus and the quantity changes of different types of housing, a more in depth analysis was performed using the scenario outputs for (1) the regional supply changes for different housing unit types and (2) the average regional consumer surplus.

First, Table 10 describes the trends in housing quantity for the non-compliance scenarios. The majority of scenarios have increases in luxury single-family housing (N=145) and decreases in both owned (N=144) and rented (N=143) multi-family housing; however, standard single-family housing has a less distinct pattern.

Table 10. Number of Scenarios by Direction of Supply Change by Housing Type in Non-Compliance Scenarios

Housing Unit Type	Number of Scenarios (N)	
	Increasing	Decreasing
Luxury Single-Family	145	5
Standard Single-Family	83	67
Owned Multi-Family	6	144
Rented Multi-Family	7	143

Next, a linear regression was performed to test the hypothesis that regional consumer surplus increases with the regional supply of luxury single-family housing. Figure 7 below presents the results of the regression for these two variables.

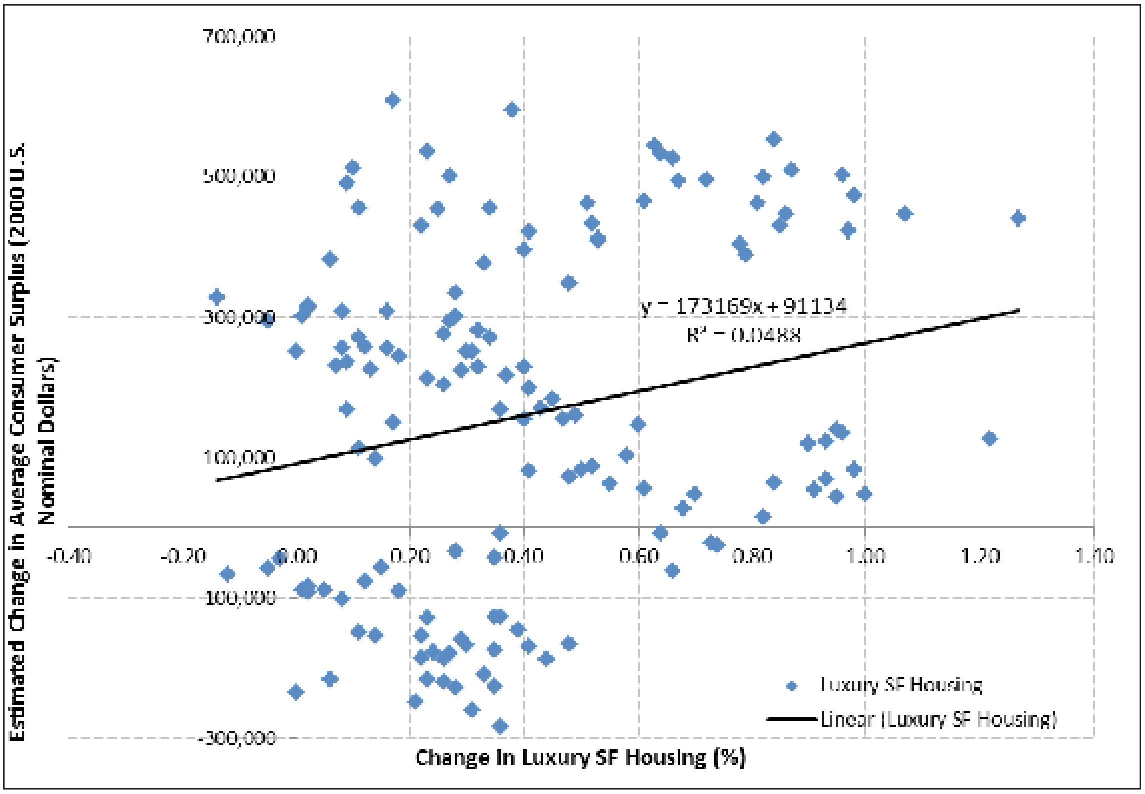

Figure 7. Estimated Change in Regional Average Consumer Surplus versus Change in Regional Supply of Luxury Single-Family Housing Units

As the graph shows, there is a positive correlation between the regional supply of luxury single-family housing and regional consumer surplus. However, because the consumer surplus value for a given quantity change of luxury housing varies so significantly, the R2 value of this correlation is only about 0.05. The low predictive power of this relationship suggests that, as one might expect with such a comprehensive model, the overall regional consumer surplus depends on other factors besides the supply of luxury single-family housing, such as which housing type replaces these housing units or where in the region these additional luxury units are located.

