A System Dynamics Approach for Analysis of the Impacts of Bergen's Green Strategy Goal T9

- 'All new passenger cars shall be fossil-free as of 2025.'

Appendix

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Appendix A: Model Documentation

		Equation	Properties	Units	Documentation
○	T4:availability_of_public_transportation	0		dmnl	
○	T4:_park_and ride_facilities	0		facilities	
○	T5:_ passengers _per_car	0		people/car	
○	T7:_capacity_ for_generatin g_ electricity	0		GW/Year	
○	T7:_ percentage_of _biofuel_used	.2		dmnl	
BERGEN CAR MARKET SECTOR					
○	"avg_age_ (electric)"	10.5		year	Consumer Reports estimates the average EV battery pack's lifespan to be at around 200,000 miles, which is nearly 17 years of use if driven 12,000 miles per year. https://electrek.co/2019/06/17/tesla-holds-value-better-than-average-car-study/#:~:text=As%20previous%20studies%20have%20found,for%20the%20average%20gasoline%20car.
○	"avg_age_ (gas)"	10.5		year	The scrapping age in Europe ranges from 8-12 years. On average we took 10.5 years https://www.honestjohn.co.uk/forum/post/126626/cars-scrapped-too

		Equation	Properties	Units	Documentation
	buying_ electric_cars	MAX(0, MIN(inventory_of_electric_cars/DT, indicated_amount_of_new_cars_electric)+(gap_of_electric_cars/switching_time))		cars/year	This flow represents electric car purchases (including both new and used models). It is determined by the indicated amount of new gas cars, but is constricted by inventory if demand increases too quickly.
	buying_gas_ cars	MAX(0, MIN(inventory_of_gas_cars/DT, indicated_amount_of_new_cars_gas))		cars/year	This flow represents gas car purchases (including both new and used models). It is determined by the indicated amount of new gas cars, but is constricted by inventory if demand increases too quickly.
	desire_for_ new_vs_used_ electric_cars	GRAPH(TIME) Points: (2010.00, 0.995515789881), (2011.00, 0.992638748438), (2012.00, 0.987949239325), (2013.00, 0.980360805397), (2014.00, 0.968224664971), (2015.00, 0.949175019386), (2016.00, 0.920134042245), (2017.00, 0.87777489905), (2018.00, 0.819809247682), (2019.00, 0.747047751905), (2020.00, 0.6650), (2021.00, 0.582952248095),		dmnl	

		Equation	Properties	Units	Documentation
		(2022.00, 0.510190752318), (2023.00, 0.45222510095), (2024.00, 0.409865957755), (2025.00, 0.380824980614), (2026.00, 0.361775335029), (2027.00, 0.349639194603), (2028.00, 0.342050760675), (2029.00, 0.337361251562), (2030.00, 0.334484210119)			
○	desire_for_ new_vs_used_ gas_cars	.33		dmnl	we made an assumption of 33% desire for new to the old car
○	desired_ inventory_ coverage	.25		year	we estimate this to 3 months
○	desired_ inventory_of_ electric_cars	desired_inventory _coverage*indica ted_buying_of_el ectric_cars		cars	
○	desired_ inventory_of_ gas_cars	desired_inventory _coverage*indica ted_buying_of_ga s_cars		cars	
○	effect_of_ indicated_ share_on_ switching_ time	GRAPH(percentag e_wanting_to_sw itch) Points: (0.0000, 0.995515789881), (0.0500,		dmnl	This variable represents how the overall imbalance in the stocks of gas and electric cars affects how quickly people will make the switch. If many people have gas cars and otherwise would prefer

		Equation	Properties	Units	Documentation
		0.987949239325), (0.1000, 0.968224664971), (0.1500, 0.920134042245), (0.2000, 0.819809247682), (0.2500, 0.6650), (0.3000, 0.510190752318), (0.3500, 0.409865957755), (0.4000, 0.361775335029), (0.4500, 0.342050760675), (0.5000, 0.334484210119)			electric cars, then on average, people will not wait the full normal time to trade in in order to make the switch. They will accelerate their time frame for trading in so they can more quickly get an electric car.
	Electric_Cars_on_the_road(t)	Electric_Cars_on_the_road(t - dt) + (buying_electric_cars - tradein_of_electric_cars - "Scrapping_(Electric)") * dt	INIT Electric_Cars_on_the_road = initial_electric_cars_on_the_road	cars	This stock represents the number of owned and active gas cars in use in Bergen. When someone purchases a gas vehicle, this stock is increased. The vehicles are used until either they are scrapped or traded in for a new car. It is initialized to 200 electric cars. Calculated based on...()
	gap_of_electric_cars	(indicated_stock_of_electric_cars- Electric_Cars_on_the_road)		cars	
	Gas_Cars_on_the_road(t)	Gas_Cars_on_the_road(t - dt) + (buying_gas_cars - "Scrapping_(Gas)" - tradein_of_gas_cars -	INIT Gas_Cars_on_the_road = total_demand_for_cars- initial_inv	cars	This stock represents the number of owned and active gas cars in use in Bergen. When someone purchases a gas vehicle, this stock is increased. The vehicles are used until either they are scrapped or traded in for a new car. In this case, we have included two

		Equation	Properties	Units	Documentation
		switching_to_electric) * dt	entory_of_electric_cars		outflows representing trade ins. One is for normal trade ins and one is specifically used for people who sell their gas car earlier than they otherwise would have so that they can purchase an electric vehicle.
○	indicated_buying_of_electric_cars	MAX(0, indicated_amount_of_new_cars_electric+(gap_of_electric_cars/switching_time))		cars/year	
○	indicated_buying_of_gas_cars	MAX(0, indicated_amount_of_new_cars_gas)		cars/year	
○	indicated_stock_of_electric_cars	total_cars*indicated_share_of_electric_cars		cars	
○	initial_electric_cars_on_the_road	200		cars	we took an estimate of 200 cars
○	initial_inventory_of_electric_cars	50		cars	we took an estimate of 200 cars
○	inventory_adjustment_time	.25		year	it takes the approximately 3 months to balance the supply and demand for cars
±	inventory_of_electric_cars(t)	inventory_of_electric_cars(t - dt) + (shipping_in_of_electric_cars + tradein_of_electric_cars - buying_electric_cars -	INIT inventory_of_electric_cars = initial_inventory_of_electric_cars	cars	This represents the total inventory of electric cars within Bergen that are held for sale but not currently being actively used on the streets. This stock aggregates both new and used vehicles. It is assumed that all new electric cars shipped in will be sold, and any trade ins

		Equation	Properties	Units	Documentation
		shipping_out_of_electric_cars) * dt			will either be resold again or exported out of Bergen.
	inventory_of_gas_cars(t)	inventory_of_gas_cars(t - dt) + (tradein_of_gas_cars + shipping_in_of_gas_cars + switching_to_electric - buying_gas_cars - shipping_out_of_gas_cars) * dt	INIT inventory_of_gas_cars = 12600	cars	This represents the total inventory of gas cars within Bergen that are held for sale but not currently being actively used on the streets. This stock aggregates both new and used vehicles. It is assumed that all new gas cars shipped in will be sold, and any trade ins will either be resold again or exported out of Bergen.
	new_market_adjustment_factor	GRAPH(TIME) Points: (2010.00, 3.000), (2011.00, 2.1959594799), (2012.00, 1.71515953878), (2013.00, 1.42765091502), (2014.00, 1.25572658296), (2015.00, 1.15291931557), (2016.00, 1.09144265256), (2017.00, 1.0546808536), (2018.00, 1.03269804262), (2019.00, 1.01955276702), (2020.00, 1.01169215854), (2021.00, 1.00699167392), (2022.00, 1.00418087935),		dmnl	

		Equation	Properties	Units	Documentation
		(2023.00, 1.00250008115), (2024.00, 1.00149499788), (2025.00, 1.00089397844), (2026.00, 1.000534581), (2027.00, 1.0003196686), (2028.00, 1.00019115535), (2029.00, 1.00011430703), (2030.00, 1.00006835329)			
○	normal_trade in_time_of_ cars	5		years	we assume one car trade in a car after 5 years
○	percentage_of _electric_cars _on_the_road	Electric_Cars_on_ the_road/total_c ars		dmnl	
○	percentage_of _electric_cars _purchased	buying_electric_c ars/(buying_elect ric_cars+buying_g as_cars)		dmnl	This variable estimates the percentage of vehicles purchased that are electric (including both new and used vehicles)
○	percentage_ wanting_to_ switch	gap_of_electric_c ars/total_cars		dmnl	
	"Scrapping_ (Electric)"	Electric_Cars_on_ the_road/"avg_ag e_(electric)"		cars/year	A simple first order delay process is used to estimate the scrapping rate of electric cars
	"Scrapping _(Gas)"	Gas_Cars_on_the _road/"avg_age_(gas)"		cars/year	A simple first order delay process is used to estimate the scrapping rate of gas cars

		Equation	Properties	Units	Documentation
○	share_of_electric_cars_in_Bergen	percentage_of_electric_cars_on_the_road*100		dmnl	
	shipping_in_of_electric_cars	MAX(desire_for_new_vs_used_electric_cars*buying_electric_cars, ((desired_inventory_of_electric_cars-inventory_of_electric_cars)/inventory_adjustment_time))		cars/year	This variable represents all brand new electric cars that are being sold in Bergen. This variable is calculated by estimating how many cars are needed to keep the inventory sufficiently stocked with new vehicles to meet the indicated demand. The minimum of either the gap between the desired inventory of electric cars and inventory of electric cars or the number of electric cars bought multiplied by a ratio representing the ratio of the desire for new vs used electric cars is what determines the quantity of this flow.
	shipping_in_of_gas_cars	MAX(buying_gas_cars*desire_for_new_vs_used_gas_cars, (desired_inventory_of_gas_cars-inventory_of_gas_cars)/inventory_adjustment_time)		cars/year	This variable represents all brand new gas cars that are being sold in Bergen. This variable is calculated by estimating how many cars are needed to keep the inventory sufficiently stocked with new vehicles to meet the indicated demand. The minimum of either the gap between the desired inventory of gas cars and inventory of gas cars or the number of gas cars bought multiplied by a ratio representing the ratio of the desire for new vs used gas cars is what determines the quantity of this flow.
	shipping_out_of_electric_cars	MAX(0, -((desired_inventory_of_electric_car		cars/year	This flow represents the export of unwanted, used electric cars out of Bergen.

		Equation	Properties	Units	Documentation
		s-inventory_of_electric_cars)/inventory_adjustment_time))			
	shipping_out_of_gas_cars	MAX(0, -((desired_inventory_of_gas_cars-inventory_of_gas_cars)/inventory_adjustment_time*2))		cars/year	This flow represents the export of unwanted, used gas cars out of Bergen.
	switching_time	normal_tradein_time_of_cars*effect_of_indicated_share_on_switching_time		years	This variable represents the real time that someone would wait on average to switch their gas car to electric.
	switching_to_electric	MAX(0, gap_of_electric_cars/switching_time)		cars/year	A simple first order delay process is used to estimate the number of gas cars that are traded in earlier than they otherwise would have been so that people can sooner switch to electric over gas vehicles. This flow is determined by the gap of electric cars over the switching time.
	T9:_percentage_of_new_cars_sold_electric	shipping_in_of_electric_cars/(shipping_in_of_electric_cars+shipping_in_of_gas_cars)*100		dmnl	This variable estimates the percentage of 'brand new' purchased cars that are electric
	total_cars	Electric_Cars_on_the_road+Gas_Cars_on_the_road		cars	
	tradein_of_electric_cars	Electric_Cars_on_the_road/(normal		cars/year	A simple first order delay process is used to estimate the normal

		Equation	Properties	Units	Documentation
		_tradein_time_of_cars*new_market_adjustment_factor)			trade in rate of electric cars. Many people do not keep a car from original purchase to scrapping, so it is necessary to model how long on average people hold a vehicle from when it is purchased.
	tradein_of_gas_cars	(Gas_Cars_on_the_road/normal_tradein_time_of_cars)		cars/year	A simple first order delay process is used to estimate the normal trade in rate of gas cars. Many people do not keep a car from original purchase to scrapping, so it is necessary to model how long on average people hold a vehicle from when it is purchased.
CAR MARKET ATTRIBUTES SECTOR					
	"1_year"	1		1/car	
	aggregate_age_of_vehicle_fleet[electric](t)	aggregate_age_of_vehicle_fleet[electric](t - dt) + (aging[electric] - removal[electric]) * dt	INIT aggregate_age_of_vehicle_fleet[electric] = electric_cars_in_bergen*"1_year"*"avg_age_(electric)"*new_fleet_adjustment_factor	year	This is a co-flow structure, arrayed by vehicle type, that tracks the average age of the gas vs electric vehicle fleet in Bergen. This stock counts total aggregate 'car years' in Bergen, meaning the total number of cars multiplied by average age. It is initialized by assuming that gas cars on average are their average age and that electric cars are their average age adjusted by the new fleet adjustment factor, which assumes that the electric flee is actually much younger than its average useful age since most electric cars on the streets were bought very recently.
	aggregate_age_of_vehicle_fleet[gas](t)	aggregate_age_of_vehicle_fleet[gas](t - dt) +	INIT aggregate_age_of_v		

		Equation	Properties	Units	Documentation
		(aging[gas] - removal[gas]) * dt	ehicle_fleet[gas] = gas_cars_in_bergen*"1_year"*"avg_age_(gas)"		
	aging[electric]	electric_cars_in_bergen*"1_year"		dmnl	For every car in Bergen, aging will add one year to the aggregate age of vehicle fleet stock.
	aging[gas]	gas_cars_in_bergen*"1_year"			
	avg_calculated_age_of_cars[electric]	aggregate_age_of_vehicle_fleet[electric]/electric_cars_in_bergen		years/car	This divides the aggregate age by the number of cars to calculate the average age of gas and electric cars
	avg_calculated_age_of_cars[gas]	aggregate_age_of_vehicle_fleet[gas]/gas_cars_in_bergen			
	electric_cars_in_bergen	inventory_of_electric_cars+Electric_Cars_on_the_road		cars	This adds together the total electric cars that are within Bergen
	gas_cars_in_bergen	inventory_of_gas_cars+Gas_Cars_on_the_road		cars	This adds together the total gas cars that are within Bergen
	indicated_amount_of_new_cars_electric	turnover_of_cars*indicated_share_of_electric_cars*supply_demand_imbalance		cars/year	This variable calculates the estimated number of electric cars that will be purchased. It assumes that all the vehicles that are turned over will need to be replaced and they will be replaced according to the indicated share of electric cars. Additionally, this variable will be adjusted up or down according to the overall

		Equation	Properties	Units	Documentation
					supply/demand imbalance of total cars in Bergen.
○	indicated_ amount_of_ new_cars_gas	turnover_of_cars *(1- indicated_share_ of_electric_cars)* supply_demand_i mbalance		cars/year	This variable calculates the estimated number of electric cars that will be purchased. It assumes that all the vehicles that are turned over will need to be replaced and they will be replaced according to the indicated share of electric cars. Additionally, this variable will be adjusted up or down according to the overall supply/demand imbalance of total cars in Bergen.
○	indicated_ demand_of_ gas_cars	total_demand_fo r_cars*(1- indicated_share_ of_electric_cars)		cars	This computes the indicated demand of gas cars by taking the total demand times the share that is not allocated to electric vehicles
○	influence_of_ age_on_price_ adjustment [car_type]	GRAPH(avg_calcul ated_age_of_cars) Points: (0.00, 1.0000), (0.50, 0.936241070084), (1.00, 0.878549604562), (1.50, 0.826348207857), (2.00, 0.779114430844), (2.50, 0.736375542007), (3.00, 0.697703796183), (3.50, 0.66271215354), (4.00, 0.631050405959), (4.50, 0.602401672026),		dmnl	This variable shows how the average age of a the vehicle fleet affects its expected price as a percentage of its new price. It is roughly estimated based on the depreciation schedule described on https://www.creditkarma.com/auto/i/how-car-depreciation-affects-value.

