Proposed Modeling System Recommendations for Boston 80/50 Decarbonization

Final Report to Boston Green Ribbon Commission
September, 2016
revision 09_14_16

Cutler J. Cleveland, PI
Peter Fox-Penner
Institute for Sustainable Energy, Boston University

DRAFT

DRAFT

Project Advisors

Michelle Manion, *Senior Associate,* Abt Associates

Bruce Biewald, *CEO*, Synapse Energy Economics, Inc.

Sharon Weber, *Deputy Division Director*, Air & Climate Programs, MA Dept. Environmental Protection

H. Hanh Chu, *Program Manager, GWSA Implementation*, MA Exec. Office of Energy and Env. Affairs

Christopher Porter, *Principal*, Cambridge Systematics

John Larsen, *Director*, Rhodium Group

Christoph Reinhart, *Associate Professor,* Dept. of Architecture, Massachusetts Institute of Technology

High-Level Methodologies for Climate Policy Assessment

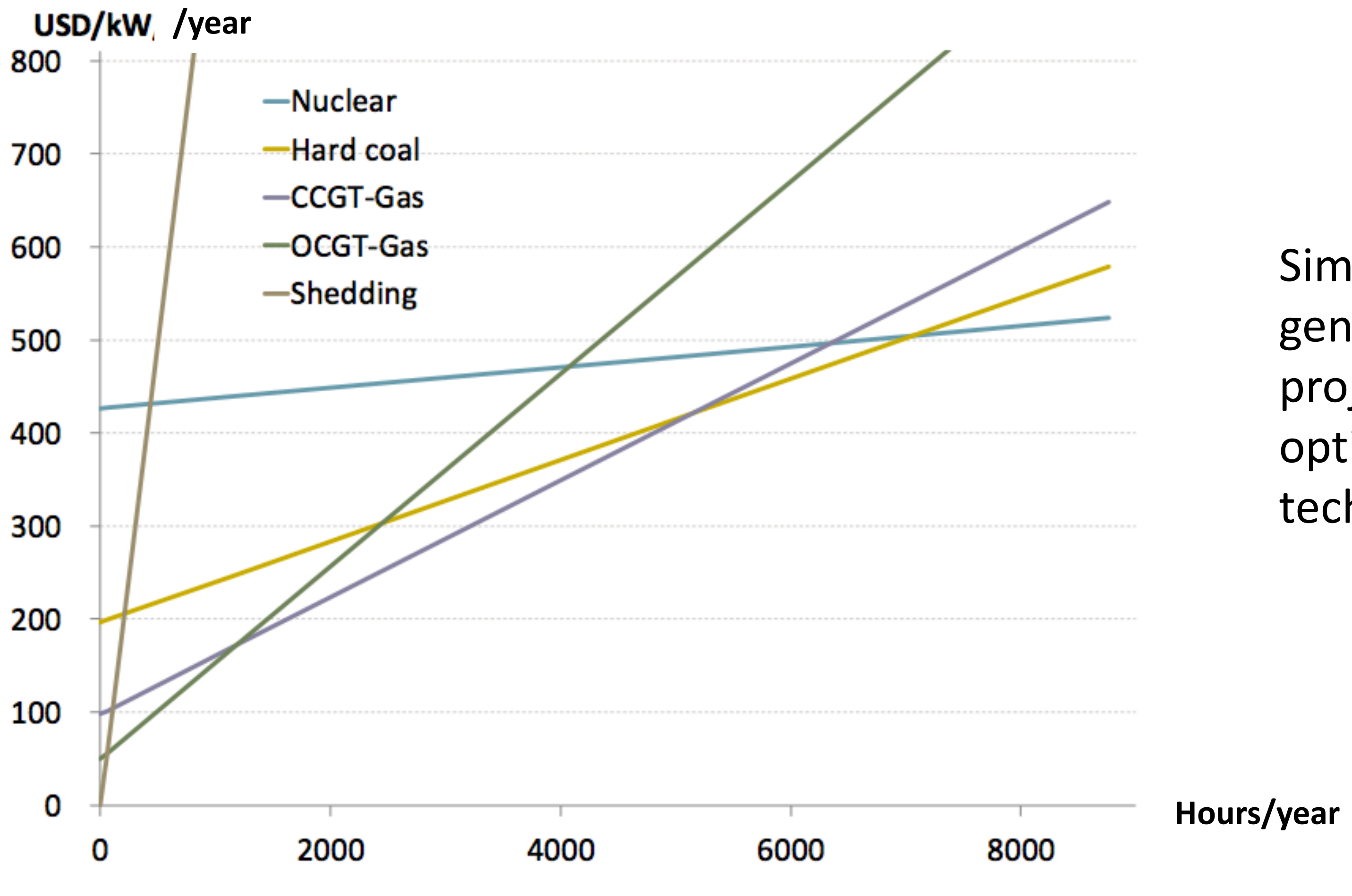
Heuristic Approach	Models
• Easy to understand	• Harder to understand
• Inaccurate estimates of many policy impacts	• More accurate estimates of policy impacts
• Substantial effort; low ROI	• Substantial effort; high ROI
• Inflexible option analysis & packaging	• Designed to explore option packages