Next, the non-compliance scenario results were split into two categories based on whether the quantity of standard single-family housing units increased in the region. The categories were comparable in size, with 83 of the scenarios in the “increased standard SF” category and 67 in the “decreased standard SF” category (see Table 10). This categorization of scenarios was done in order to determine whether, in accordance with the hypothesis mentioned previously, increasing both single-family housing units types will result in a lower regional consumer surplus than if only luxury single-family housing units increase.

Before looking at consumer surplus, the change in luxury single-family housing was plotted against the change in both rented and owned multi-family housing to determine whether there is in fact a significant difference in the reduction of the latter for a given increase in luxury units that would lead to a difference in consumer surplus. The results in Figure 8 verify this hypothesis; in cases that both single-family housing types increase, multi-family housing decreases by almost three percent for each percentage increase luxury units (R2 = 0.63). By contrast, when standard single-family housing decreases, the same increase in luxury housing results in less than a two percent reduction in multi-family housing (R2 = 0.57). Thus, there is evidence that the impact of non-compliance on the supply of multi-family housing, and accordingly the living expenses for low-income residents, depends on the supply of standard single-family housing.

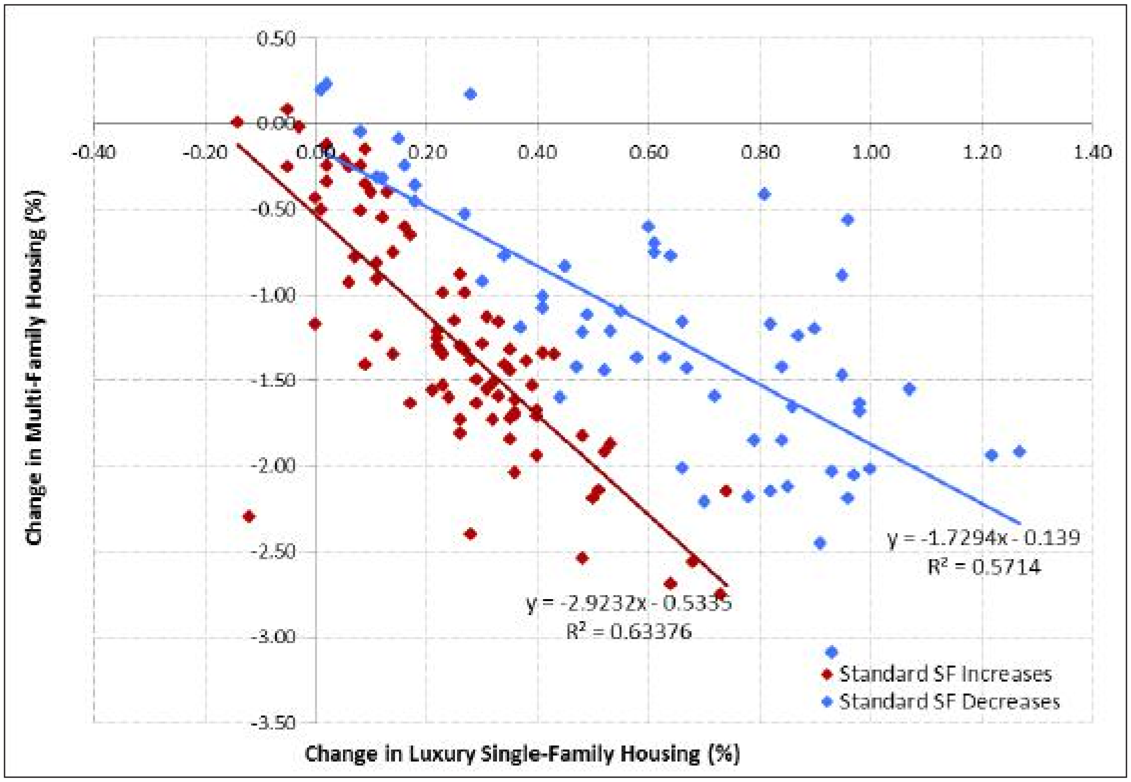

Figure 8. Change in Regional Supply of Luxury Single-Family Housing Units versus Change in Regional Supply of Multi-Family Housing Units

The mean and standard deviation of average consumer surplus for each of the categories is shown in Table 11. With a t-statistic of 0.013 (two-tailed), the difference in consumer surplus between these two groups is statistically significant at the 95 percent level, with a lower average consumer surplus in the group with an increasing supply of standard single-family housing and thus a greater reduction in the supply of multi-family housing.