		Equation	Properties	Units	Documentation
		(5.00, 0.576479225585), (5.50, 0.553023626078), (6.00, 0.531800121981), (6.50, 0.512596301333), (7.00, 0.495219965841), (7.50, 0.479497207299), (8.00, 0.465270667056), (8.50, 0.452397961115), (9.00, 0.440750255108), (9.50, 0.430210974879), (10.00, 0.420674639769), (10.50, 0.412045806929), (11.00, 0.404238116103), (11.50, 0.397173425294), (12.00, 0.390781028704), (12.50, 0.384996949078), (13.00, 0.379763297404), (13.50, 0.375027693536), (14.00, 0.370742741959), (14.50, 0.366865557438),			

		Equation	Properties	Units	Documentation
		(15.00, 0.363357335806), (15.50, 0.360182965604), (16.00, 0.357310676666), (16.50, 0.354711722159), (17.00, 0.352360090873), (17.50, 0.350232246893), (18.00, 0.34830689404), (18.50, 0.346564762735), (19.00, 0.344988417144), (19.50, 0.343562080669), (20.00, 0.342271478055)			
○	new_cars_as_a_percentage_of_total_cars	(shipping_in_of_electric_cars*year+shipping_in_of_gas_cars*year)/total_cars		dmnl	
○	new_fleet_adjustment_factor	.1		dmnl	This adjusts for the fact that electric cars are very early in their life cycle as of 2010, so it is not appropriate to assume electric vehicles are their average lifespan initially. This variable was calibrated to initialize the aggregate age stock in somewhat of an equilibrium.
○	price_adjustment [electric]	MIN(1, ((1-((ratio_of_used_to_total_electric)*		dmnl	This variable returns the average price of a car expressed as a percentage of the new price. This

		Equation	Properties	Units	Documentation
		influence_of_age_on_price_adjustment[electric]))))			variable estimates the average price of an electric or gas vehicle considering all used and new models on the market. It estimates a price adjustment using the following method: It assumes that all new models bought (represented as net shipping in of vehicles) are at full new price. The rest are assumed to be used and thus devalued in some way. According to the average age of the vehicle, its price is adjusted for the depreciation that has occurred. Additionally, since the market is transitioning away from gas, it is assumed that there will potentially be some supply/demand imbalances in the used gas market, so the price is further adjusted to reflect any imbalance in the overall market. The result of this variable should be a weighted average price of the average electric or gas car considering the proportion of new cars being bought and the average age of the used cars being bought and in the case of gas vehicles, and adjustment for imbalances in supply and demand. This variable is multiplied by the base car price to return the car

		Equation	Properties	Units	Documentation
					purchase price in the decision matrix sector of the model.
○	price_ adjustment [gas]	MIN(1, ((1-(ratio_of_used_to_total_gas)*influence_of_age_on_price_adjustment[gas]/supply_demand_imbalance_of_gas_cars)))			
○	ratio_of_used_to_total_ electric	(buying_electric_ cars-shipping_in_of_electric_cars)//buying_electric_cars		dmnl	This variable calculates the proportion of new car purchases that are of used vehicles
○	ratio_of_used_to_total_gas	(buying_gas_cars-shipping_in_of_gas_cars)//buying_gas_cars		dmnl	This variable calculates the proportion of new car purchases that are of used vehicles
	Removal [electric]	(shipping_out_of_electric_cars+"Scrapping_(Electric)")*avg_calculated_age_of_cars[electric]		dmnl	Every time a car is scrapped or shipped out of the city, the average calculated age of cars is removed from the aggregate stock (consistent with co-flow structures).
	removal[gas]	("Scrapping_(Gas)"+shipping_out_of_gas_cars)*avg_calculated_age_of_cars[gas]			
○	supply_ demand_ imbalance	total_demand_for_cars/total_cars		dmnl	This computes the total demand/supply imbalance of cars in Bergen, irrespective of the type of vehicle.
○	supply_ demand_	indicated_demand_of_gas_cars/gas_cars_in_bergen		dmnl	This variable compares the supply of gas cars in Bergen with the indicated demand of gas cars to

		Equation	Properties	Units	Documentation
	imbalance_of_gas_cars				compute a ratio of the demand over supply of gas cars in Bergen.
○	turnover_of_cars	"Scrapping_(Electric)"+"Scrapping_(Gas)"+tradein_of_gas_cars+tradein_of_electric_cars		cars/year	This variable represents the total number of cars in a given year that turn out of people's ownership- either voluntarily by switching or trading in, or involuntarily through scrapping. In an equilibrium situation, it is assumed that all of these vehicles will need to be replaced with new or used vehicles.
DECISION CRITERIA SECTOR					
○	"%_area_that_is_emissions_free"	IF TIME <= 2021 THEN 0 ELSE T2:_emission_zones_in_Bergen/100		dmnl	This converts to a percentage.
○	"2010_price"	100000		NOK/year	
○	"2010_reference_electric_car_price"	780000		NOK	This is the reference for a electric volkswagen car https://images.app.goo.gl/EWLFuzvemDSvxHhp8
○	"2010_reference_gas_car_price"	300000		NOK	This is the reference for a volkswagen gas car https://images.app.goo.gl/EWLFuzvemDSvxHhp8
	addition_of_recharging_stations	5.2		station/years	
	adjustemt_to_car_price [car_type]	base_car_price*annual_price_change		NOK/year	
○	annual_price_change [electric]	-.04+RAMP(.01, 2020, 2026.5)		dmnl/year	We assume for this model that cars are subject to an average 2.5% increase in price annually to

		Equation	Properties	Units	Documentation
					keep up with inflation and cost changes. However, electric cars will enjoy initially a 4% annual decrease in price as technological advances drive down the cost of manufacturing electric vehicles and as the market matures. Gradually the effect is diminished until by 2026, electric cars are considered mature and subject to the annual price increases.
○	annual_price_change[gas]	.025			
○	average_cost_of_a_car	(yearly_cost_of_a_car[electric]*percentage_of_electric_cars_on_the_road)+(yearly_cost_of_a_car[gas]*(1-percentage_of_electric_cars_on_the_road))		NOK/year	This calculates the overall weighted average annual price to own and use a car in Bergen.
○	average_cost_of_parking [electric]	0+STEP(27.5*12, 2017)		NOK/year	This was introduced in 2017. If you drive an electric car with EL or EK in your license plate, you get a 50% discount on the original price. https://en.visitbergen.com/visitor-information/travel-information/getting-here/driving-to-bergen/car-parking-and-car-parks
○	average_cost_of_parking [gas]	27.5			This is the average price from the different parking garages in Bergen.

		Equation	Properties	Units	Documentation
					https://en.visitbergen.com/visitor-information/travel-information/getting-here/driving-to-bergen/car-parking-and-car-parks
○	average_cost_of_toll [electric]	normal_toll_price *(1-toll_discount)		NOK/use	This variable calculates the total average cost of passing throught a single tollbooth in Bergen for both gas and electric cars.
○	average_cost_of_toll[gas]	normal_toll_price			
○	average_km_driven_per_year	15000		km/year	This captures the average distance travelled per passenger car per year. https://images.app.goo.gl/t2myXqEdfbLnSHtE9
○	average_kwh_per_km	.2		kwh/km	An electric car is estimated to use 0.2 kilo watts per kilometre https://www.virta.global/blog/ev-charging-101-how-much-electricity-does-an-electric-car-use#:~:text=An%20average%20electric%20car%20consumes%20approximately%200%2C20%20kWh%2Fkm.&text=On%20a%20daily%20basis%2C%20this%20makes%20approximately%2047%20kilometers%20of%20driving.
◎	average_price_of_a_driving_a_car	SMTH1(average_cost_of_a_car, 1, 100000)		NOK/year	This variable adds a perception delay into how car cost affects demand on cars (delay Converter)

		Equation	Properties	Units	Documentation
	base_car_price[electric](t)	base_car_price[electric](t - dt) + (adjustemt_to_car_price[electric]) * dt	INIT base_car_price[electric] = "2010_reference_electric_car_price"	NOK	To adjust the 2010 reference price to assumed changes in base price level over time
	base_car_price[gas](t)	base_car_price[gas](t - dt) + (adjustemt_to_car_price[gas]) * dt	INIT base_car_price[gas] = "2010_reference_gas_car_price"		
	base_price_of_driving_a_car	"2010_price"*((1+price_increase)^(sim_year_dmnl))		NOK/year	This represents a price-level adjusted base price of driving a car relative to 2010 price levels.
	car_fees[electric]	2000		NOK	
	car_fees[gas]	10000			
	car_payment[car_type]	PMT(interest_rate, loan_term, -(taxes_and_fees+car_price), 0)		NOK/year	This variable calculates the total estimated annual car payment for a gas or electric vehicle by using the total net cost of the car (purchase price plus taxes and fees) and figuring what the annual car payment would be given the prevailing interest rate and loan duration.
	car_price[car_type]	price_adjustment*base_car_price		NOK	
	Convenience[electric]	distance_to_refueling_station[electric]*effect_of_ra		dmnl	This variable factors in all major variables associated with the convenience of using a gas vs electric vehicle and represents the

		Equation	Properties	Units	Documentation
		nge_on_convenience[electric]			comprehensive 'convenience' component of our qualities assessment formulation.
○	Convenience [gas]	distance_to_refueling_station[gas]*effect_of_range_on_convenience[gas]			
○	distance_to_refueling_station [car_type]	GRAPH(fueling_station_density) Points: (5.00, 1.000), (14.50, 0.670320046036), (24.00, 0.449328964117), (33.50, 0.301194211912), (43.00, 0.201896517995), (52.50, 0.135335283237), (62.00, 0.0907179532894), (71.50, 0.0608100626252), (81.00, 0.0407622039784), (90.50, 0.0273237224473), (100.00, 0.0183156388887)		dmnl	This variable assumes what the impact is on convenience of the distance to nearest fueling station.
○	effect_of_emission_zones_on_the_electric_cars_share	(indicated_share_of_gas_cars*(1-effect_of_emissions_zones_on_convenience_on_gas_car))		dmnl	This variable calculates the effect of the emissions free zones on the real indicated share of gas cars. All previous variables come together to estimate the indicated split of gas and electric vehicles based on many different considerations.

		Equation	Properties	Units	Documentation
					However emissions free zones are essentially ordinances outlawing gas cars. This has a much more direct effect, so it is factored in separately after the other calculations are completed. It assumes that the indicated share of gas cars will be further reduced to a certain extent if these zones are established in Bergen. Thus what would have otherwise been demand for gas cars is overridden by the fact that they are simply not legal anymore in certain areas. A portion of these 'would be' gas cars then go toward the electric share.
○	effect_of_ emissions_ zones_on_ convenience_ on_gas_car	GRAPH(SMTH3("% _area_that_is_e missions_free", 1)) Points: (0.000, 1.0000), (0.010, 0.964710495237), (0.020, 0.930804711748), (0.030, 0.898228393045), (0.040, 0.86692941007), (0.050, 0.83685767777), (0.060, 0.80796507496), (0.070, 0.78020536731), (0.080, 0.753534133366), (0.090, 0.727908693464),		dmnl	This shows the effect of how establishing emissions free zones in Bergen affects the usability of gas cars. As these zones are established, gas cars immediately become less usable in Bergen, as more and more of Bergen falls under these zones, the usability of gas cars in Bergen will decline to zero

		Equation	Properties	Units	Documentation
		(0.100, 0.703288041432), (0.110, 0.679632778975), (0.120, 0.656905052626), (0.130, 0.635068493173), (0.140, 0.614088157464), (0.150, 0.593930472485), (0.160, 0.574563181639), (0.170, 0.555955293129), (0.180, 0.538077030364), (0.190, 0.520899784309), (0.200, 0.504396067705), (0.210, 0.488539471086), (0.220, 0.473304620513), (0.230, 0.458667136976), (0.240, 0.444603597378), (0.250, 0.431091497054), (0.260, 0.418109213763), (0.270, 0.40563597308), (0.280, 0.393651815161), (0.290, 0.382137562794),			

		Equation	Properties	Units	Documentation
		(0.300, 0.371074790721), (0.310, 0.360445796145), (0.320, 0.350233570408), (0.330, 0.340421771769), (0.340, 0.330994699258), (0.350, 0.321937267547), (0.360, 0.313234982814), (0.370, 0.304873919545), (0.380, 0.296840698257), (0.390, 0.289122464081), (0.400, 0.281706866195), (0.410, 0.274582038062), (0.420, 0.267736578435), (0.430, 0.26115953312), (0.440, 0.254840377441), (0.450, 0.248768999399), (0.460, 0.242935683496), (0.470, 0.237331095181), (0.480, 0.231946265917), (0.490, 0.226772578829),			

		Equation	Properties	Units	Documentation
		(0.500, 0.221801754913), (0.510, 0.217025839791), (0.520, 0.212437190979), (0.530, 0.20802846566), (0.540, 0.203792608934), (0.550, 0.199722842526), (0.560, 0.195812653941), (0.570, 0.192055786044), (0.580, 0.188446227044), (0.590, 0.184978200877), (0.600, 0.18164615796), (0.610, 0.178444766316), (0.620, 0.175368903033), (0.630, 0.172413646075), (0.640, 0.169574266399), (0.650, 0.166846220393), (0.660, 0.164225142601), (0.670, 0.161706838739), (0.680, 0.159287278984), (0.690, 0.156962591524),			

		Equation	Properties	Units	Documentation
		(0.700, 0.154729056363), (0.710, 0.152583099368), (0.720, 0.150521286551), (0.730, 0.14854031857), (0.740, 0.146637025455), (0.750, 0.144808361531), (0.760, 0.143051400545), (0.770, 0.141363330984), (0.780, 0.139741451578), (0.790, 0.138183166972), (0.800, 0.136685983581), (0.810, 0.135247505589), (0.820, 0.133865431126), (0.830, 0.132537548579), (0.840, 0.13126173305), (0.850, 0.130035942964), (0.860, 0.128858216795), (0.870, 0.127726669929), (0.880, 0.126639491651), (0.890, 0.125594942243),			

		Equation	Properties	Units	Documentation
		(0.900, 0.124591350203), (0.910, 0.123627109569), (0.920, 0.122700677352), (0.930, 0.121810571061), (0.940, 0.120955366337), (0.950, 0.120133694671), (0.960, 0.119344241211), (0.970, 0.118585742664), (0.980, 0.11785698527), (0.990, 0.117156802862), (1.000, 0.116484075)			
○	effect_of_price_on_on_demand_for_cars	GRAPH(average_price_of_a_driving_a_car//base_price_of_driving_a_car) Points: (0.000, 1.582), (0.200, 1.382), (0.400, 1.227), (0.600, 1.118), (0.800, 1.036), (1.000, 0.955), (1.200, 0.891), (1.400, 0.827), (1.600, 0.718), (1.800, 0.582), (2.000, 0.409)		dmnl	This variable is an assumption for how changes in the relative price of driving a car will affect demand. It is assumed that if the cost of driving a car is cheaper, it will be more desirable and more people will demand vehicles.

		Equation	Properties	Units	Documentation
○	effect_of_ range_on_ convenience [car_type]	GRAPH(range) Points: (0.0, 0.000), (40.0, 0.244780743012), (80.0, 0.434275789329), (120.0, 0.580971857562), (160.0, 0.694535440638), (200.0, 0.782449776423), (240.0, 0.850507953413), (280.0, 0.90319464454), (320.0, 0.943981623339), (360.0, 0.975556535407), (400.0, 1.000)		dmnl	This is an assumption of how the average range of each vehicle affects the convenience of using a vehicle.
○	Elasticities [yearly_cost]	-3.16		dmnl	After the rest of the model was built and calibrated to the best of our research and knowledge, the last step was to determine these elasticities for the different values. Since these are highly abstract values with high impact on the model, and since the rest of the model was reasonably validated, these values were set using a calibration/optimization method. Utilizing Stella Architect, these values were calibrated according to the following procedure. It was then optimized with the

		Equation	Properties	Units	Documentation
					following criteria: Change time horizon of model to 2010-2020 Payoff = percentage of electric cars on the road Weight = 1 Comparison Variable = historical data Comparison Run = current run Comparison Type = Absolute error Comparison Tolerance = Absolute error Additional Starts = 5 Optimization Method = Powell Tolerance = 0.00001 Initial Step = 0.1 Max Sims = 5000 Optimization of elasticities[*] Min Value = -5 Max Value = 5 Scaling = 1 The results returned were the logical polarity and a reasonable degree. See Appendix D for more details.
○	Elasticities [convenience]	.78			
○	Elasticities [other_factors]	1.05			
○	Elasticities [socialpressure]	.247			

		Equation	Properties	Units	Documentation
○	electricity_ cost_per_kwh	3		NOK/kwh	it costs 3 kr per kilo watt https://thedriven.io/2020/01/20/norway-horrified-as-new-rates-make-ev-charging-prices-higher-than-petrol/#:~:text=Ionity's%20new%20rate%20of%200.79,NOK20%20per%20mile%20(%24A0.
○	environmental _consideratio n	GRAPH(TIME) Points: (2010.00, 0.416404395165), (2011.00, 0.421427563767), (2012.00, 0.427837885935), (2013.00, 0.435918667087), (2014.00, 0.44594911473), (2015.00, 0.458163681347), (2016.00, 0.472696108299), (2017.00, 0.489515513915), (2018.00, 0.508371047455), (2019.00, 0.528768516432), (2020.00, 0.5500), (2021.00, 0.571231483568), (2022.00, 0.591628952545), (2023.00, 0.610484486085), (2024.00, 0.627303891701), (2025.00,		dmnl	This is a graphical variable to show an assumption that people's general environmental awareness will increase over time.

		Equation	Properties	Units	Documentation
		0.641836318653), (2026.00, 0.65405088527), (2027.00, 0.664081332913), (2028.00, 0.672162114065), (2029.00, 0.678572436233), (2030.00, 0.683595604835)			
○	environmental_friendliness_electric	GRAPH(TIME) Points: (2010.00, 1.03148667803), (2011.00, 1.04045673361), (2012.00, 1.05170022573), (2013.00, 1.06562223472), (2014.00, 1.0826024351), (2015.00, 1.1029351859), (2016.00, 1.12675300833), (2017.00, 1.15394524785), (2018.00, 1.18409379113), (2019.00, 1.21645354752), (2020.00, 1.2500), (2021.00, 1.28354645248), (2022.00, 1.31590620887), (2023.00, 1.34605475215),		dmnl	This is a variable to show how technological advances and changes in energy infrastructure will make electric vehicles a more and more sustainable transportation method.