Integrated or "All-in-One" Models	Sectoral Models
• Reduced accuracy within sectors	• Greater accuracy
• Not well-suited to specific state & local policies	• Well-suited to analyze impacts of specific policies
• Expensive to calibrate & run at small scales	• More complex and labor-intensive
	• Models must be linked together

DRAFT

Screening Curve for Electricity Supply

DRAFT

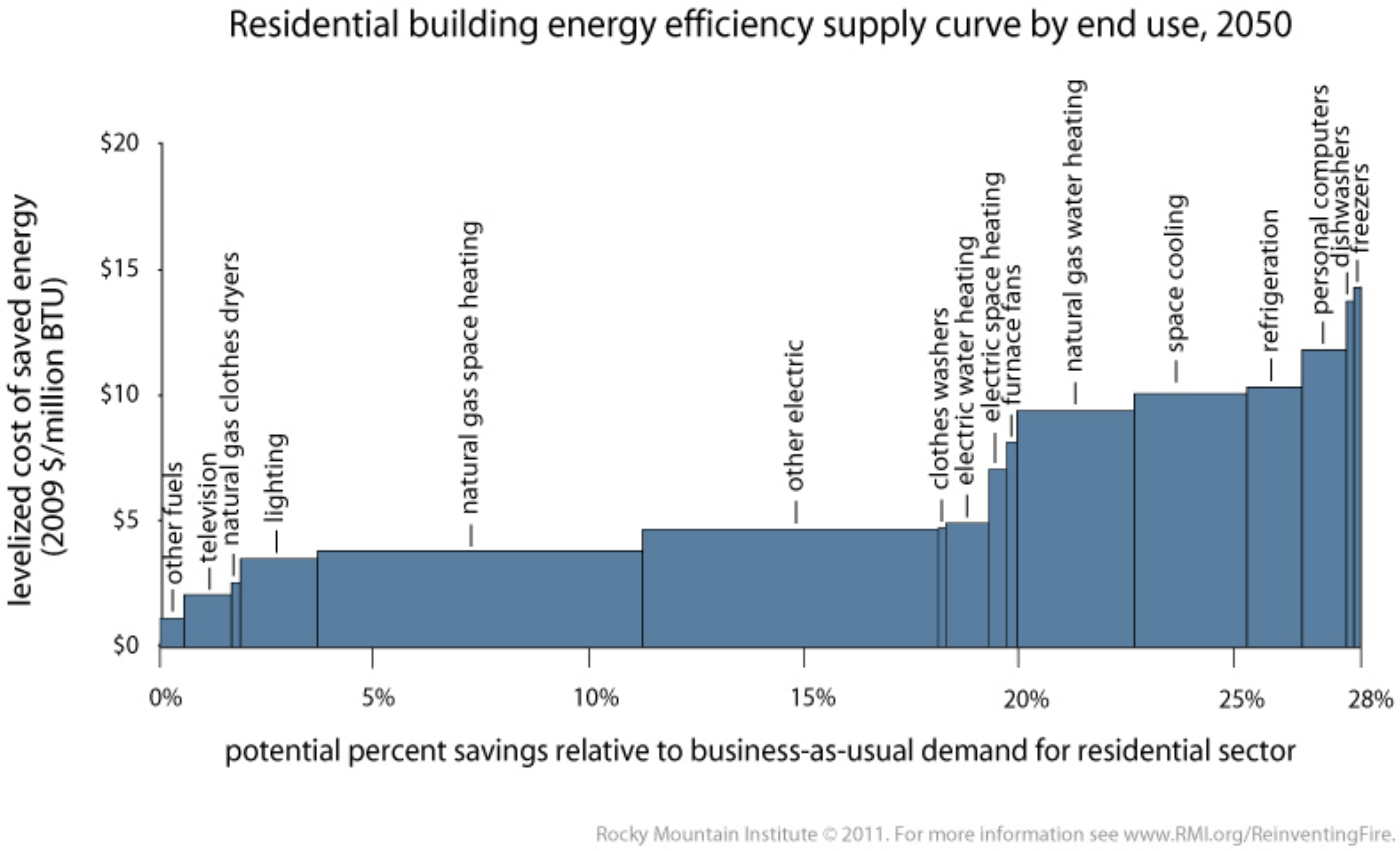


Simplified representations of generation costs and system load projections that approximate the optimum mix of generating technologies.

Source: Electricity markets: Opening up to competition and investments Lars Dittmar (TU Berlin), Dennis Volk & Matthew Wittenstein (IEA) IEA Energy Training Week Paris, 10.04.14

Screening Curve for Energy Efficiency

DRAFT



Integrated, “All-in-One” Models (partial listing)

DRAFT

1. *Siemens City Performance Tool (CyPT)*
   - Black box, PC-based dynamic simulation model
   - Loaded with city data and characteristics of 70 transport, building, & energy technologies
   - Generates scenarios of emissions relative to a baseline for user-specified levels of technology penetration
   - No capacity to quantify effects, costs, or tradeoffs among specific policy strategies
   - Not open source
2. *Pathways (E3)*
   - Bottom-up, stock rollover model similar to NEMS
   - Built for national implementation; high level of aggregation; costly to down-scale
   - No capacity to quantify effects, costs, or tradeoffs among specific local policy strategies
   - Not open source
3. *Clearpath (Local Governments for Sustainability (ICLEI)*
   - Black box, web-based inventory, reporting, and forecasting modules for major sectors
   - Captures some local information
   - Limited capacity to quantify effects, costs, or tradeoffs among specific policy strategies
   - Not open source

Takeaway: Integrated models are largely policy-agnostic, and thus less useful than sectoral models in the assessment of specific policies

Useful Summary of Models as Applied to the Power Sector

A Guide to Clean Power Plan Modeling Tools

Analytical Approaches for State Plan CO_2 Performance Projections

February 1, 2016

Synapse Energy Economics
Jeremy Fisher, Ph.D.
Nidhi R. Santen, Ph.D.
Patrick Luckow

Argonne National Laboratory
Fernando de Sisternes, Ph.D.
Todd Levin, Ph.D.
Audun Botterud, Ph.D.

Argonne NATIONAL LABORATORY
Center for Energy, Environmental, and Economic Systems Analysis (CEEESA)

Synapse Energy Economics, Inc.
485 Massachusetts Avenue, Suite 2