Table 11. Mean and Standard Deviation of Average Consumer Surplus by Scenario Type

Scenario Category	Number of Scenarios (N)	Average Consumer Surplus (in $1,000)	
		Mean	Standard Deviation
Standard Single-Family Increases	87	144	237
Standard Single-Family Decreases	63	228	235

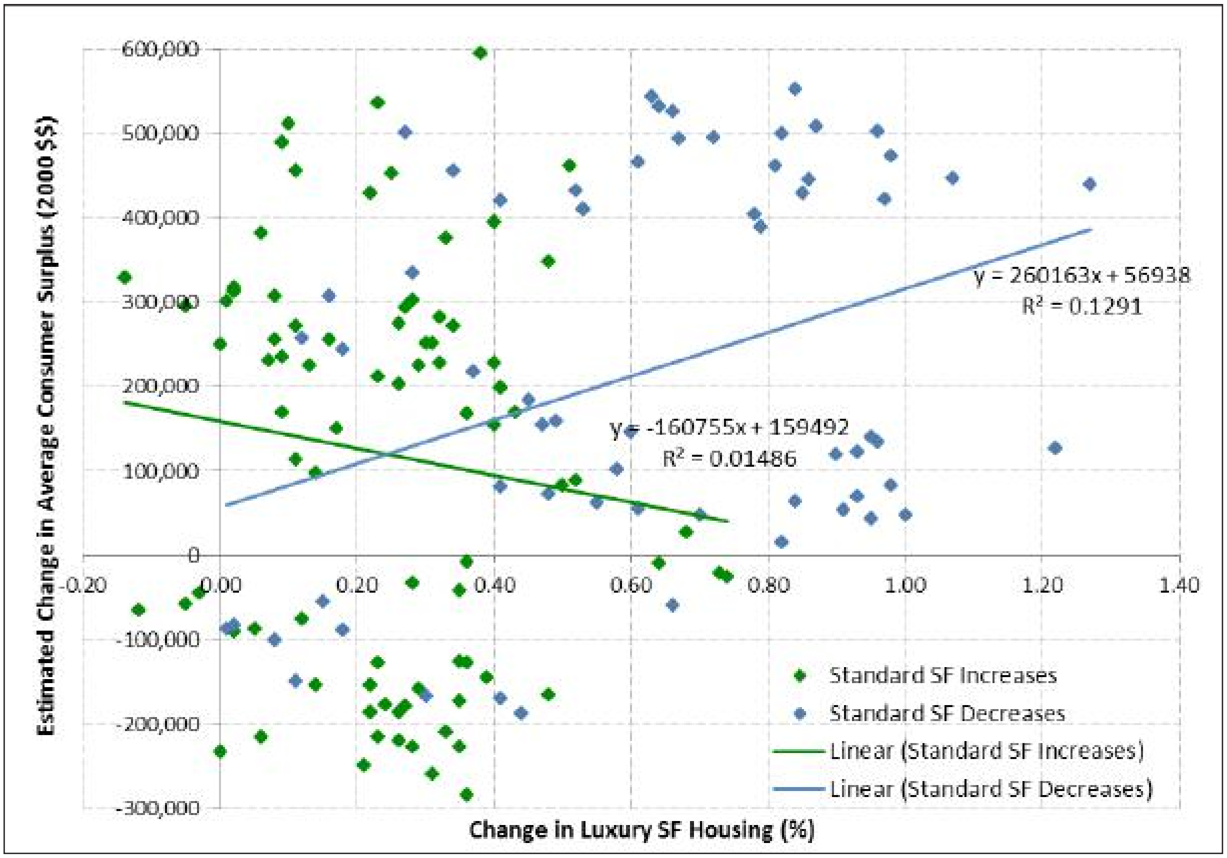

Figure 9. Estimated Change in Regional Average Consumer Surplus versus Change in Regional Supply of Luxury Single-Family Housing Units