		Equation	Properties	Units	Documentation
		(2024.00, 1.37324699167), (2025.00, 1.3970648141), (2026.00, 1.4173975649), (2027.00, 1.43437776528), (2028.00, 1.44829977427), (2029.00, 1.45954326639), (2030.00, 1.46851332197)			
○	environmental_friendliness_gas	GRAPH(TIME) Points: (2010.00, 0.6), (2011.00, 0.608333569557), (2012.00, 0.616181829803), (2013.00, 0.623573042954), (2014.00, 0.630533825359), (2015.00, 0.637089243354), (2016.00, 0.643262903525), (2017.00, 0.649077037717), (2018.00, 0.654552583091), (2019.00, 0.659709257527), (2020.00, 0.664565630623), (2021.00, 0.669139190565), (2022.00,		dmnl	This is a variable to show how technological advances and changes in biofuel composition will make gas vehicles a more and more sustainable transportation method over time

		Equation	Properties	Units	Documentation
		0.673446407112), (2023.00, 0.677502790894), (2024.00, 0.681322949274), (2025.00, 0.684920638949), (2026.00, 0.688308815488), (2027.00, 0.691499679986), (2028.00, 0.694504723002), (2029.00, 0.697334765936), (2030.00, 0.7)			
○	fuel_cost [electric]	average_km_driven_per_year*average_kwh_per_km*electricity_cost_per_kwh*(1-percentage_of_free_charging_stations)		NOK/year	This variable calculates the average annual fuel cost for both gas and electric vehicles.
○	fuel_cost [gas]	average_km_driven_per_year/km_per_liter*gasoline_price_per_liter			
○	fueling_station_density [electric]	land_area_of_Bergen//T7:_number_of_recharging_stations		km^2/station	This variable calculates the average density of fueling stations by calculating on average how much area each fueling station must serve.
○	fueling_station_density [gas]	land_area_of_Bergen//number_of_gas_stations			

		Equation	Properties	Units	Documentation
○	gasoline_price_per_liter	gasoline_spot_price*(1+(gasoline_tax/100))		NOK/liter	
○	gasoline_spot_price	13		NOK/liter	This is the price of gas per liter https://www.ssb.no/statbank/table/09654/tableViewLayout1/
○	gasoline_tax	31.65		dmnl	Gasoline tax accounts for 31.65 percent (88.7/280.3 $ cents) https://energypedia.info/wiki/Fuel_Prices_Norway
○	indicated_share_of_electric_car_before_emission_zones	SUM(weight_of_attribute*unweighted_perception_of_each_variable)		dmnl	This multiplies the perception of each variable by the weights to return a weighted average of how all the various variables contribute to peoples decision to go gas or electric.
○	indicated_share_of_electric_cars	indicated_share_of_electric_car_before_emission_zones+effect_of_emission_zones_on_the_electric_cars_share		dmnl	
○	indicated_share_of_gas_cars	1-(SUM(weight_of_attribute*unweighted_perception_of_each_variable))		dmnl	This is the inverse of the indicated share of electric cars
○	interest_rate	.05		NOK/year	Price car loan young adults: from 3.50 % nom. from 5.08 % eff. interest rate. https://www.dnb.no/en/personal/loans/car-loans.html
○	km_per_liter	10		km/liter	A car consumes approximately 0.5 litres per 10km

		Equation	Properties	Units	Documentation
					https://www.numbeo.com/gas-prices/in/Bergen
○	land_area_of_Bergen	445		km^2	
○	loan_term	5		years	Consumer loan repayment can be repaid over a maximum of 5 years. It is possible to obtain a loan with a repayment period of up to 15 years. https://www.multinorfinans.no/en#:~:text=Consumer%20loan%20repayment%20can%20be,of%20up%20to%2015%20year
○	normal_toll_price	26+RAMP(1, 2010)		NOK/use	This is the average calculated for those vehicles with agreement and those without agreement. https://ferde.no/ufaqs/what-is-the-monthly-ceiling-rate-for-bomringen-i-bergen/?lang=en&lang=en
▭	number_of_gas_stations(t)	number_of_gas_stations(t - dt)	INIT number_of_gas_stations = 58	station	
○	number_of_tolls_per_year	250		use/year	The number of tolls per year is estimated at 250 https://ferde.no/ufaqs/what-is-the-monthly-ceiling-rate-for-bomringen-i-bergen/?lang=en&lang=en
○	other_costs_per_year [electric]	0		NOK/year	
○	other_costs_	0			

		Equation	Properties	Units	Documentation
	per_year[gas]				
○	other_factors [electric]	25+RAMP(5, 2010)		dmnl	for the sake of this model, 'other factors' includes only the number of electric car models available at any point. It is assumed that as more and more electric car models become available, that the electric car option will be come more and more attractive to more buyers. Additionally, as more electric car models become available, generally the few gas models will be developed. This assumption is not backed by data and potentially would contain many other different variables within it. This is an opportunity for future model development.
○	other_factors [gas]	195+RAMP(-5, 2010)			
○	peer_pressure	SMTH1(percentage_of_electric_cars_on_the_road, 1, .001)		dmnl	This just uses percentage of population using an electric vehicle as a proxy for peer pressure effect.
○	percentage	100		dmnl	
○	percentage_of_free_charging_stations	.25		1	We assume free charging stations account 25 % of the 427 currently in Bergen. These are those offered mostly by employers/ institutions to their employees.
○	perception_delays [yearly_cost]	.5		year	The perception delays used represent the time it takes for changes in the underlying criteria to affect peoples real time decision making. These variables were estimated according to intuition and should be subject to

		Equation	Properties	Units	Documentation
					further research and validation in future models.
○	perception_ delays [convenience]	2			
○	perception_ delays [other_factors]	.5			
○	perceptiondel ay [socialpressur e]	2			
○	price_increase	.02		dmnl	
○	range[electric]	100+RAMP(10, 2010)		km	This variable estimates the range of an electric or gas vehicle
○	range[gas]	400			
○	social_pressur e_to_buy_ electric [electric]	((environmental_f riendliness_electr ic)*environmental _consideration)*(peer_pressure)		dmnl	Social pressure is estimated by taking a multiplication of theses three characteristics: environmental consideration which represents a general change over time in how much environment weighs into peoples decision making; environmental friendliness of gas and electric cars, which represents the relative changes in environmental impact over time; and peer pressure which represents the social conformity pressure to buy as more and more people own electric. If all of these values interact with each other and the higher the value produced, the higher the pressure is to buy electric.

		Equation	Properties	Units	Documentation
○	socialpressure_to_buy_electric[gas]	(1-environmental_friendliness_gas)*environmental_consideration*(1-peer_pressure)			
○	sum_of_weights	SUM(weight_of_attribute)		dmnl	
○	T2:_emission_zones_in_Bergen	GRAPH(TIME) Points: (2021.000, 0.0), (2022.000, 10.0), (2023.000, 10.0), (2024.000, 10.0), (2025.000, 10.0), (2026.000, 10.0), (2027.000, 10.0), (2028.000, 10.0), (2029.000, 10.0), (2030.000, 10.0)		dmnl	This variable hold the assumed policy regarding the establishment of emissions free zones in Bergen. It is measured as % of land area in Bergen that becomes emissions free.
	T7:_number_of_recharging_stations(t)	T7:_number_of_recharging_stations(t - dt) + (addition_of_rechargring_stations) * dt	INIT T7:_number_of_recharging_stations = 10	station	
○	T8:_unweighted_impact_of_each_variable[yearly_cost]	((yearly_cost_of_a_car[electric]//yearly_cost_of_a_car[gas])^elasticities) // ((yearly_cost_of_a_car[electric]//yearly_cost_of_a_car[gas])^(elasticities) +(yearly_cost_of_a_car[gas]//yearly		dmnl	This is an array variable, arrayed by attribute, that calculates how differences in the attribute affect the final estimated split between what proportion of people will choose gas or electric. The formula works in the following way: It first calculates compares the underlying value of electric vehicles to the underlying value of gas vehicles. Then it expresses that

		Equation	Properties	Units	Documentation
		_cost_of_a_car[electric])^elasticities)			as a ratio. It then takes that ratio divided by the sum of the ratio of electric to gas (same as in the numerator) and the ratio of gas to electric. The resulting ratio is then taken to an elasticity that is defined in the elasticities variable. What results is a sort of analytic S-shaped curve for each attribute so that if the values are equal between gas and electric, it would return an assumed 50-50 split between gas and electric. As the difference between the two values becomes greater and greater, a proportion approaching either one or zero will be returned depending on the polarity of the elasticity.
○	T8:_ unweighted_ impact_of_ each_variable [convenience]	((convenience[electric]//convenience[gas])^elasticities) // ((convenience[electric]//convenience[gas])^(elasticities) +(convenience[gas]//convenience[electric])^elasticities)			
○	T8:_ unweighted_ impact_of_ each_variable [other_factors]	((other_factors[electric]//other_factors[gas])^elasticities) // ((other_factors[electric]//other_factors[gas])^(elasticities) +(other_factors[g			

		Equation	Properties	Units	Documentation
		as]//other_factors[electric])^elasticities)			
○	T8:_ unweighted_ impact_of_ each_variable [socialpressure]	((social_pressure_to_buy_electric[electric]//social_pressure_to_buy_electric[gas])^elasticities) // ((social_pressure_to_buy_electric[electric]//social_pressure_to_buy_electric[gas])^(elasticities) +(social_pressure_to_buy_electric[gas]//social_pressure_to_buy_electric[electric])^elasticities)			
○	tax_rate [electric]	IF TIME <= 2021 THEN 0 ELSE VAT_tax_policy_for_electric_cars		dmnl	This variable tracks the total tax rate, expressed as a percentage of the purchase price of the car for both gas and electric cars over time. https://elbil.no/english/norwegian-ev-policy/
○	tax_rate[gas]	25			
○	taxes_and fees[car_type]	((tax_rate/100)*car_price)+car_fees		NOK	This variable calcuates the total amount (in NOK) that one would pay in taxes and fees from purchasing an average gas or electric vehicle.
○	toll_discount	IF TIME <= 2019 THEN 1 ELSE IF TIME<=2021 AND TIME > 2019		dmnl	https://ferde.no/ufaqs/what-is-the-monthly-ceiling-rate-for-

		Equation	Properties	Units	Documentation
		THEN 1-10.5/36 ELSE toll_policy/percentage			bomringen-i-bergen/?lang=en&lang=en
	toll_policy	GRAPH(TIME) Points: (2021.000, 67.8), (2022.000, 67.8), (2023.000, 67.8), (2024.000, 0.0), (2025.000, 0.0), (2026.000, 0.0), (2027.000, 0.0), (2028.000, 0.0), (2029.000, 0.0), (2030.000, 0.0)		dmnl	
	tolls_and_parking_per_year [car_type]	(average_cost_of_toll*number_of_tolls_per_year)+(average_cost_of_parking)		NOK/year	This variable calculates the total annual cost of tolls and parking for both gas and electric vehicles in Bergen.
	unweighted_perception_of each_variable [car_attribute]	SMTH3(T8:_unweighted_impact_of_each_variable, perception_delays, 0.001)		dmnl	This calculates an information delay of the unweighted impact of each variable, since it is assumed to take time for changes in the underlying variables to be perceived and affect people's decision making. (Delay Converter)
	VAT_tax_policy_for_electric_cars	GRAPH(TIME) Points: (2021.000, 0.00), (2022.000, 0.00), (2023.000, 25.00), (2024.000, 25.00), (2025.000, 25.00), (2026.000, 25.00), (2027.000, 25.00), (2028.000,		dmnl	

		Equation	Properties	Units	Documentation
		25.00), (2029.000, 25.00), (2030.000, 25.00)			
○	weight_of_attribute [yearly_cost]	.54		dmnl	
○	weight_of_attribute [convenience]	.16			
○	weight_of_attribute [other_factors]	.05			
○	weight_of_attribute [socialpressure]	.25			
○	yearly_cost_of_a_car [car_type]	(car_payment)+tolls_and_parking_per_year+other_costs_per_year+fuel_cost		NOK/year	This variable adds up all major costs associated with owning and using a gas or electric vehicle and represents the comprehensive 'price' component of our qualities assessment formulation.
MISCELLANEOUS SUPPORTING STRUCTURES					
○	annual_electric_car_toll_revenue	((average_cost_of_toll[electric])*number_of_tolls_per_car_per_year*total_cars*percentage_of_electric_cars_on_the_road)		NOK/year	
○	annual_gas_car_toll_revenue	((average_cost_of_toll[gas])*number_of_tolls_per_car_per_year*total_cars*(1-percentage_of_el		NOK/year	

		Equation	Properties	Units	Documentation
		ectric_cars_on_the_road))			
○	average_km_driven_per_car_per_year	average_km_driven_per_year/car		km/car/year	
○	car	1		car	
○	Current_cars_per_household_2020	1.35		cars/household	The estimated car per house hold is currently 1.35 (Bergen Kommune, 2016)
○	demand_for_electricity	Electric_Cars_on_the_road*average_km_driven_per_car_per_year*average_kwh_per_km		kwh/year	This variable estimates the total amount of electricity needed to serve the private transportation sector.
○	electricity_demand_per_year	demand_for_electricity/kwh_to_twh		mwh/year	
○	historical_data	GRAPH(TIME) Points: (2010.00, 0.001), (2011.00, 0.002), (2012.00, 0.003), (2013.00, 0.005), (2014.00, 0.025), (2015.00, 0.07), (2016.00, 0.1), (2017.00, 0.14), (2018.00, 0.19), (2019.00, 0.25), (2020.00, 0.32), (2021.00, 0.0), (2022.00, 0.0), (2023.00, 0.0), (2024.00, 0.0), (2025.00, 0.0), (2026.00, 0.0), (2027.00,		dmnl	

		Equation	Properties	Units	Documentation
		0.0), (2028.00, 0.0), (2029.00, 0.0), (2030.00, 0.0)			
○	household_ size	2.2		people/household	In 2015, number of private households in Norway amounted to 2 316 600. An average of 2.20 persons lived in each household https://www.ssb.no/en/befolkning/statistikker/familie/aar/2016-04-14
○	initial_ population	256000		people	This is the initial population Bergen as at 2010 https://www.ssb.no/en/ifhus
○	kwh_to_twh	1e6		kwh/mwh	
○	lost_toll_ revenue	(total_cars*average_cost_of_toll[gas]*number_of_tolls_per_car_per_year)-total_toll_revenue		NOK/year	This variable represents the total estimated toll revenue that is forfeited by the city as a result of their policies to offer discounts to electric vehicles.
○	number_of_ tolls_per_car_ per_year	number_of_tolls_ per_year/car		use/car/year	
○	population	initial_population *(1+population_growth_rate)^sim_ year_dmnl		people	This variable estimates the population of Bergen over time.
○	population_ growth_rate	.007		dmnl	The population growth rate stands at 0.07 percent https://www.ssb.no/en/befolkning/statistikker/familie/aar/2016-04-14
○	sim_time	TIME		year	
○	sim_time_	sim_time/year		dmnl	

		Equation	Properties	Units	Documentation
	dmnl				
○	sim_year	TIME-STARTTIME		year	
○	sim_year_dmnl	sim_year/year		dmnl	
○	simulation_year	TIME-(TIME MOD 1)		year	
○	"T1/T3:_total_(passenger)_km_driven_in_Bergen"	total_cars*average_km_driven_per_year/car		km/year	
○	T6_GOAL	1		cars/household	
○	T6:_cars_per_household	(IF TIME <=2020 THEN Current_cars_per_household_2020 ELSE (Current_cars_per_household_2020 - (((Current_cars_per_household_2020- T6_GOAL)/10)*(sim_time_dmnl-2020))))*effect_of_price_on_on_demand_for_cars		cars/household	
○	total_demand_for_cars	population/household_size*T6:_cars_per_household		cars	
○	total_toll_revenue	annual_gas_car_toll_revenue+annual_electric_car_toll_revenue		NOK/year	This variable calculates the total estimated annual toll revenue in Bergen.
○	year	1		year	

Total	Count	Including Array Elements
Variables	155	197
Sectors	4	
Stocks	8	10
Flows	15	18
Converters	132	169
Constants	45	56
Equations	102	131
Graphicals	15	18
Macro Variables	60	

Run Specs	
Start Time	2010
Stop Time	2030
DT	1/50
Fractional DT	True
Save Interval	0.02
Sim Duration	0
Time Units	years
Pause Interval	0
Integration Method	Euler
Keep all variable results	True
Run By	Run
Calculate loop dominance information	True
Exhaustive Search Threshold	1000

Array Dimension	Indexed by	Elements
car_attribute	Label (4)	yearly_cost convenience other_factors social_pressure
car_type	Label (2)	electric gas
transport_type	Label (4)	public_transport walkingbiking

		carpooling using_a_car

Custom Unit	Aliases	Equation
car	cars	

Appendix B: Further Model Documentation

Software: Stella Architect version 2.0.3

Integration Method: Eulers' (Not sensitive to integration method)

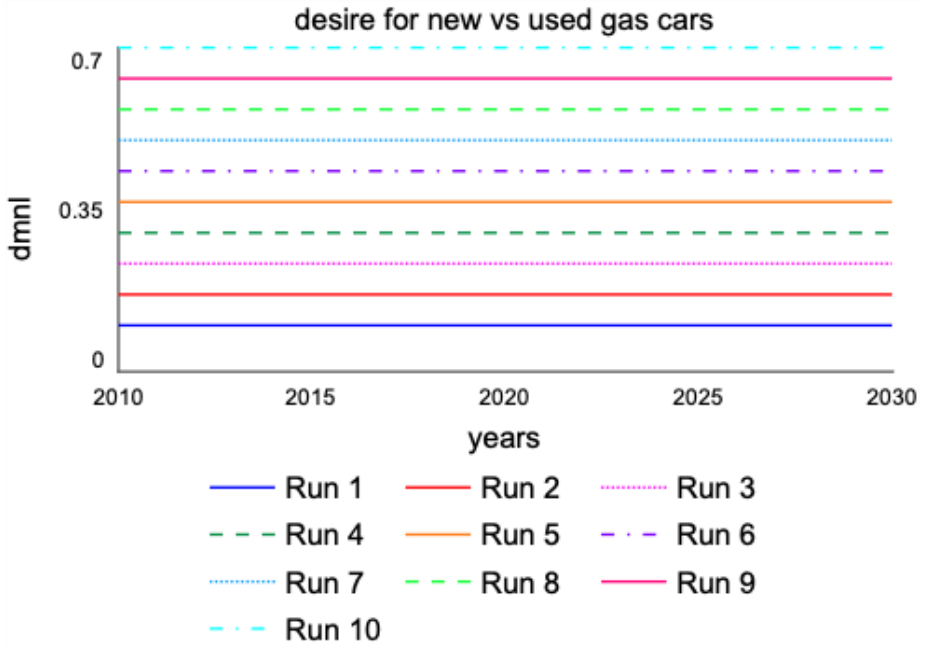
DT = 1/50 (.02) The model is not sensitive to a smaller DT, the shortest delay time used is the inventory adjustment time, which is set to equal approximately 1 month or .0833 years.