Cambridge, Massachusetts 02139
617.661.3248 | www.synapse-energy.com

Oriented towards electric power sector, but conceptually relevant for all sectors

DRAFT

Table 1. Summary of modeling capabilities for five model classifications

		Features represented			
		Generation	**Transmission**	**Demand and Renewable Resources**	**Geographic scope**
Production Cost Models *e.g., PROSYM (ABB), PLEXOS (Energy Exemplar), PCI Gentrader, AURORAxmp (EPIS), and GE-MAPS*		Output decision at the individual EGU level	Major transmission lines and nodes represented	Chronological, hourly resolution or less	Regional to interconnect
Utility-Scale Capacity Expansion Models *e.g., System Optimizer (ABB), Strategist (ABB), PLEXOS-LT, AURORAxmp, RPMI (NREL)*		Investment and dispatch decisions at the individual EGU level	Discrete/selected transmission lines represented	Non-chronological, Hourly (typical week) or coarser resolution	Utility, state or discrete region
National-Scale Capacity Expansion Models *e.g., IPM (ICF), ReEDS (NREL), NEMS EMM (EIA), HAIKU (RFF), POM (Navigant)*		Aggregated capacity buildout by technologies (generally does not incorporate individual EGU granularity)	Representation of transmission capacity limits between major zones	Non-chronological, demand in multi-hour blocks Poor representation of extreme events	Interconnect to national
Multi-Sector Models *e.g., MARKAL (IEA ETSAP), NE-MARKAL (NESCAUM), NEMS (EIA), EPPA (MIT), NewERA (NERA)*	*General equilibrium*	Model plants representing individual technologies.	No representation of transmission	Large demand blocks	Regional to national
	Partial equilibrium	Model plants representing individual technologies.	No representation of transmission	Demand blocks/hourly resolution	Varies
Non-Optimization Approaches *e.g., EGU Growth Tool (ERTAC), AVERT (EPA), CP3T (Synapse), CPP Planning Tool (MJ Bradley), CPP Evaluation Model (Energy Strategies) SUPR (ACEEE), STEER (AEEI), LEAP (SEI)*	*Screening curves-based heuristics*	Model plants representing individual technologies.	No representation of transmission	Demand blocks/hourly resolution	Varies
	Net present value (NPV) calculations [13]	EGUs are price takers Simulation of the cash-flows of an individual EGU	Representation of transmission congestion through historical locational marginal prices	Hourly resolution	Varies
	Merit order-based heuristics	Variable cost-based dispatch of the EGUs in the system	No representation of transmission	Hourly resolution	Varies