Linear regressions were also performed on the two groups of scenarios, with the results shown in Figure 9. Illustrating the results in this manner shows a clear difference between scenarios in which both single-family housing unit types increase and those in which there are only increases in luxury single-family housing units. When both commodities increase, there is no longer a positive correlation between luxury single-family housing and consumer surplus; instead, there is a decrease in consumer surplus for each percentage increase in the housing quantity. This is in contrast to cases in which only one housing type increases, where a one-percentage increase in luxury single-family housing increases consumer surplus by over $200,000. This supports the hypothesis that increases in luxury housing needs to be coupled with decreases in standard single-family housing in order to dampen the impact of the shift on low-income residents.

As in the previous regression, however, the predictive powers of these relationships are not strong, with R2 values of 0.02 and 0.13 for the increasing and decreasing groups, respectively. Despite the weaknesses of the associations, these results provide some preliminary evidence that the supply of standard single-family housing is an important factor in how consumer surplus in the region will be impacted by non-compliance.

VII. CONCLUSIONS

In this study, the economic production and consumption data from the PRB and BAU scenarios, as simulated with the Sacramento PECAS model, are used to estimate the change in life cycle GHG emissions. The EIOLCA is applied to evaluate effects related to changes in economic production and consumption as well as housing construction. The results indicate that total CO_2e would increase by 1,037,864 metric tons from upstream economic activities in the PRB scenario relative to the BAU. However, GHG emissions arising from the shift in construction from luxury to smaller single- and multi-family housing units are estimated to reduce CO_2e emissions by a larger 2,165,959 metric tons. Changes in economic activities may be underestimated in the PRB scenario because of the assumption of constant total economic size. However, changes in economic activities (from the BAU to the PRB) would have to at least double to offset the reductions in GHG emissions from housing construction, which is unlikely.

It is important to note that the analysis of life cycle GHG emissions included production, but not use and distribution of goods and services demanded by consumers or purchasers in each scenario. GHG emissions from the distribution and use of the travel system is estimated to decline in the PRB relative to the BAU, as discussed above; however, it is unclear how use of products and services impact the results of this study.

In addition, a set of non-compliance scenarios are developed where multiple jurisdictions partially pursue BAU as opposed to the PRB, and at differing rates. One hundred and fifty (150) non-compliance scenarios were developed in which randomly assigned jurisdictions developed 5 percent, 10 percent, 15 percent or 20 percent according to the BAU. The results indicate that, on average, when non-conformity increases the supply of luxury single-family housing units in non-complying jurisdictions, the average household in the non-complying jurisdiction experiences increased economic benefits, while the average household in the complying region experiences economic losses. The total net benefits in the non-complying jurisdictions are large enough to offset the losses in conformity jurisdiction to produce net benefits for the average regional household. However, if both luxury and standard single-family housing increase as a result of non-conformity, then economic benefits decline on the average for non-complying and complying jurisdictions. At this point, the more heavily weighted gains of the higher income households are not great enough to offset the less heavily weighted losses of the lower income classes.

The following are key findings, implications, and policy recommendations:

- Coordinated land use and transportation plans, such as those envisioned by SB 375, may reduce housing, transport, and labor costs and increase net economic benefits.

- A shift in the supply of larger luxury single-family to multi-family housing in land use and transportation plans may benefit all but the highest income household (assuming consumer preferences remain constant from the year 2000 model estimation and calibration year).

- The overall reduction in home size from this shift in housing supply may more than offset increases in life cycle GHG emissions due to greater economic production that may result from the plan.

- If the consumer preference for larger homes returns to levels observed prior to 2007, developers and jurisdictions may face significant economic incentives to increase the supply of luxury single-family homes over and above that recommended in the regional land use and transportation plan. If this is at the expense of multi-family housing units, then low-income households may face significant economic losses.

- If, however, the early evidence that consumer preferences are shifting in favor of smaller homes coupled with high quality local and regional accessibility, then the land use and transportation plans envisioned under SB 375 are more likely to match market demand and be implemented.