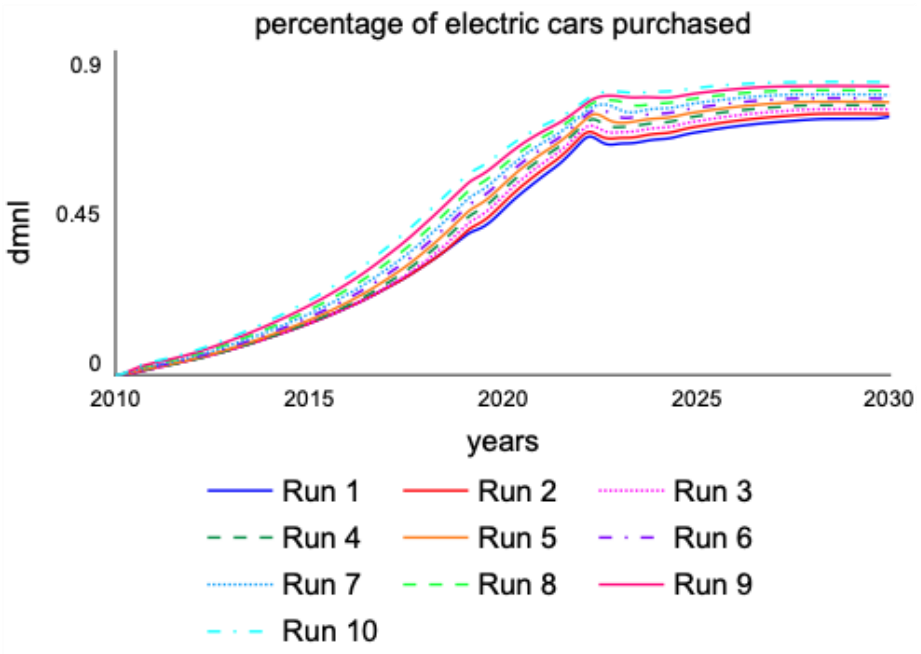
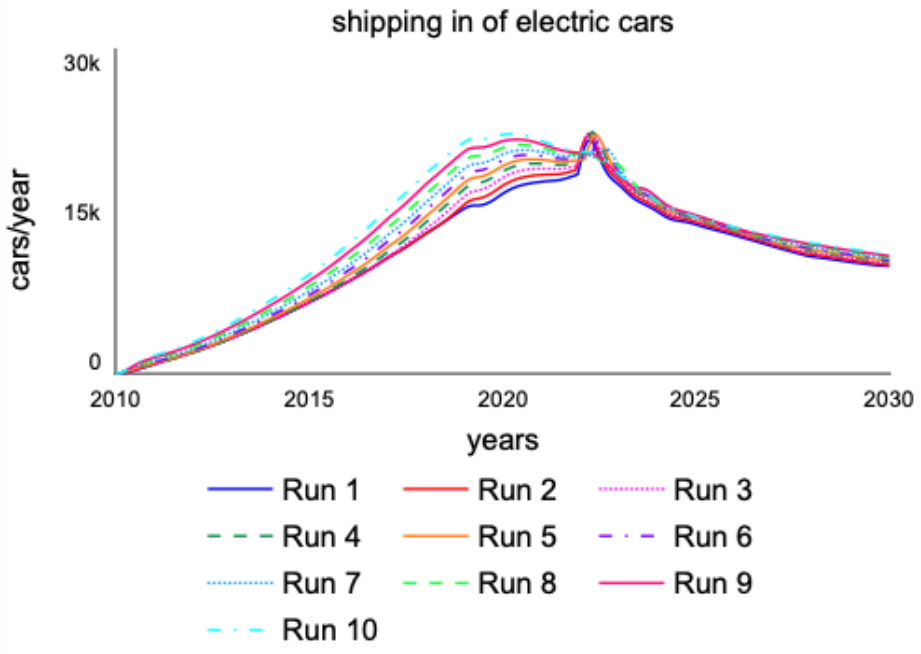
Time Unit: Years

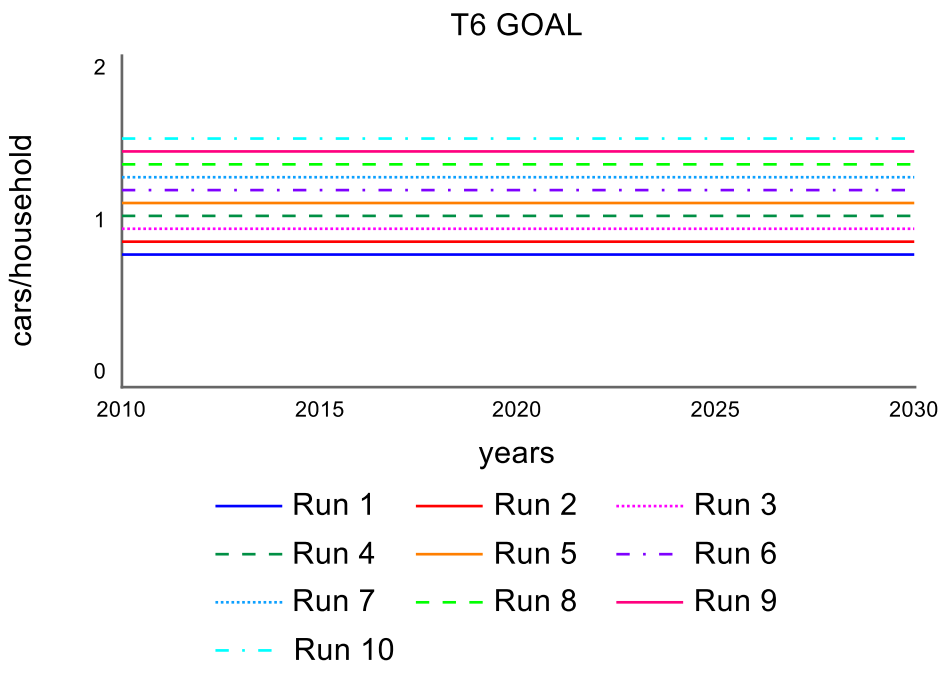
Simulation Start: 2010

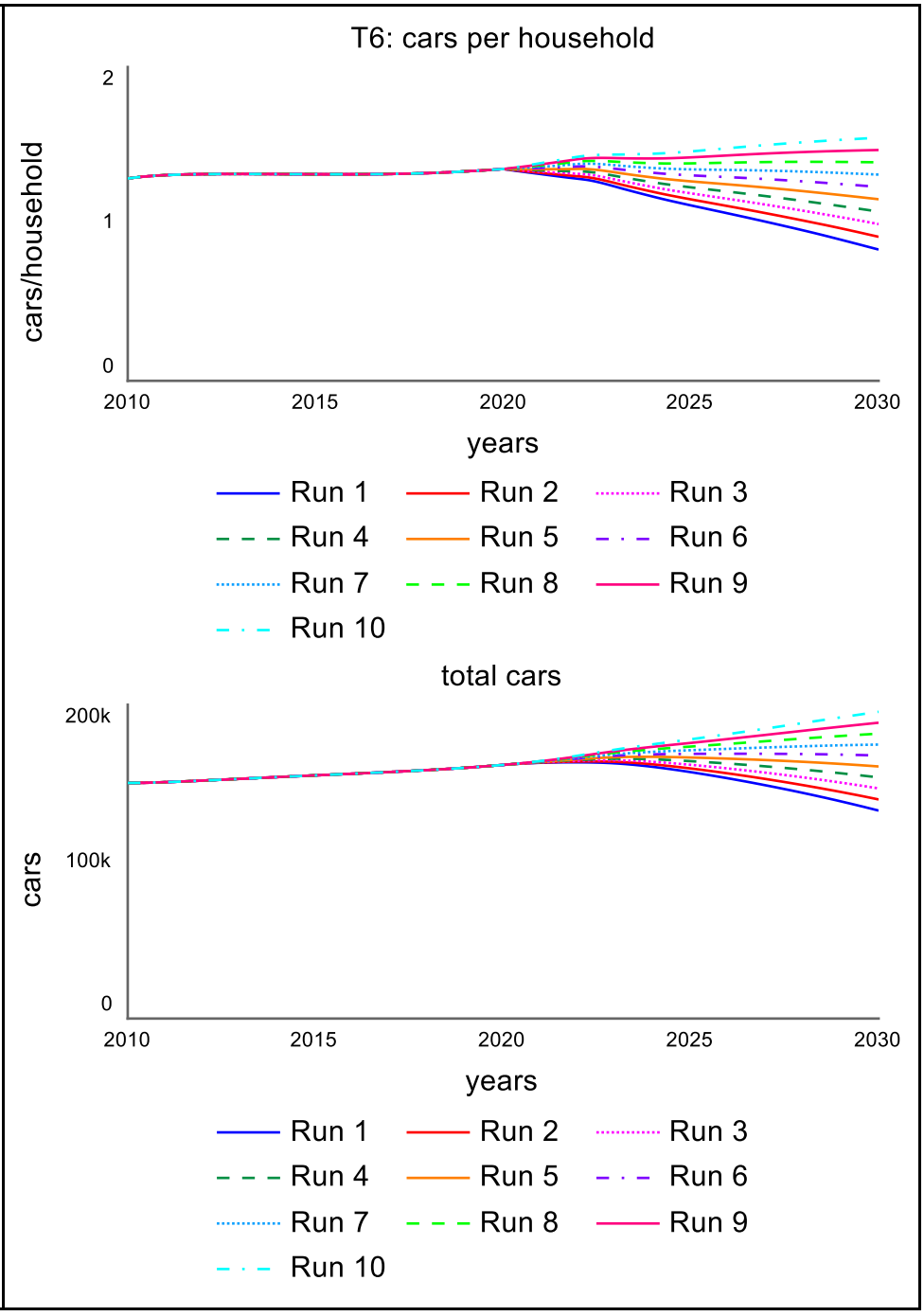
Simulation End: 2030

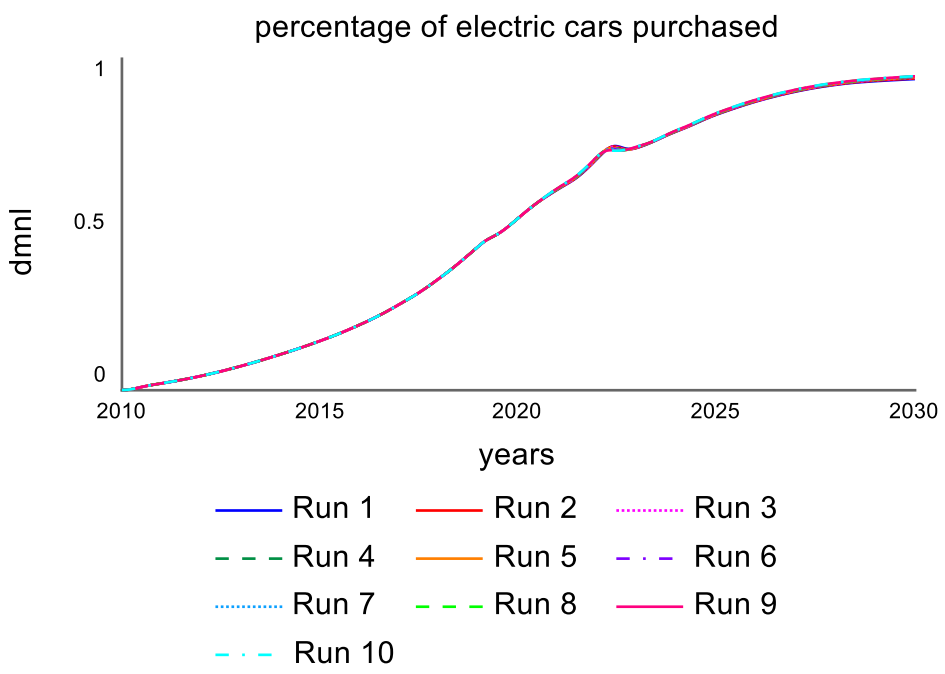
Appendix C: Sensitivity Testing

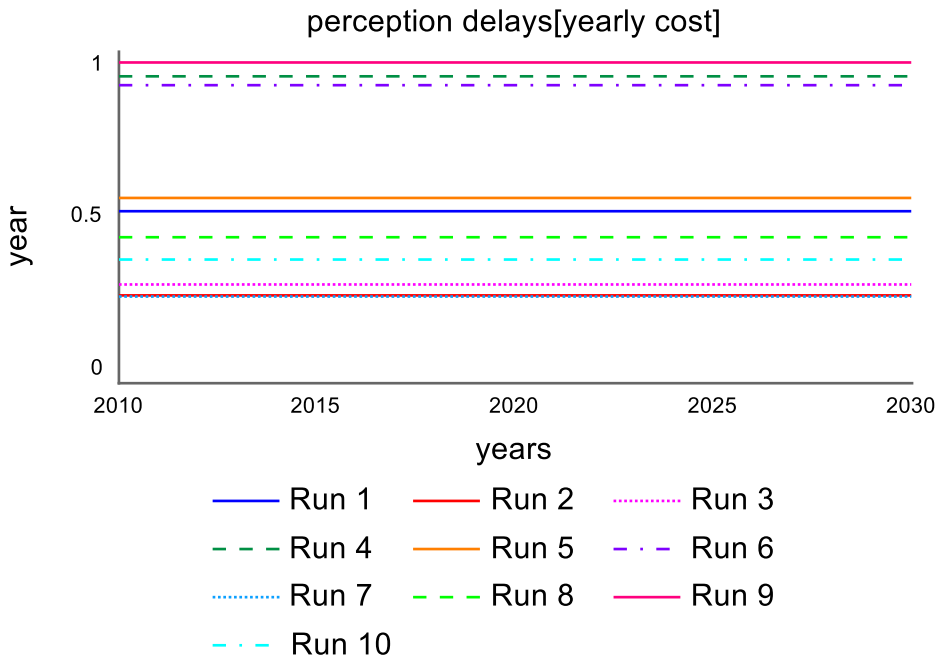
Variable	**Desire for new vs used gas cars**
Runs	10
Distribution	Incremental
Starting Value	0.1
Ending Value	0.7
Assumed Values	

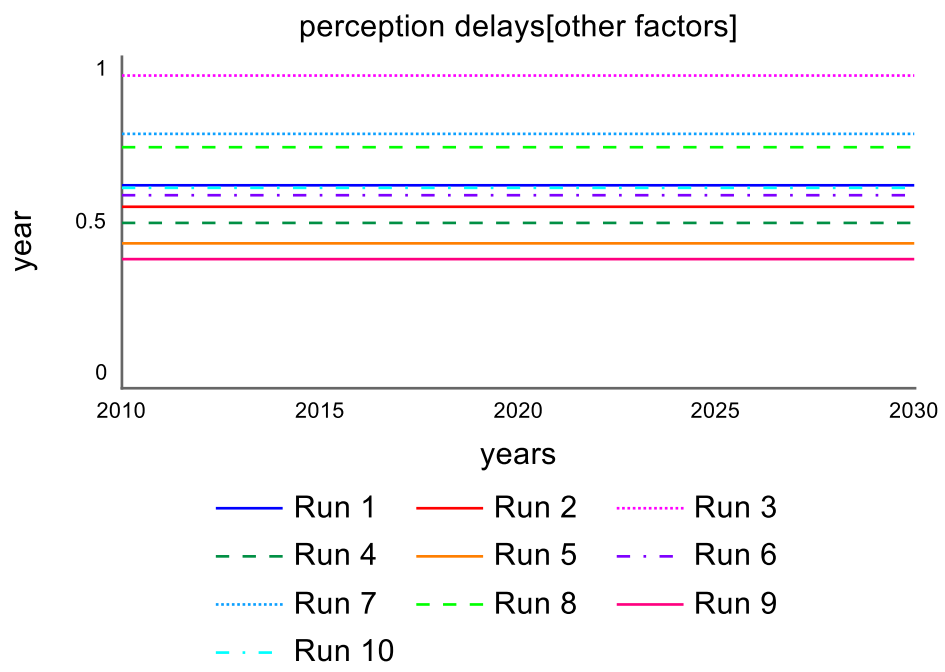
Results	 
Discussion	The behavior mode of the model is not particularly sensitive to a change in this variable, though as the desire for new vs used cars increases, the transition to electric happens faster.