Modeling (Production Cost, Utility-Scale Capacity Expansion, National-Scale Capacity Expansion, Multi-Sector Models)

Heuristics (Non-Optimization Approaches)

Ability to Address State/Local Policies

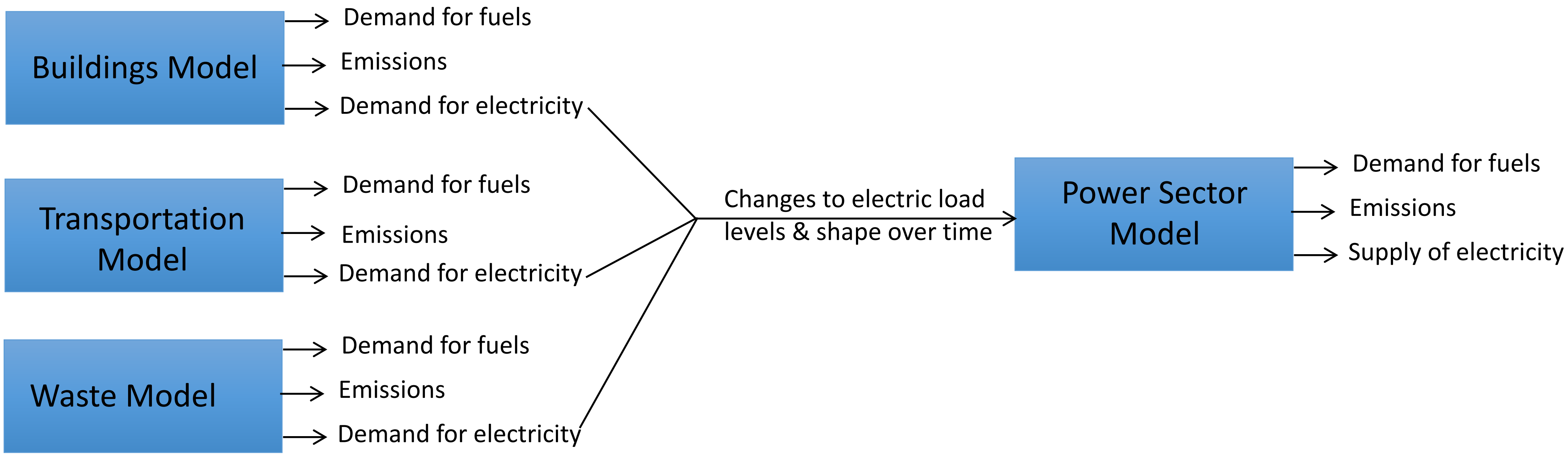
- Production Cost Models: GOOD
- Utility-Scale Capacity Expansion Models: BEST
- National-Scale Capacity Expansion Models: DIFFICULT
- Multi-Sector Models: WORST
- Non-Optimization Approaches: DIFFICULT OR NOT USEFUL

DRAFT

Source: Synapse Energy Economics and Argonne National Laboratory. 2016. A Guide to Clean Power Plan: Modeling Tools Analytical Approaches for State Plan CO_2 Performance Projections

Sectoral Models: Key Linkages

DRAFT



Demand changes are the key drivers and linkages; models with better treatment of demand changes are preferred.