- More research is needed to understand the market preferences for housing in regional land use and transportation plans under SB 375 to realize their potential to improve the economy, equity, and GHG reductions.

- Implementation of SB 375, as well as the regional supply of multi-family housing, should be carefully monitored. Decision makers may find the results of monitoring very useful as they contemplate the need for future revisions to SB 375 over time.

APPENDIX A: COUNTY BUSINESS PATTERN ECONOMIC BREAKDOWN OF SACRAMENTO BY EIOLCA CATEGORY BY PECAS OUTPUT SECTOR

This appendix presents the linked payroll data from the County Business Patterns (CBP) as aligned with the EIOLCA categories in groups defined by the PECAS economic output categories.[40] The dollar values in each table comprise the input to EIOLCA for each custom product. Each PECAS sector had its own custom product constructed. Only the Agriculture sector did not pull information from the CBP. Rather, agricultural data from the USDA was available, reporting sales within Sacramento that pertained to specific EIOLCA sectors that aligned better than the alignment in the CBP.[41] All other data is CBP data for 2009.

CONSTRUCTION			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
230101	Nonresidential commercial and health care structures	88.9545	14%
230102	Nonresidential manufacturing structures	88.9545	14%
230103	Other nonresidential structures	88.9545	14%
230201	Residential permanent site single- and multi-family structures	87.0727	14%
230202	Other residential structures	87.0727	14%
230301	Nonresidential maintenance and repair	88.9545	14%
230302	Residential maintenance and repair	87.0727	14%
	Total	**617.0360**	**100%**

TRANSPORTATION SERVICES			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
481000	Air transportation	46.078	6%
484000	Truck transportation	203.284	28%
485000	Transit and ground passenger transportation	39.619	6%
486000	Pipeline transportation	3.932	1%
48A000	Scenic and sightseeing transportation and support activities for transportation	108.886	15%
492000	Couriers and messengers	147.39	21%
493000	Warehousing and storage	165.475	23%
	Total	**714.664**	**100%**

COMMUNICATIONS AND UTILITIES			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
221100	Electric power generation, transmission, and distribution	139.09	9%
221200	Natural gas distribution	85.033	5%
221300	Water, sewage and other systems	10.256	1%
511110	Newspaper publishers	80.783	5%
511120	Periodical publishers	29.449	2%
511130	Book publishers	0.773	0%
5111A0	Directory, mailing list, and other publishers	20.366	1%
511200	Software publishers	170.164	11%
512100	Motion picture and video industries	17.608	1%

COMMUNICATIONS AND UTILITIES			
512200	Sound recording industries	1.946	0%
515100	Radio and television broadcasting	107.779	7%
515200	Cable and other subscription programming	1.536	0%
517000	Telecommunications	718.253	45%
518200	Data processing, hosting, and related services	181.34	11%
519100	Other information services	40.829	3%
	Total	**1605.205**	**100%**

WHOLESALE TRADE			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
420000	Wholesale trade	1879.055	100%
	Total	**1879.055**	**100%**

RETAIL TRADE			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
4A0000	Retail trade	2378.284	100%
	Total	**2378.284**	**100%**

RESTAURANTS			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
722000	Food services and drinking places	882.967	100%
	Total	**882.967**	**100%**

FINANCE INSURANCE LEGAL			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
52A000	Monetary authorities and depository credit intermediation	582.79	23%
522A00	Nondepository credit intermediation and related activities	275.256	11%
523000	Securities, commodity contracts, investments, and related activities	334.418	13%
524100	Insurance carriers	987.69	38%
524200	Insurance agencies, brokerages, and related activities	392.951	15%
525000	Funds, trusts, and other financial vehicles	0.116	0%
	Total	**2573.221**	**100%**

REAL ESTATE			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
531000	Real estate	402.37	75%
532100	Automotive equipment rental and leasing	58.761	11%
532A00	General and consumer goods rental except video tapes and discs	26.591	5%
532230	Video tape and disc rental	9.623	2%
532400	Commercial and industrial machinery and equipment rental and leasing	38.63	7%
533000	Lessors of nonfinancial intangible assets	2.077	0%
	Total	**538.052**	**100%**