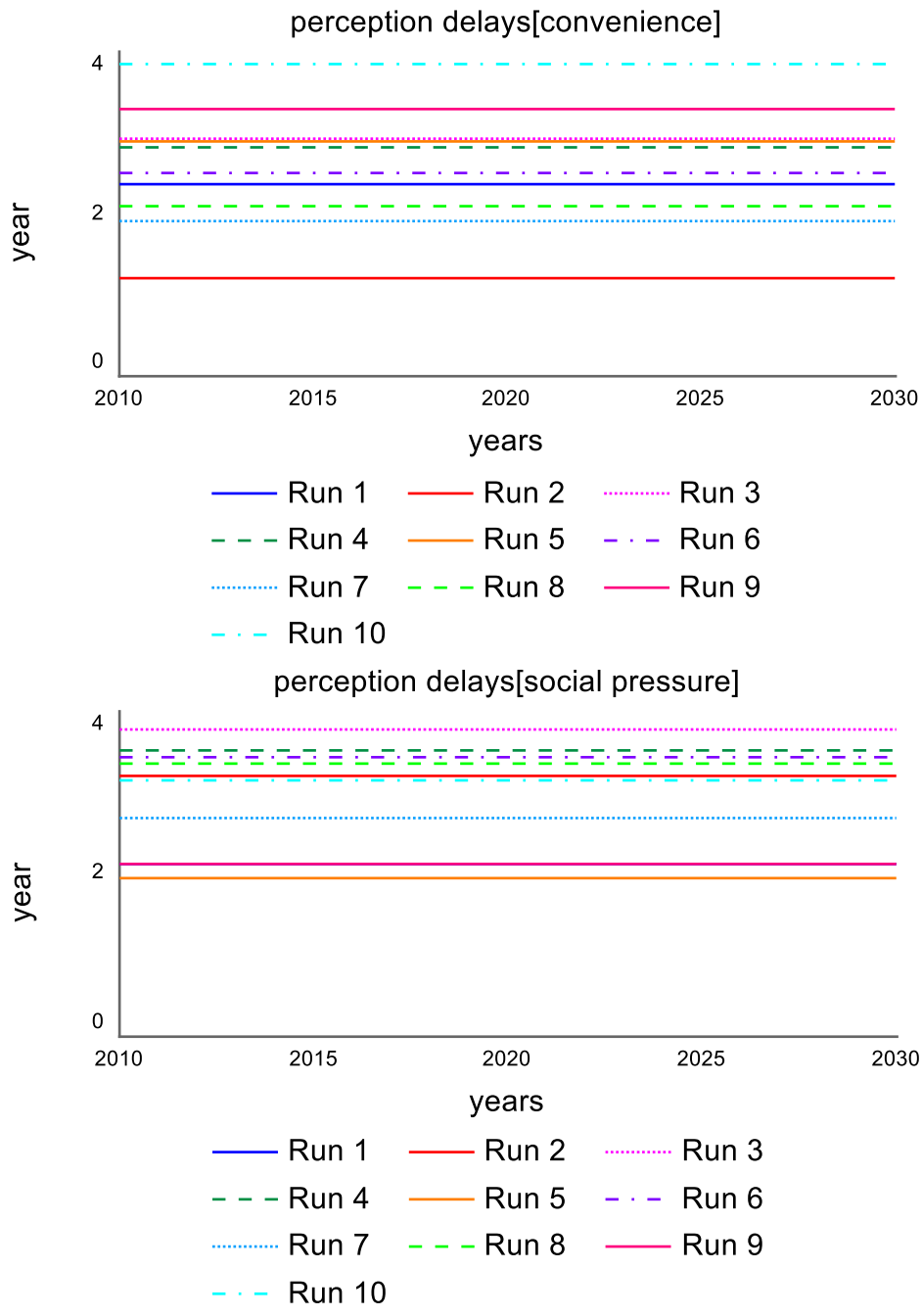
Variable	**T6 GOAL**
Runs	10
Distribution	Incremental
Starting Value	0.8
Ending Value	1.5
Assumed Values	
Results	

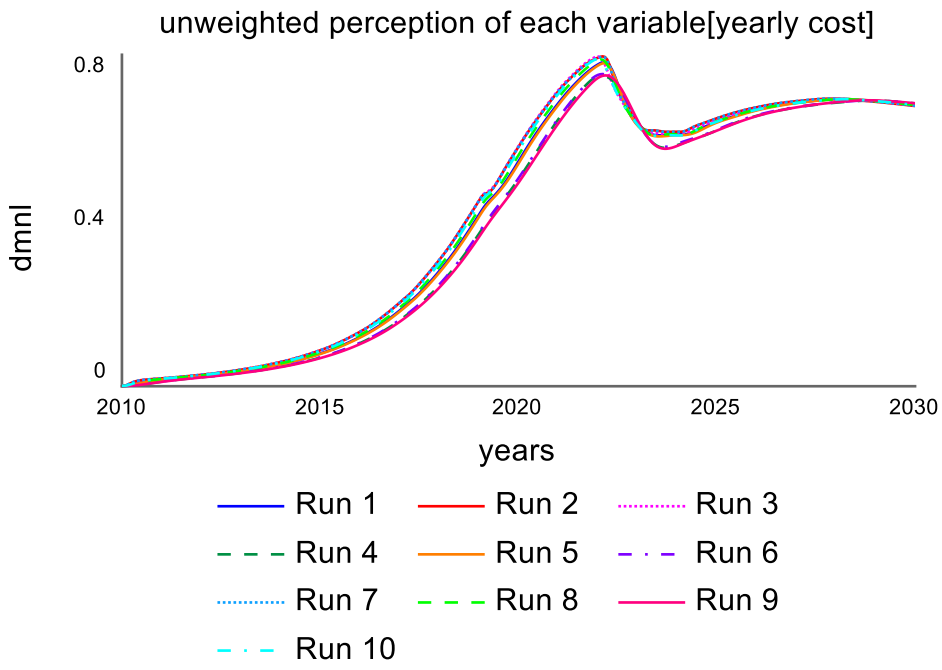

T6: cars per household
cars/household
2
1
0
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5
Run 6
Run 7
Run 8
Run 9
Run 10
total cars
cars
200k
100k
0
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5
Run 6
Run 7
Run 8
Run 9
Run 10

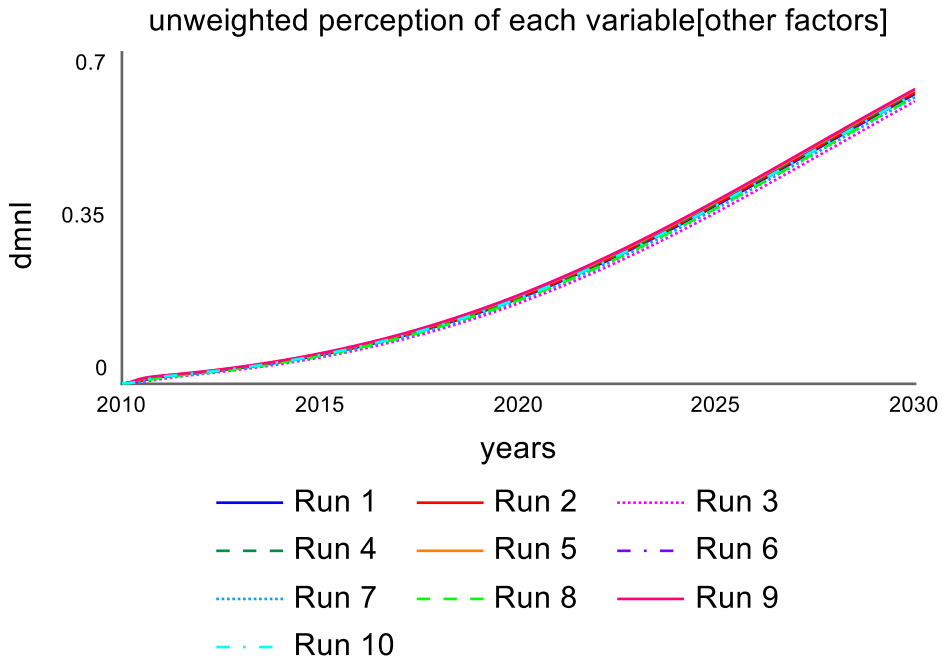
	
Discussion	T6 GOAL, the cars per household, has direct and sensitive effects on total car numbers, which is quite reasonable, but it is not sensitive to T9 goal, the percentage of electric cars purchased, so it means the number of cars per household want to have will not affect on people's decision on whether choosing an electric car or gas car.

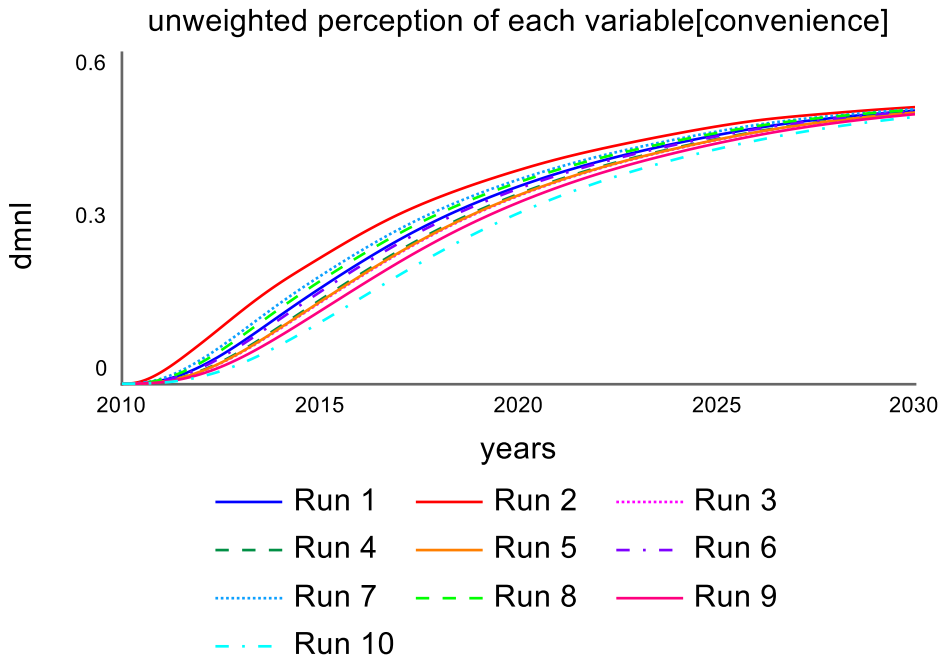
Variable	**Perception delays [yearly cost], [other factors]**
Runs	10
Distribution	Uniform
Starting Value	0.25
Ending Value	1
Assumed Values	

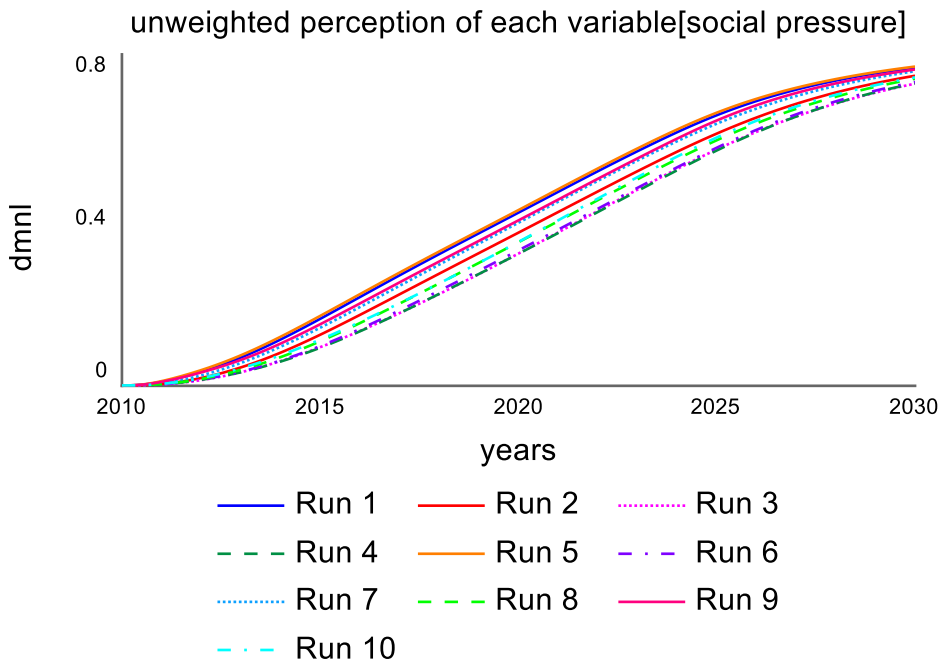
	
Variable	**Perception delays [convenience], [social pressure]**
Runs	10
Distribution	Uniform
Starting Value	1
Ending Value	4

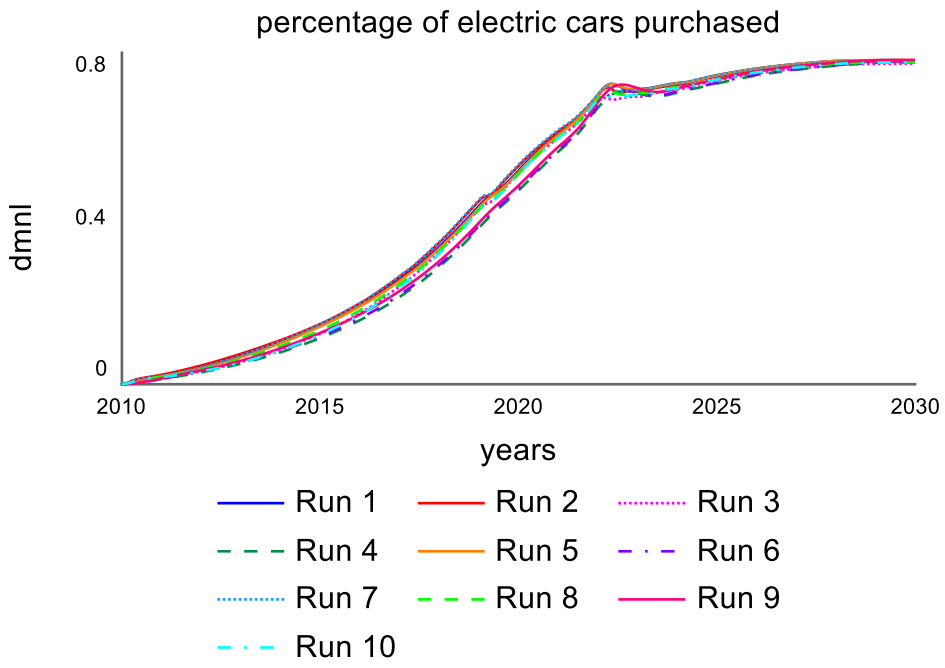
Assumed Values	
Results	

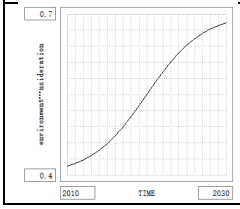
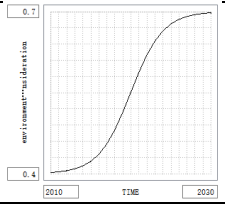
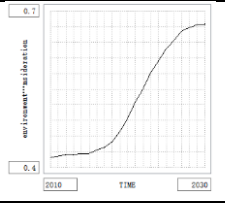
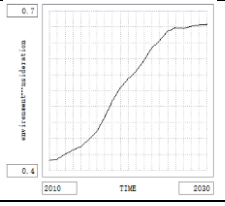
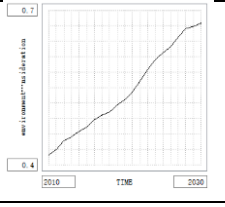

unweighted perception of each variable[yearly cost]
0.8
0.4
0
dmnl
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5
Run 6
Run 7
Run 8
Run 9
Run 10