Power Sector Model Comparisons

DRAFT

Overview of Most Relevant Electricity Sector Models*

Name of Model	Multi-Sector Tool Kit and ReEDS	Xpand	FACETS	RHG-NEMS
Associated Consulting Firm	Synapse	Brattle Group	Dunsky Consulting Group	Rhodium Group
Websites	www.synapseenergy.com; www.synapse-energy.com/tools/clean-power-plan-planning-tool-cp3t	www.brattle.com	www.dunsky.ca; http://www.iea-etsap.org/web/tools.asp; www.facets-model.com	http://www.eia.gov/forecasts/aeo/nems/documentation/electricity/pdf/m068(2014).pdf
Recent Relevant Project	RGGI Deep Cuts Case Study	New York City 80x50 Climate Plan, ongoing	Energy Policy Options of Vermont (to achieve GHG Goals) June 2014	National Energy Impacts of Clean Power Plan
Model Objective	Minimize total capital plus operating costs (i.e, total customer bills) of meeting net loads	Minimize total capital plus operating costs (i.e, total customer bills) of meeting net loads	Lowest cost to supply all energy services	Solve for prices, quantities that match supply and demand across energy sector and economy
Regional Structure	National model but readily converted to region	Regional; flexibility to create sub-regional	New England one aggregate region, but can create subregional (state) version	New England is one aggregate region in national model
Level of Detail in Supply Options	Representative techology profiles (ReDS); unit-specific in c3pt	Generators in New England modeled with unit-specific costs, efficiencies, and proposed retirement dates as available; geographically specific renewable energy generation profiles	Average regional technology exemplars	Average regional technology exemplars
Time Structure of Optimization	17 annual load bins, not chrono dispatch	40 annual load bins, not chrono dispatch; captures seasonal fluctuations in fuel prices	Solves for global equilibrium by annual or subannual period	Modules vary between chronological dispatch and load bins; ultimately the latter
Transmission Detail	134 nodes in U.S. and 365 wind/CSP regions	Regional; flexibility to create sub-regional	TBD	No intraregional detail
Level of Detail in EE and DR (Demand Side Options)	EE Savings Tool Linked Model allows for EE savings target adjustment and splits out cost of EE programs	Must be modeled separately	Demand by end use is part of model, so less need for some policy submodels	Representative Residential and Commercial buildings by type are part of NEMS so buildings EE policies at this level are easily addressed; all else submodeled
Level of Detail in Transportation Options	Evs and other transport demand must be modeled separately	Evs and other transport demand must be modeled separately	Demand by end use is part of model, so less need for some policy submodels	Transport module allows modeling of transport options
Open Source or Proprietary	Open Source	Proprietary	proprietary based on open source	proprietary based on open source

* List is not exhaustive, but meant to include the most likely candidates we have found

Transportation Sector Model Comparisons

DRAFT

Modeling approach will use some combination of the models below, plus “side-” or “sub-” models with additional Boston-specific data