HOTELS			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
7211A0	Hotels and motels, including casino hotels	243.074	21%
721A00	Other accommodations	9.904	1%
722000	Food services and drinking places	882.967	78%
	Total	**1135.945**	**100%**

BUSINESS SERVICES			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
550000	Management of companies and enterprises	693.338	100%
	Total	**693.338**	**100%**

AUTOMOTIVE SERVICES			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
8111A0	Automotive repair and maintenance, except car washes	179.679	91%
811192	Car washes	16.857	9%
	Total	**196.536**	**100%**

AMUSEMENT SERVICES			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
711100	Performing arts companies	10.738	2%
711200	Spectator sports	97.458	22%
711A00	Promoters of performing arts and sports and agents for public figures	13.485	3%
711500	Independent artists, writers, and performers	1.725	0%
712000	Museums, historical sites, zoos, and parks	9.349	2%
713A00	Amusement parks, arcades, and gambling industries	158.916	36%
713B00	Other amusement and recreation industries	91.597	21%
713940	Fitness and recreational sports centers	52.89	12%
713950	Bowling centers	6.427	1%
	Total	**442.585**	**100%**

HEALTH SERVICES			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
621A00	Offices of physicians, dentists, and other health practitioners	1975.639	38%
621B00	Medical and diagnostic labs and outpatient and other ambulatory care services	390.955	8%
621600	Home health care services	100.561	2%
622000	Hospitals	1858.964	36%
623000	Nursing and residential care facilities	401.83	8%
624A00	Individual and family services	270.331	5%
624200	Community food, housing, and other relief services, including rehabilitation services	56.974	1%
624400	Child day care services	81.074	2%
	Total	**5136.328**	**100%**

PRIMARY EDUCATION			
IO Code	IO Sector	Millions ($)	% of Economy
611100	Elementary and secondary schools	129.124	60%
611A00	Junior colleges, colleges, universities, and professional schools	87.767	40%
	Total	**216.891**	**100%**

OTHER EDUCATION			
IO Code	IO Sector	Millions ($)	% of Economy
611B00	Other educational services	140.173	100%
	Total	**140.173**	**100%**

PERSONAL SERVICES			
IO Code	IO Sector	Millions ($)	% of Economy
811200	Electronic and precision equipment repair and maintenance	44.177	19%
811300	Commercial and industrial machinery and equipment repair and maintenance	19.6	8%
811400	Personal and household goods repair and maintenance	13.195	6%
812100	Personal care services	53.598	23%
812200	Death care services	15.761	7%
812300	Dry-cleaning and laundry services	62.355	27%
812900	Other personal services	26.183	11%
	Total	**234.869**	**100%**

MEMBERSHIP & NON-PROFIT ORGS			
IO Code	IO Sector	Millions ($)	% of Economy
813100	Religious organizations	175.578	28%
813A00	Grantmaking, giving, and social advocacy organizations	131.114	21%
813B00	Civic, social, professional, and similar organizations	314.88	51%
	Total	**621.572**	**100%**

PROFESSIONAL SERVICES			
IO Code	IO Sector	Millions ($)	% of Economy
541100	Legal services	541.526	19%
541200	Accounting, tax preparation, bookkeeping, and payroll services	208.502	7%
541300	Architectural, engineering, and related services	720.676	25%
541400	Specialized design services	14.621	1%
541511	Custom computer programming services	203.655	7%
541512	Computer systems design services	168.304	6%
54151A	Other computer related services, including facilities management	164.742	6%
541610	Management, scientific, and technical consulting services	201.457	7%
5416A0	Environmental and other technical consulting services	134.396	5%
541700	Scientific research and development services	199.018	7%
541800	Advertising and related services	124.22	4%

PROFESSIONAL SERVICES			
5419A0	All other miscellaneous professional, scientific, and technical services	77.546	3%
541920	Photographic services	5.84	0%
541940	Veterinary services	87.198	3%
	Total	**2851.701**	**100%**

GOVERNMENT NONUTILITY ENTERPRISES			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
561100	Office administrative services	190.324	15%
561200	Facilities support services	26.317	2%
561400	Business support services	125.058	10%
561600	Investigation and security services	144.127	11%
561700	Services to buildings and dwellings	287.06	23%
561900	Other support services	41.164	3%
561300	Employment services	329.396	26%
561500	Travel arrangement and reservation services	27.107	2%
562000	Waste management and remediation services	91.837	7%
	Total	**1262.39**	**100%**