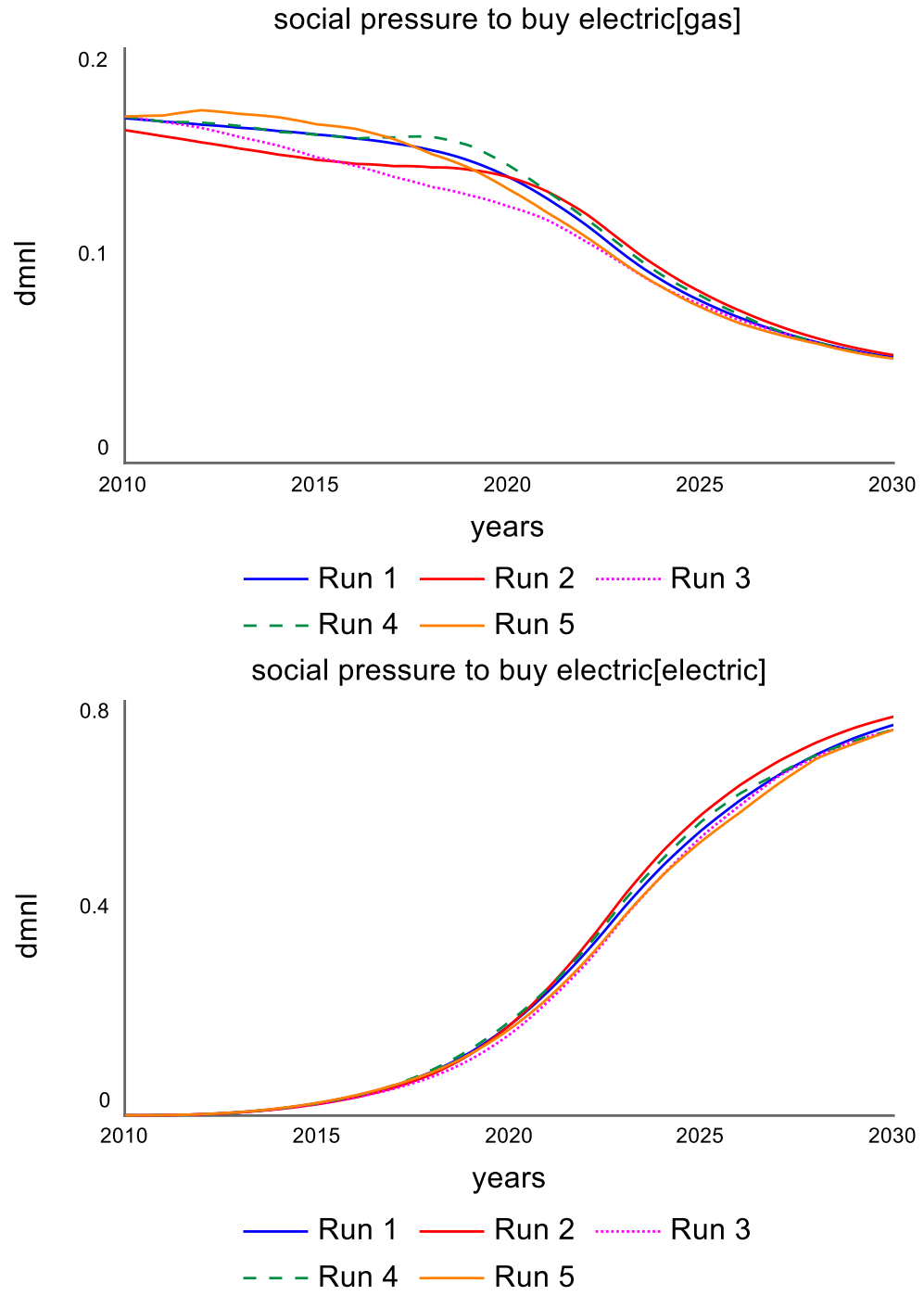

unweighted perception of each variable[other factors]
0.7
0.35
0
dmnl
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5
Run 6
Run 7
Run 8
Run 9
Run 10


unweighted perception of each variable[convenience]
0.6
0.3
0
dmnl
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5
Run 6
Run 7
Run 8
Run 9
Run 10

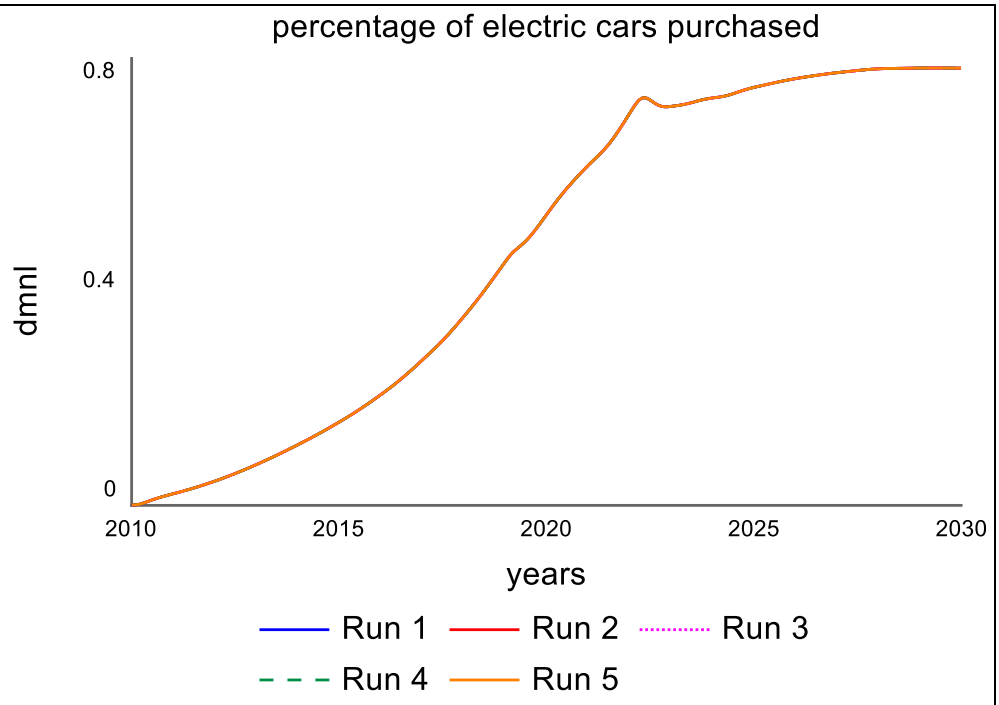

unweighted perception of each variable[social pressure]
0.8
0.4
0
dmnl
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5
Run 6
Run 7
Run 8
Run 9
Run 10

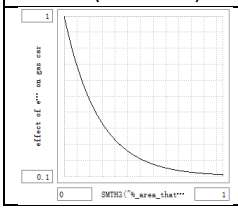
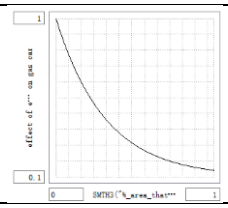
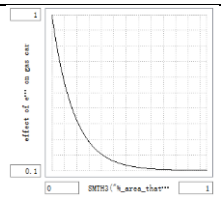
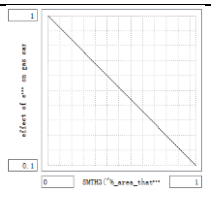
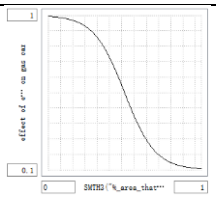
	
Discussion	The behavior mode of the model is not particularly sensitive to a change in these 4 attributes, and less sensitive to the percentage of electric cars purchased.

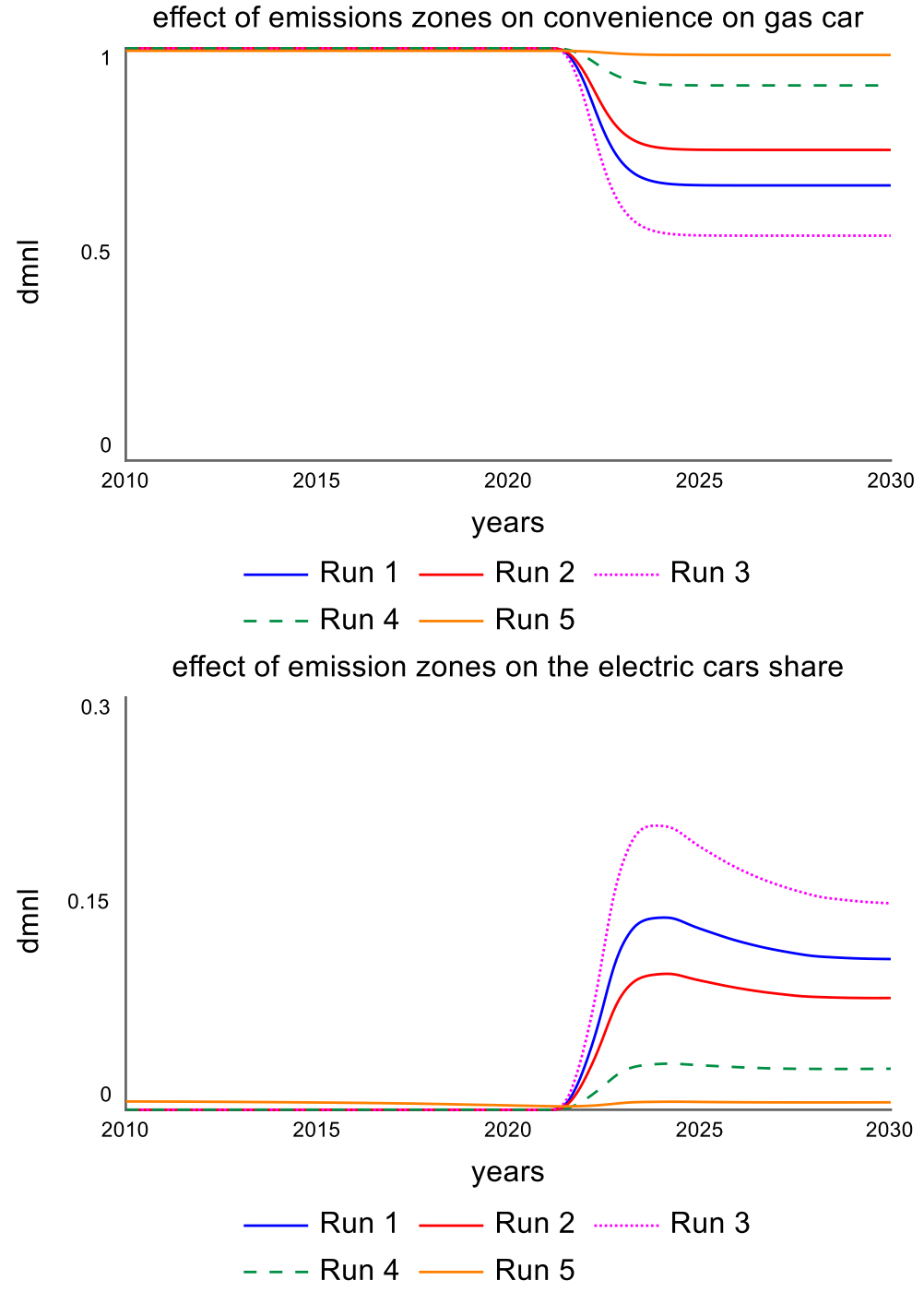
Variable	**Environmental consideration**			
Run 1 (Base case)	Run 2	Run 3	Run 4	Run 5
				

Results	

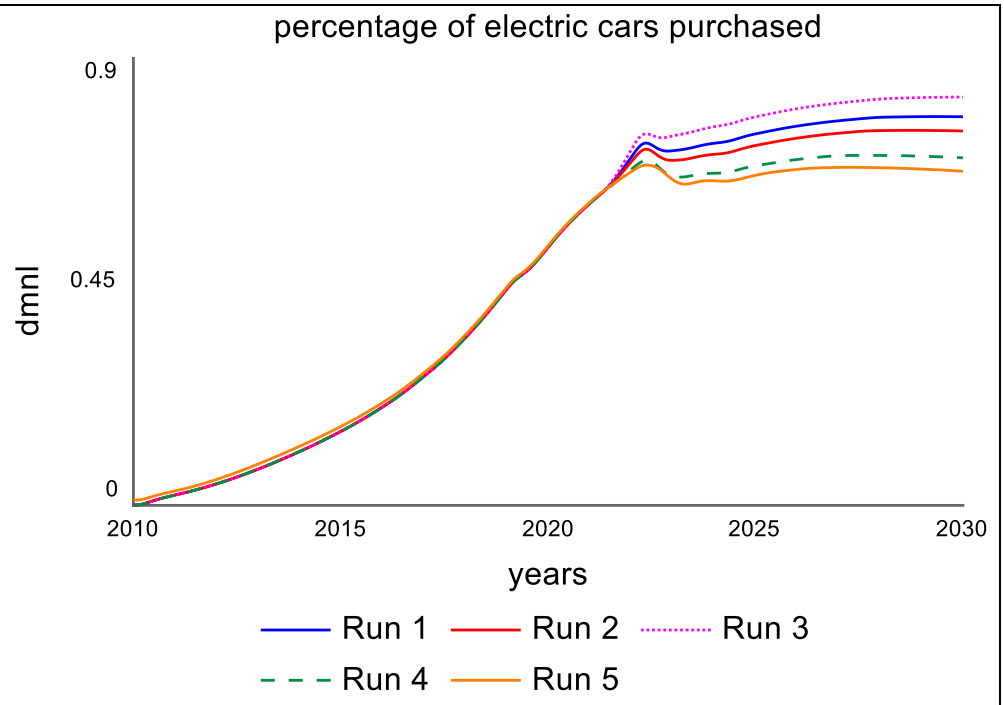
social pressure to buy electric[gas]
0.2
0.1
0
dmnl
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5
social pressure to buy electric[electric]
0.8
0.4
0
dmnl
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5

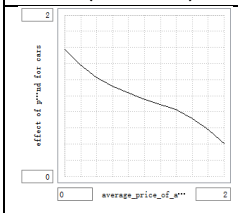
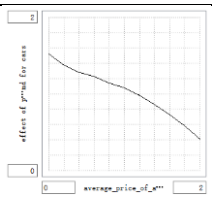
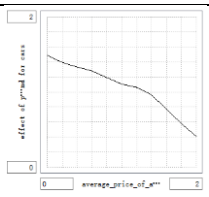
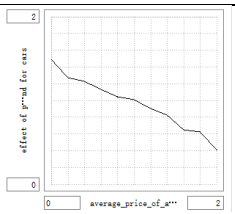
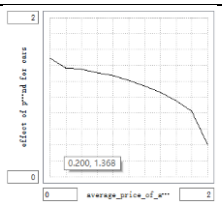
	
Discussion	This graphical variable is not sensitive the to percentage of electric cars purchased.

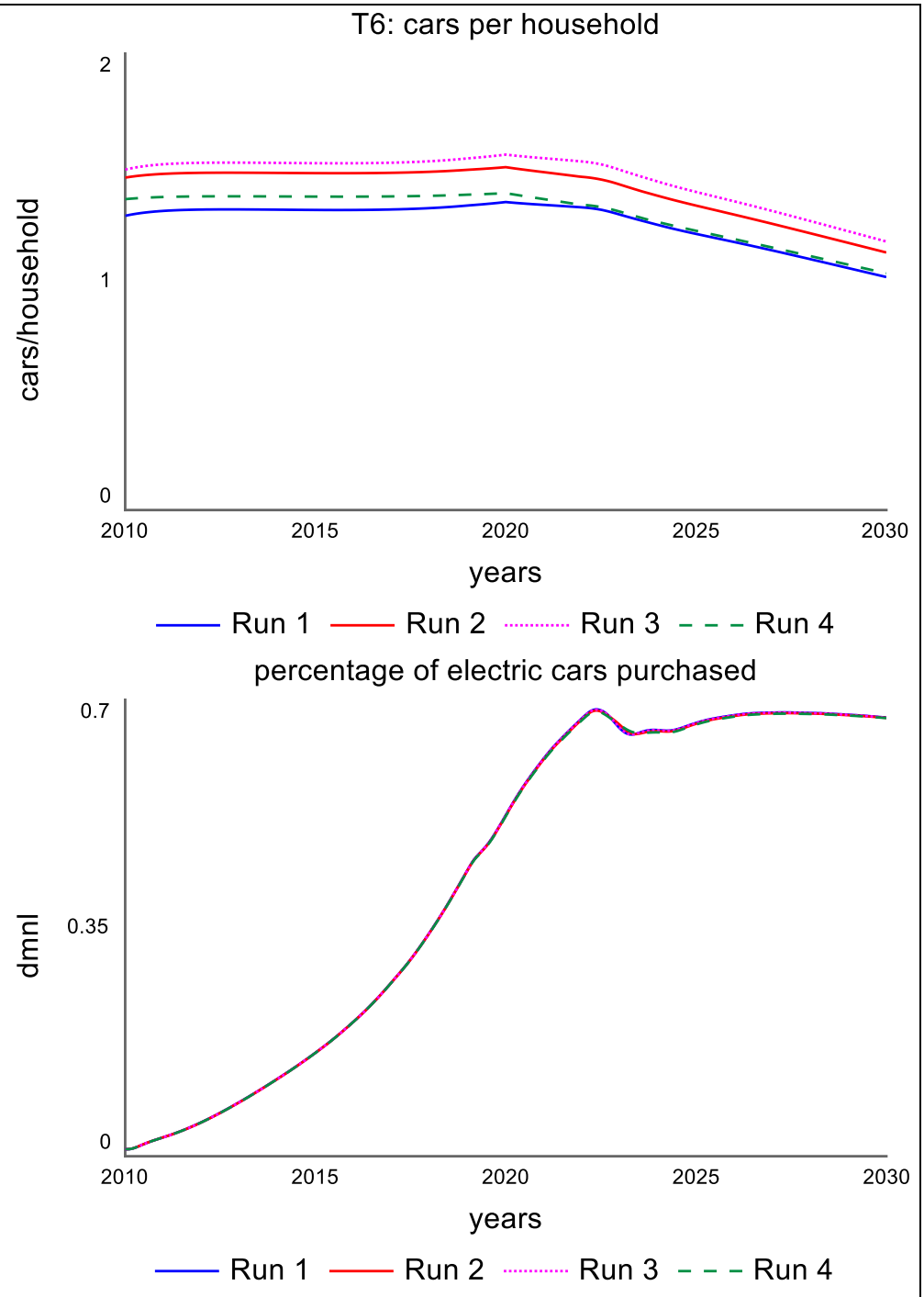
Variable	**effect of emissions zones on convenience on gas car**			
Run 1 (Base case)	Run 2	Run 3	Run 4	Run 5
				