	Network	Fuel Use & Emissions		GHG/Emissions Specific		Municipal-level	Land Use/Regional Planning	Regional microsimulation	Travel Demand Management		Other
Model Examples	Boston region travel model (CTPS/Boston MPO)	MOVES (EPA)	GREET (Argonne)	TEAM (EPA)	EERPAT (FHWA)	Clearpath (ICLEI)	CommunityViz (Placeways)	TRANSIMS (FHWA)	TRIMMS (University of South Florida)	COMMUTER (EPA)	Impacts 2050
Description	Regional-scale network models used to forecast flows based on socioeconomic projections and alternative transportation networks	Emission modeling system that estimates emissions for mobile sources at the national, county, and project level for criteria air pollutants, greenhouse gases, and air toxics.	LCA of a host of different fuel production, and vehicle material and production pathways, as well as alternative vehicle utilization assumptions.	A sketch tool (non-spatial) that covers TDM, land use, transit, and pricing, with a baseline of travel activity data from the MPO, along with MOVES emission factors.	A screening tool to compare, contrast, and analyze the effects of various greenhouse gas (GHG) reduction policy scenarios on GHG emissions from the surface transportation sector at a statewide level.	web application for community level energy and emissions accounitng, inventory, forecasting, and planning	Geographic information systems (GIS) -based tools designed to assist planners and stakeholders with the development and analysis of alternative land-use scenarios at a site, community, or regional level.	Agent-based cellular automata model used for creating activity-based travel demand models for individuals.	Sketch tool that estimates the impacts of a broad range of transportation demand initiatives and provides program cost effectiveness assessment, such as net program benefit and benefit-to-cost ratio analysis	Analysis of the impact of TDM strategies (support and incentive) on mode choice/use, travel times and costs, and emissions	Non-spatial system dynamics model that represents links between population, land use, employment, and travel behavior; forecasting/scenario model designed for long-range scenario evaluation
Platform	Various, priopretary or open-source software (Emme for Boston region)	Menu-driven blackbox calculator	Spreadsheet calculator, or menu-driven blackbox calculator	Spreadsheet	programming language "R" with GUI	Menu-driven blackbox calculators; inventory, reporting and forecasting modules for major sectors	GIS-based tools		visual basic (VB) application spreadsheet model	spreadsheet	
Method(s)	cost minimization, logit, gravity model	data-driven	data-driven	Elasticities	Household level microsimulation	Elasticities, rule-based, or input-driven	Transportation/emissions impacts typically based on elasticities	cellular automata	Elasticities	logit pivot-point, rule-based	systems dynamics
Model Input	Highway and transit networks, socioeconomic and demographic projections by TAZ, various behavioral parameters	vehicle types, time periods, geographical areas, pollutants, vehicle operating characteristics, and road types	various attributes of fuel and vehicle technologies	outputs from regional travel demand model; income and population; vehicle ownerhip, mode, and use; fuel prices, fuel efficiency, emissions factors	socioeconomic, demographic, road network data, fuel use by vehicles	GHG inventory; exogenous assumptions about drivers	detailed land-use and transportation data	extremely detailed data on demographics, vehicle properties, transport network parking, travel times and speeds,travel restrictions, etc.	employer demand; financial, pricing, access, and travel times; land use controls; employee transportation choices; vehicle and fuel use	Metropolitan Area Size, Application Setting Characteristics, Employment Mode Choice, Mode Shares, Average Trip Lengths, Vehicle Occupancy, Peak and Off-Peak Travel Characteristics	demographics, employment, location/type of residences, basic travel data (mode, rates, ownership)
Model Ouptut	trip generation, trip distribution, mode choice, and trip assignment; traffic volumes	Total emissions or emission rates per vehicle or unit of activity.	life cycle energy use (by different energy sources), emissions of greenhouse gases (in terms of CO2 equivalent) and emissions of air pollutants	changes in mode shares, travel time, VMT, speeds, fuel use, emissions	VMT and GHG emissions from surface transportation	forecast of emissions by sector	wide variety of community indicators related to transportation, land use, the environment	detailed data on travel, congestion, and emissions	Scenarios of land use, transportation choices, and emissions	impacts of TDM strategies on transport choice,use, cost, emissions	Scenarios of changes in sociodemographics, employment, travel behavior, land use, and transport supply
Geographic Scale	typically metropolitan or statewide	national, county/regional, project	technology-based--no spatial representation	national, state, local	state with subregions; parametrized with nat'l data	national, state, local	site or neighborhood level; sometimes applied at a regional scale.	variable	regional, local	state, regional, local	state, regional
Coupling to GHG decision-making	Poor; vehicle and fuel choices are not modeled; nonmotorized modes often excluded (although the CTPS model includes bike and ped trips); requires additional data/models for City-specific questions	Moderate; emissions estimates not directly tied to drivers; requires additional data/models for City-specific questions	Poor; emissions estimates not directly tied to drivers; requires additional data/models for City-specific questions	Moderate; requires additional data/models for City-specific questions	Moderate; requires additional data/models for City-specific questions	Moderate; captures some local information; emissions estimates not directly tied to drivers; requires additional data/models fo City-specific questions	Moderate; captures some local information; requires additional data/models for City-specific questions	Poor; requires additional data/models for City-specific questions	Poor; requires additional data/models for City-specific questions	Moderate; captures some local information; requires additional data/models for City-specific questions	Poor; requires additional data/models for City-specific questions
GHG strategies or policies that can be modeled	Road capacity, traffic flow improvements, new transit project or expanded service, pricing	Traffic flow improvements, truck idle reduction, fleet turnover	Emissions benefits of alternative fuel or electric vehicles	Transit improvements, TDM, pricing, land use, non-motorized	Road, fuel, and parking pricing, transit expansion, ITS, TDM, carsharing, land use, alternative fuels	Various	Land use	Highway and transit expansion and service improvements, traffic flow improvements, pricing	TDM, pricing, land use	TDM, pricing	Pricing, land use, vehicle occupancy, alternative fuels
Intellectual Property	Software is proprietary; input data public domain	Public domain	Public domain	Public domain	Public domain	Basic version is free to cities; Advanced version is fee-based	Proprietary	Public domain	Public domain	Public domain	Public domain
Ability for City to Learn/Maintain	Difficult	Moderate	Moderate	Moderate	Moderate	Moderate	Difficult	Difficult	Easy	Easy	Moderate