AGRICULTURE			
IO Code	**EIOLCA Sector**	**Adjusted Sales ($1,000)**	**% of Economy**
	Oilseed farming	$13,512	4%
	Grain farming	$13,512	4%
111910	Tobacco farming	$0	0%
111920	Cotton farming	$0	0%
	Vegetable and melon farming	$15,838	5%
111335	Tree nut farming	$48,047	14%
1113A0	Fruit farming	$48,047	14%
111400	Greenhouse and nursery production	$57,813	17%
113A00	Forest nurseries, forest products, and timber tracts	$0	0%
1119B0	All other crop farming	$0	0%
112300	Poultry and egg production	$19,764	6%
1121A0	Cattle ranching and farming	$18,353	5%
112120	Milk production	$74,103	22%
112A00	Animal production, except cattle and poultry and eggs	$2,738	1%
114100	Fishing	$23,529	7%
	Total	**$335,256**	**100%**

MINING			
IO Code	**IO Sector**	**Millions ($)**	**% of Economy**
211000	Oil and gas extraction	1.874	4%
2122A0	Gold, silver, and other metal ore mining	0.044	0%
212310	Stone mining and quarrying	19.524	41%
212320	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	13.899	29%
213111	Drilling oil and gas wells	8.358	17%

MINING			
213112	Support activities for oil and gas operations	3.472	7%
21311A	Support activities for other mining	0.674	1%
	Total	**47.845**	**100%**

Manufacturing Payroll			
IO Code	**IO Sector**	**Millions ($)**	**% of Sector**
311111	Dog and cat food manufacturing	0.102	0.014%
311119	Other animal food manufacturing	0.071	0.010%
311210	Flour milling and malt manufacturing	23.121	3.133%
31122A	Soybean and other oilseed processing	0.073	0.010%
311330	Confectionery manufacturing from purchased chocolate	0.457	0.062%
311340	Nonchocolate confectionery manufacturing	0.24	0.033%
31161A	Animal (except poultry) slaughtering, rendering, and processing	0.604	0.082%
311820	Cookie, cracker, and pasta manufacturing	3.022	0.410%
311940	Seasoning and dressing manufacturing	4.178	0.566%
311990	All other food manufacturing	2.462	0.334%
312110	Soft drink and ice manufacturing	37.169	5.037%
312130	Wineries	8.471	1.148%
313310	Textile and fabric finishing mills	0.456	0.062%
314120	Curtain and linen mills	0.977	0.132%
314910	Textile bag and canvas mills	1.791	0.243%
314990	All other textile product mills	0.752	0.102%
315210	Cut and sew apparel contractors	0.738	0.100%
315230	Women's and girls' cut and sew apparel manufacturing	0.292	0.040%
315900	Apparel accessories and other apparel manufacturing	0.251	0.034%
321910	Wood windows and doors and millwork	26.711	3.620%
321920	Wood container and pallet manufacturing	4.497	0.609%
321991	Manufactured home (mobile home) manufacturing	10.253	1.389%
321992	Prefabricated wood building manufacturing	4.817	0.653%
322210	Paperboard container manufacturing	22.375	3.032%
323110	Printing	127.831	17.322%
323120	Support activities for printing	3.963	0.537%
325120	Industrial gas manufacturing	9.163	1.242%
325414	Biological product (except diagnostic) manufacturing	2.786	0.378%
3259A0	All other chemical product and preparation manufacturing	1.675	0.227%
326122	Plastics pipe and pipe fitting manufacturing	4.159	0.564%
326140	Polystyrene foam product manufacturing	0.912	0.124%
32619A	Other plastics product manufacturing	38.296	5.189%
327320	Ready-mix concrete manufacturing	18.679	2.531%
327330	Concrete pipe, brick, and block manufacturing	5.284	0.716%
327390	Other concrete product manufacturing	22.662	3.071%
327991	Cut stone and stone product manufacturing	3.658	0.496%
331520	Nonferrous metal foundries	0.621	0.084%
33211A	All other forging, stamping, and sintering	0.615	0.083%