Results	

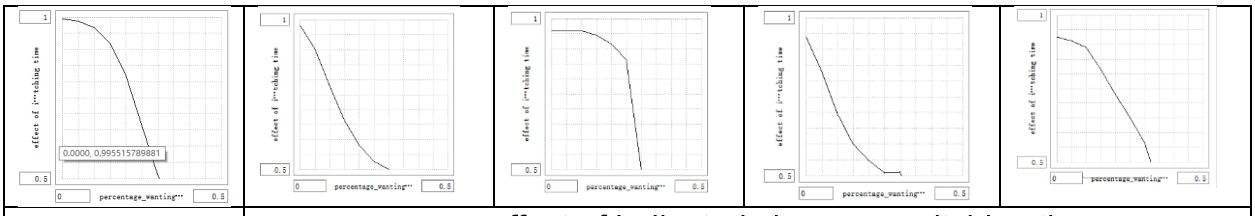
effect of emissions zones on convenience on gas car
dmnl
1
0.5
0
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5
effect of emission zones on the electric cars share
dmnl
0.3
0.15
0
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5

	
Discussion	The effect of emissions zones on convenience on gas car has very sensitive effect on the gas car convenience in Bergen, since this is an outlaw policy, residents have to obey it. The convenience will affect customers decision of buying a more convenient car - electric car. In this model we assume that most of the people will follow the outlaw and use electric cars, few people may like to keep an gas car for trips outside of Bergen or have a hybrid car consuming biofuel and other clean fuels.

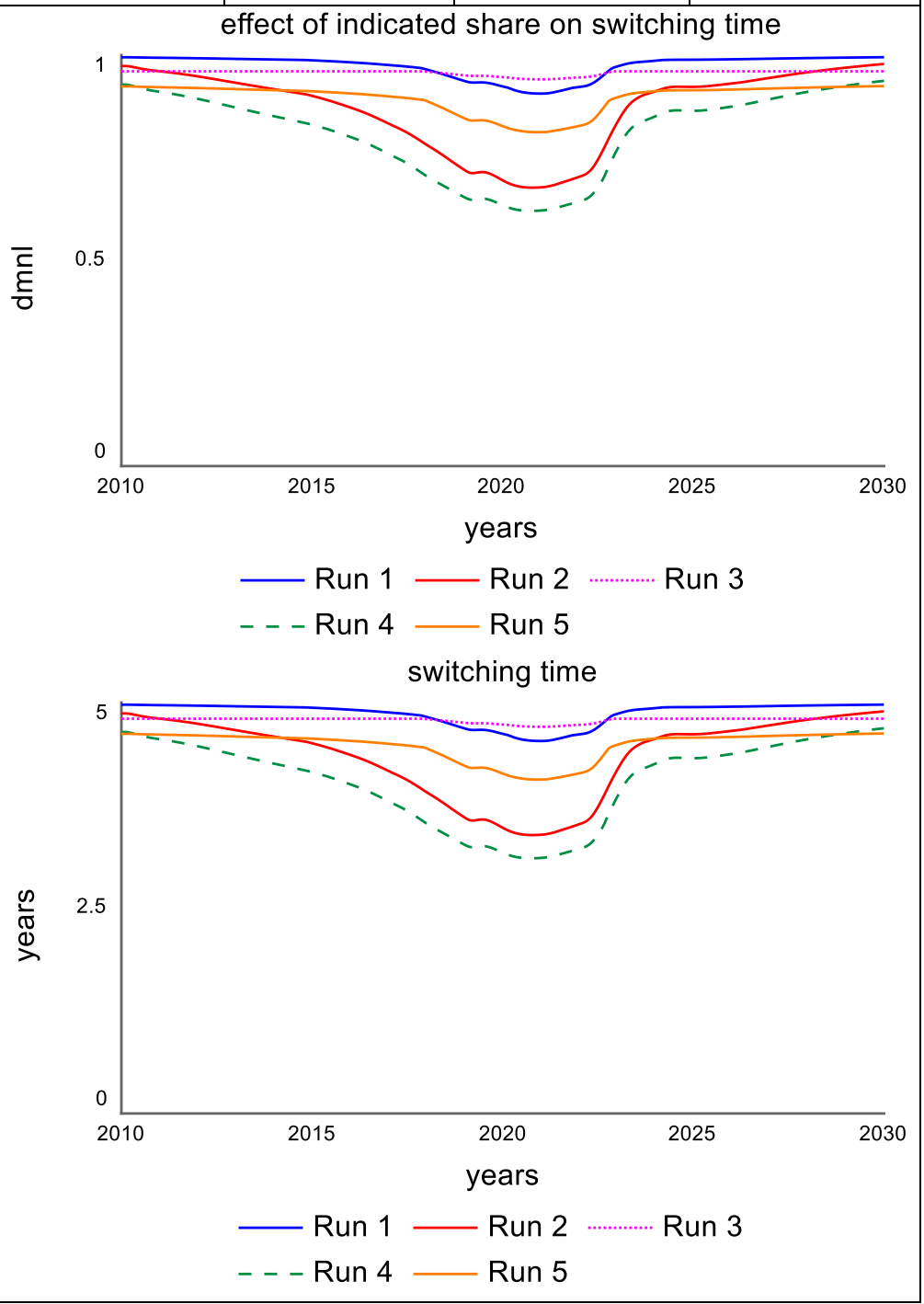
Variable	**effect of price on demand for cars**			
Run 1(Base case)	Run 2	Run 3	Run 4	Run 5
				

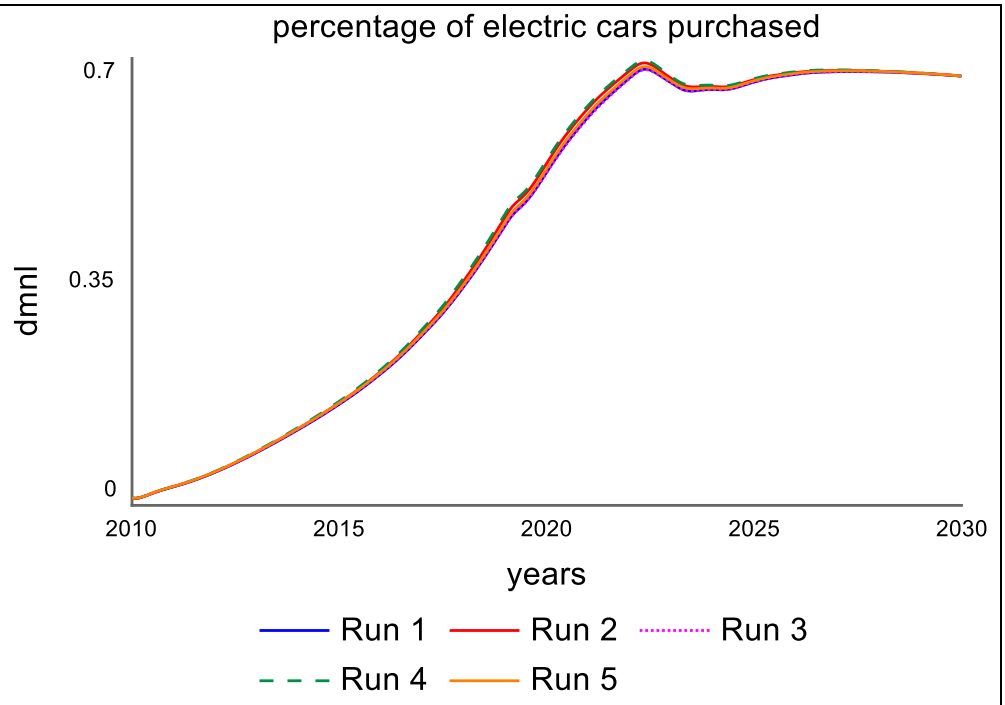
Results	
Discussion	Price of cars is sensitive for customers. However, it is not to sensitive for people choosing a car type.

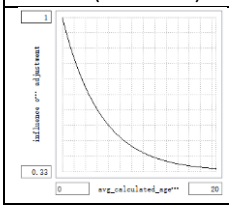
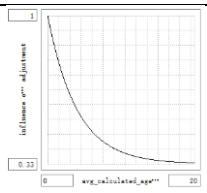
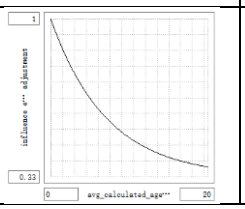
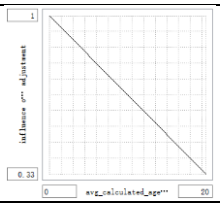
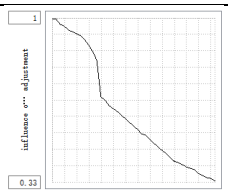
Variable	effect of indicated share on switching time			
Run 1 (Base case)	Run 2	Run 3	Run 4	Run 5

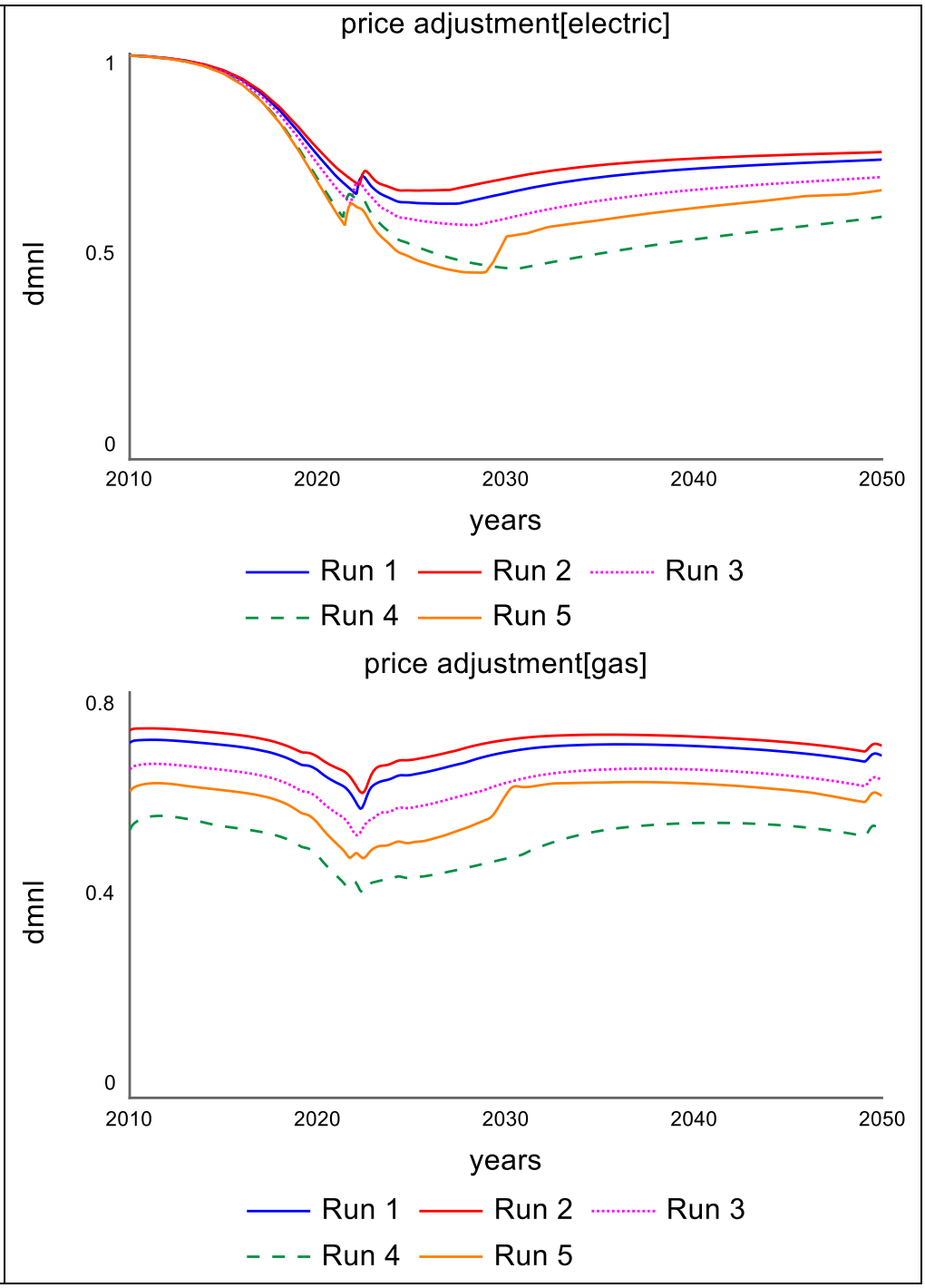


Results

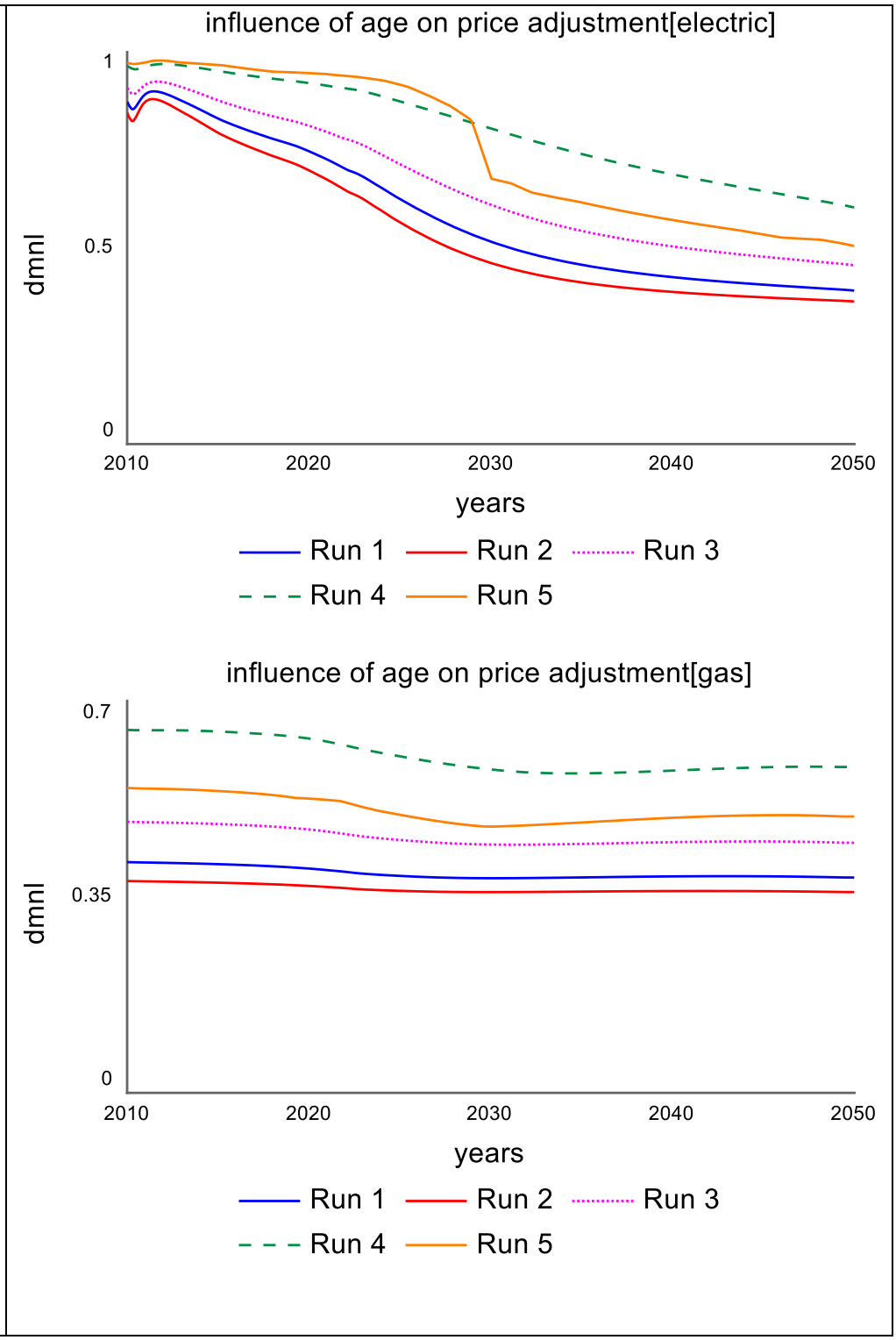

effect of indicated share on switching time
dmnl
1
0.5
0
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5
switching time
years
5
2.5
0
2010
2015
2020
2025
2030
years
Run 1
Run 2
Run 3
Run 4
Run 5