Building Sector Model

DRAFT

Recommendation: Boston Citywide Energy Model used in the Boston Community Energy Study

- Justification:
  - Spatially explicit model that is already loaded with City data
  - Potential to answer city-specific strategies to reduce GHG emissions when enhanced with socioeconomic data
  - Websites
    - http://www.bostonredevelopmentauthority.org/planning/planning-initiatives/boston-community-energy-study
    - http://web.mit.edu/sustainabledesignlab/projects/BostonEnergyModel/index.html

Waste Sector Model

DRAFT

Recommendation: *Waste Reduction Model (WARM);* U.S. Environmental Protection Agency; 2009

- Justification
  - Open source, easy to use, Excel spreadsheet model
  - Strong planning capability
  - Modest data requirements (but will require loading with City-specific data)
- Website: https://www.epa.gov/warm

Options for Project Execution

DRAFT

$200 K Budget	$500 K Budget	$900-1,000 K Budget
• Single contractor for entire project	• Single contractor for each major sector (electric power, transportation, buildings)	• Single contractor for each major sector (electric power, transportation, buildings)
• Possible use of single integrated modeling platform	• "Spreadsheet" approach with substantial degree of aggregation within sectors	• Detailed models with software and methods specific to sector
• Contractor can be selected via RFP or be sole-sourced; if RFP, selection based on extent to which sector-specific and integrating questions can be addressed within budget	• Single project manager who oversees project, including drafting RFPs, managing sub-contractors, construction of integrating model, communication, reporting, etc.)	• Single project manager who oversees project, including drafting RFPs, managing sub-contractors, construction of integrating model, communication, reporting, etc.)
	• RFPs should specify policies, inputs, and outputs; let marketplace identify the model	• RFPs should specify policies, inputs, and outputs; let marketplace identify the model
	• Project manager can be selected via RFP or be sole-sourced	• Project manager can be selected via RFP or be sole-sourced

VERY LOW → HIGHEST

Increasing # and sophistication of specific policy questions that can be rigorously assessed

Comparison of “Simple” and “Complex” Models

DRAFT

Electric Power Sector

1) Policy Question 1: Effect of demand-side management program, which changes the shape of the load curve
   a. Spreadsheet model: use rules of thumb to guess which power plants will run less, which will run more
   b. Simulation model: model quantifies which plants run more/less with high degree of specificity

2) Policy Question 2: Effect of a large-scale solar purchase by the city of Boston
   a. Spreadsheet model: use rules of thumb and side calculations to guesstimate whether this will cause marginal power plants to retire or not, and how the hours of operation (therefore emissions) of the remaining plants will change
   b. Simulation model: calculate whether and when plants will retire, and how hours of operation will change

Comparison of "Simple" and "Complex" Models

DRAFT

Transportation Sector

1) Policy Question 1: Effect of parking fees on vehicles trips into the city
   a. Spreadsheet model: guesstimate how drivers will respond to fee
   b. Simulation model: use disaggregate household-level models that quantify feedback from costs to travel behavior to account for induced demand

2) Policy Question 2: Effect of investment in bicycling infrastructure
   a. Spreadsheet model: use rules of thumb to guesstimate increase in bicycle use
   b. Simulation model: use demographic factors such as household size, structure, age, and income to quantify changes in demand for travel by mode

Summary of Recommendations

DRAFT

1. Use detailed models with software and methods specific to electric power, transportation, and buildings sectors in order to answer specific policy questions
2. Issue RFPs for electric power and transportation sectors that request scope-of work and cost estimates for two scenarios: simpler “spreadsheet” models and more complex models that emulate specifics of sector dynamics
3. For the buildings sector, extend model behind the Boston Community Energy Study in order to answer specific policy questions
4. Assign a Project Manager to supervise the Contractors for electric power, transportation, and buildings sectors, and to provide overall integration, coordination, communication, and quality control
5. Fold the waste sector model into the Scope of Work for the Project Manager
6. Generate candidate list of 6-8 list of policy options per sector, and get stakeholder buy-in