Manufacturing Payroll			
33211B	Crown and closure manufacturing and metal stamping	2.693	0.365%
332310	Plate work and fabricated structural product manufacturing	27.577	3.737%
332320	Ornamental and architectural metal products manufacturing	49.123	6.657%
332600	Spring and wire product manufacturing	0.711	0.096%
332710	Machine shops	31.36	4.250%
332720	Turned product and screw, nut, and bolt manufacturing	5.889	0.798%
332800	Coating, engraving, heat treating and allied activities	4.904	0.665%
33299C	Other fabricated metal manufacturing	4.474	0.606%
333120	Construction machinery manufacturing	2.87	0.389%
33329A	Other industrial machinery manufacturing	1.45	0.196%
333319	Other commercial and service industry machinery manufacturing	2.377	0.322%
333515	Cutting tool and machine tool accessory manufacturing	8.2	1.111%
333920	Material handling equipment manufacturing	0.398	0.054%
33399A	Other general purpose machinery manufacturing	12.618	1.710%
333993	Packaging machinery manufacturing	0.481	0.065%
334300	Audio and video equipment manufacturing	3.369	0.457%
334418	Printed circuit assembly (electronic assembly) manufacturing	21.649	2.934%
334419	Other electronic component manufacturing	17.295	2.344%
334511	Search, detection, and navigation instruments manufacturing	25.431	3.446%
334515	Electricity and signal testing instruments manufacturing	16.833	2.281%
33451A	Watch, clock, and other measuring and controlling device manufacturing	2.866	0.388%
335930	Wiring device manufacturing	2.002	0.271%
336211	Motor vehicle body manufacturing	3.051	0.413%
336214	Travel trailer and camper manufacturing	7.878	1.068%
336300	Motor vehicle parts manufacturing	9.268	1.256%
336991	Motorcycle, bicycle, and parts manufacturing	0.125	0.017%
337110	Wood kitchen cabinet and countertop manufacturing	15.845	2.147%
337122	Nonupholstered wood household furniture manufacturing	2.423	0.328%
337212	Office furniture and custom architectural woodwork and millwork manufacturing	8.096	1.097%
337215	Showcase, partition, shelving, and locker manufacturing	5.433	0.736%
337910	Mattress manufacturing	1.16	0.157%
339114	Dental equipment and supplies manufacturing	3.365	0.456%
339116	Dental laboratories	12.151	1.647%
339920	Sporting and athletic goods manufacturing	11.395	1.544%
339950	Sign manufacturing	12.399	1.680%
33999A	All other miscellaneous manufacturing	6.614	0.896%
	Total	**737.957**	**100%**

ABBREVIATIONS AND ACRONYMS

AA Module	Activity Allocation Module
AB 32	California Assembly Bill 32 Global Warming Solutions Act
ARB	California Air Resources Board
BAU	Business-as-Usual
BEA	Bureau of Economic Analysis
CBP	County Business Patterns
CH_4	Methane
CO_2e	Carbon Dioxide (CO_2) Equivalent
DOC	Department of Commerce
ED Module	Economic Demographic Aggregate Forecasting Model Module
EIOLCA	The Economic Input-Output Life Cycle Assessment Model
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
IO	Input-Output
LCA	Life Cycle Assessment
LUSTRE	Land Use, Strategic Transport, and Regional Economy
LUZ	Land Use Zone
MF	Multi-Family
MPO	Metropolitan Planning Organization
MSA	Metropolitan Statistical Area
N_2O	Nitrous Oxide
NAICS	North American Industry Classification System
PECAS	Production, Exchange and Consumption Allocation System
PRB	Preferred Blueprint Plan
PUMS	U.S. Census Public Use Microsample
SACOG	Sacramento Area Council of Governments
SACSIM	Sacramento Activity-Based Travel Simulation Model
SB 375	California Senate Bill 375
SCS	Sustainable Community Strategy
SD Module	Space Development Module
SF	Single-Family
t	Metric Ton
TAZ	Transportation Analysis Zone
TR Module	Transport Model Module
ULTRANS	Urban Land Use and Transportation Center
VBA	Visual Basic for Applications
VMT	Vehicle Miles Traveled

ENDNOTES

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