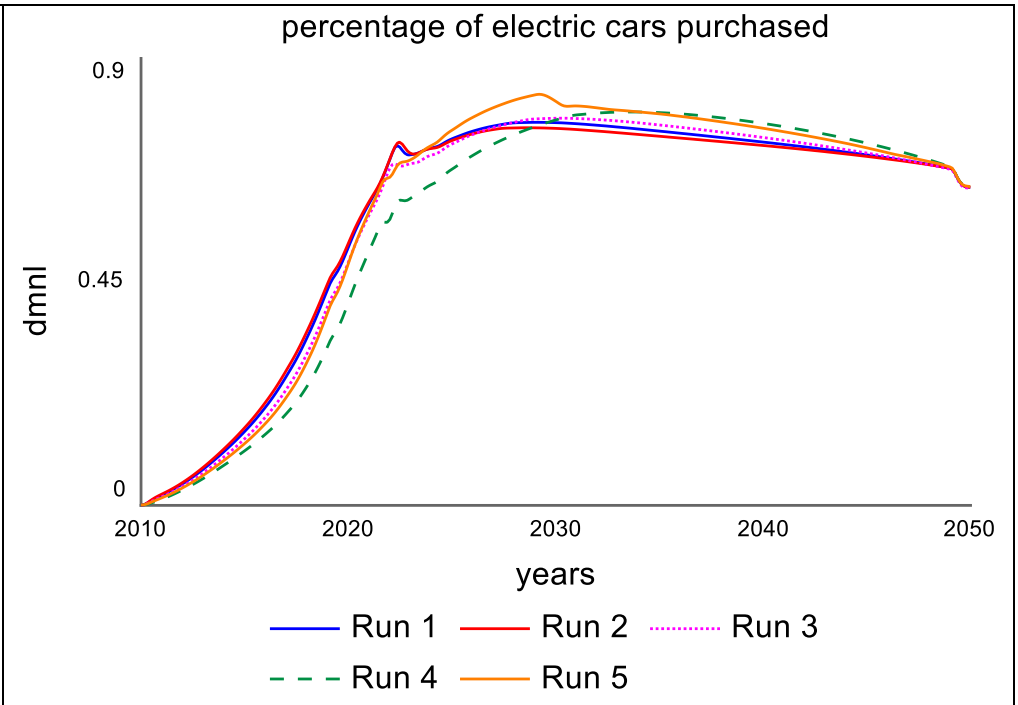
	
Discussion	This variable is sensitive to people to switch time from a gas car to an electric one. However, it is not sensitive to the total percentage of electric cars purchased.

Variable	**influence of age on price adjustment**			
Run 1 (Base case)	Run 2	Run 3	Run 4	Run 5
				

Results	

price adjustment[electric]
1
0.5
0
dmnl
2010
2020
2030
2040
2050
years
Run 1
Run 2
Run 3
Run 4
Run 5
price adjustment[gas]
0.8
0.4
0
dmnl
2010
2020
2030
2040
2050
years
Run 1
Run 2
Run 3
Run 4
Run 5


influence of age on price adjustment[electric]
1
0.5
0
dmnl
2010
2020
2030
2040
2050
years
Run 1
Run 2
Run 3
Run 4
Run 5
influence of age on price adjustment[gas]
0.7
0.35
0
dmnl
2010
2020
2030
2040
2050
years
Run 1
Run 2
Run 3
Run 4
Run 5

	
Discussion	Price relevant variables are always sensitive to peoples decision.

Appendix D: Calibration Procedures

The following Calibration procedure was used to determine the 'elasticities' parameter in the model.

Starting optimization "Optimization" at 2020-Dec-06 12:08:39

Method	additional starts	maxiter	init_step	tolerance
Powell	5	5000	0.1	0.00001

Payoff:	Payoff
Action	minimize
Kind	Calibration
Element	percentage of electric cars on the road
Weight	1
Comparison Variable	historical data
Comparison Run	-2
Comparison Type	Squared Error
Comparison Tolerance	0

Parameter:	elasticities[yearly cost]	elasticities[convenience]	elasticities[other factors]	elasticities[social pressure]

min_value	-5	-5	-5	-5
max_value	5	5	5	5
scaling	1	1	1	1

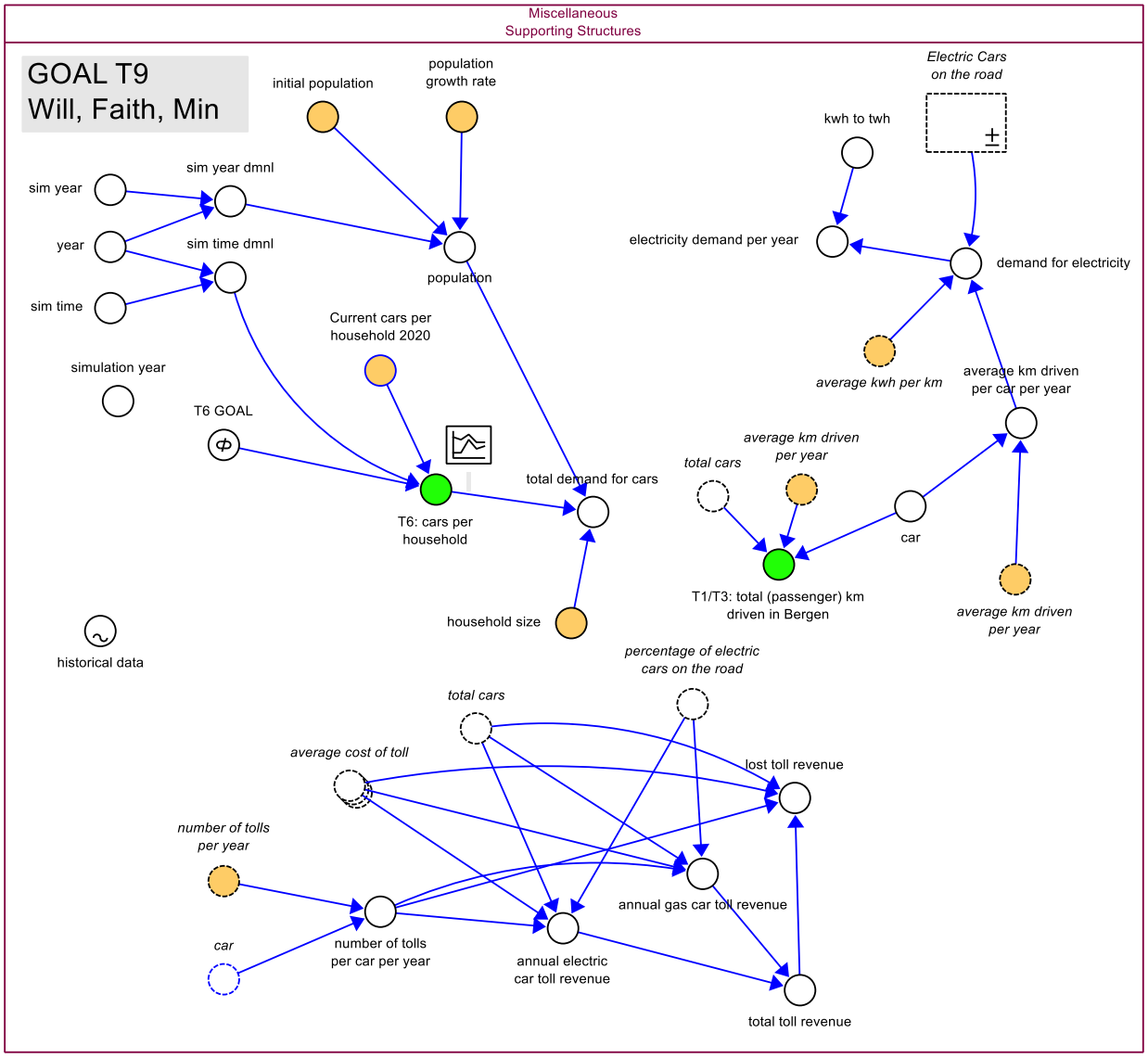
	elasticities[yearly cost]	elasticities[convenience]	elasticities[other factors]	elasticities[social pressure]	Payoff
Starting at	-3.16	0.78	1.05	0.247	
This pass gave	-3.16018575768	0.7801264280 41	1.0496610123 3	0.2474036155 29	0.0394533645 423
Restarting at	0	0	0	0	
This pass gave	-3.16020164988	0.7801161892 55	1.0497308659 9	0.2474002343 14	0.0394533644 835
Restarting at	-2.5	2.5	-2.5	-2.5	
This pass gave	-4.00058102754	1.2074104132 8	-5(min)	0.4326085635 33	0.2233877013 29
Restarting at	2.5	-2.5	2.5	2.5	
This pass gave	-3.10483693816	0.7531937736 27	4.9798187557 9	0.2426468737 17	0.0428360753 497

Restarting at	-1.25	1.25	-3.75	1.25	
This pass gave	-4.00058395705	1.20741015849	-5(min)	0.432608149867	0.223387701329
Restarting at	3.75	-3.75	1.25	-3.75	
This pass gave	-3.16019036914	0.780121590993	1.04972672034	0.247401120876	0.039453364484
After 533 runs	-3.16020164988	0.780116189255	1.04973086599	0.247400234314	0.039453364483 5

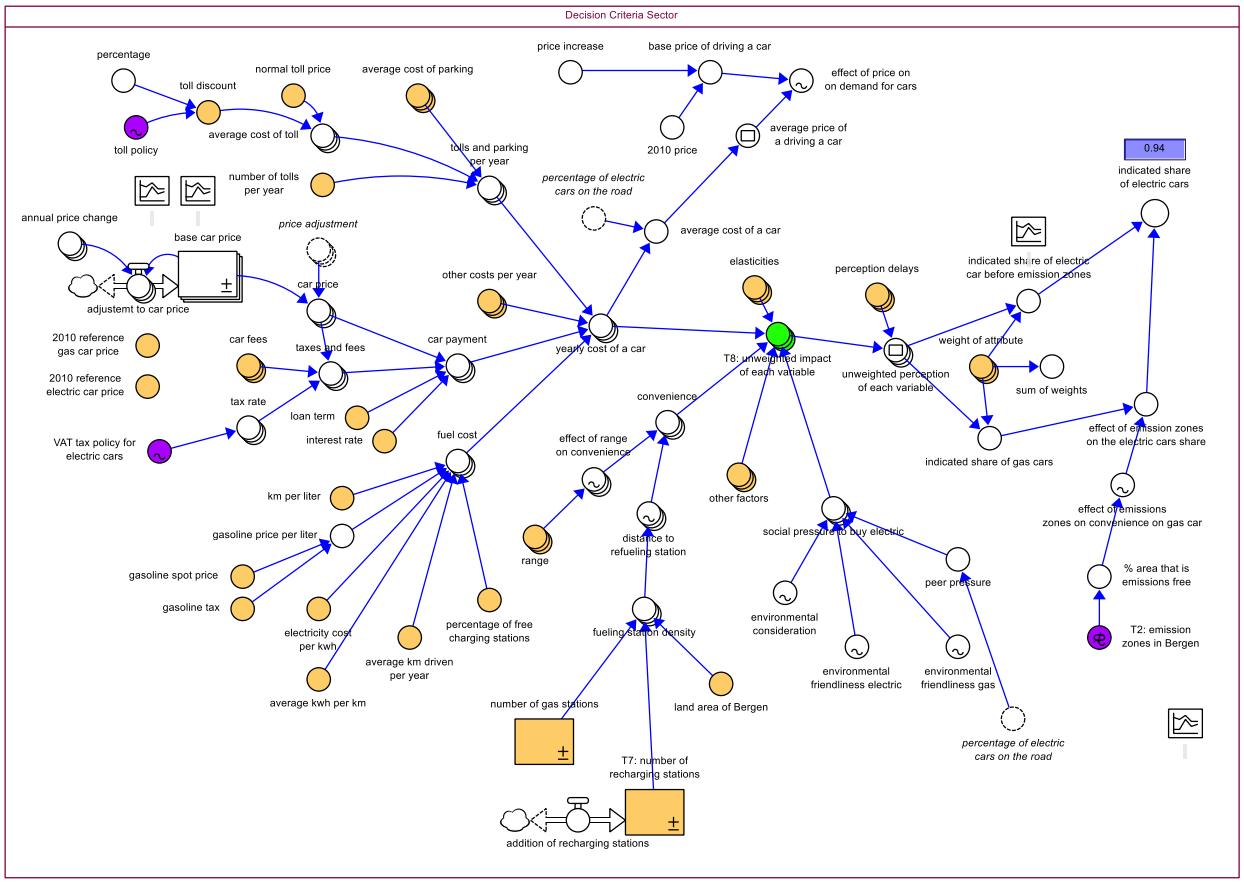
Finishing optimization at 2020-Dec-06 12:08:47

Appendix E: Model Diagram

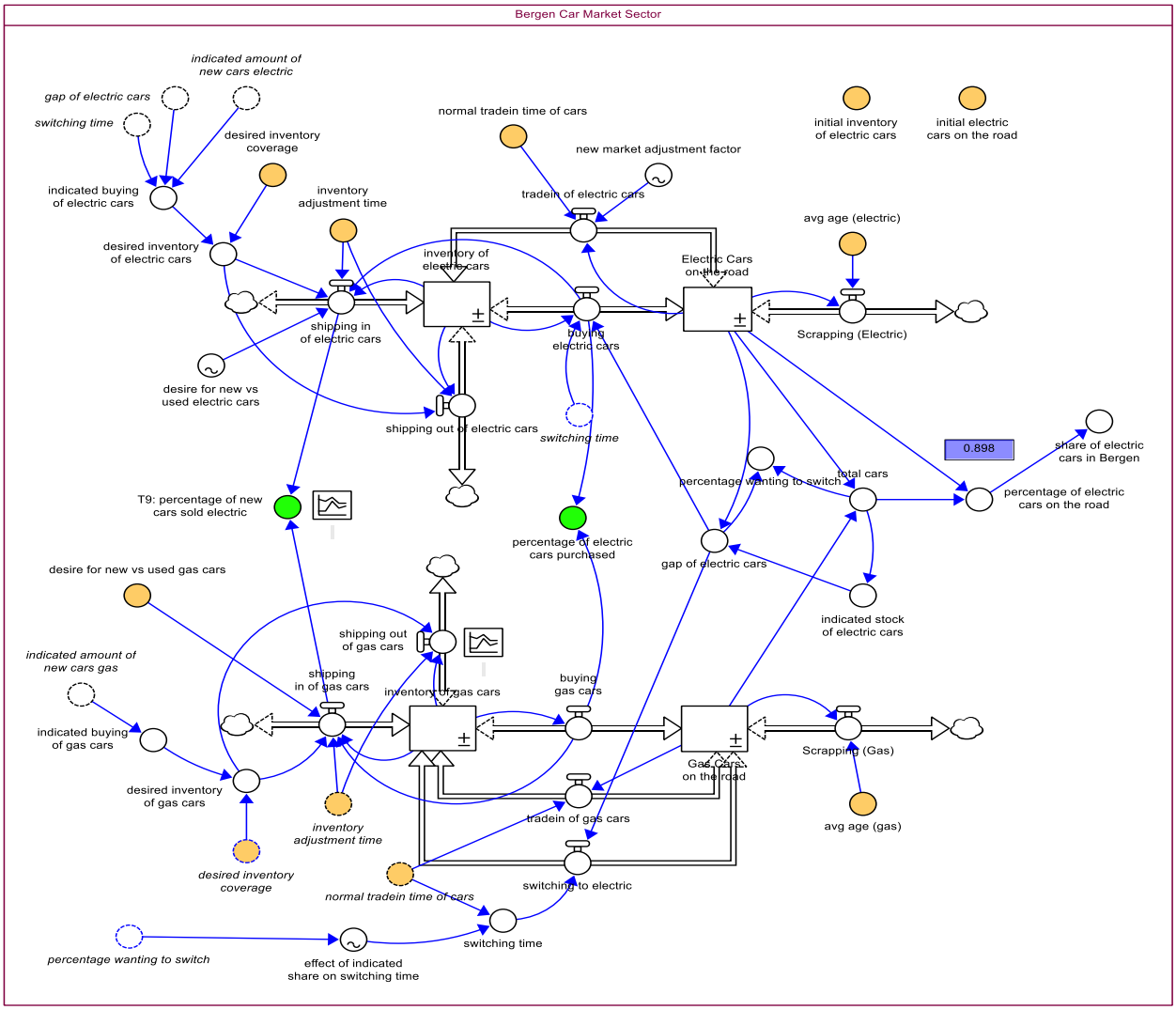
1. Miscellaneous Supporting Structure



2. Decision Criteria Sector



3. Bergen Car Market Sector



4. Car Markets Attribute Sector