Citation: Ulli-Beer, S. G. P. Richardson and D. F. Andersen, (2004). A SD-choice structure for policy compliance: Micro behavior explaining aggregated recycling dynamics. Proceedings of the 22nd International Conference of the System Dynamics Society. Oxford, England (July 25-29, 2004).

Supportive Material

A SD-choice structure for policy compliance: micro behavior explaining aggregated recycling dynamics

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Appendix

In this section the reader interested in technical details will find hints to additional information about the model. The Appendix is rather an index that describes the main additional supportive material that is available for this study from silvia.ulli-beer@ikaoe.unibe.ch. Only the **model equations** and **the list of parameters, initial values and graphs** are completely portrayed in this Appendix.

A Model structure, equations and parameters

A1 Overview model structure

The design of the model is represented in 24 views. While designing the views especially care was given on the readability of the stock and flow diagrams and for representing them in logical consistent clusters (views) facilitating the understanding of the model structure. Mainly two different kind of views can be distinguished: Interfaces for policy analysis and views representing the model structure.

Interfaces for policy analysis and model testing

For the policy experiments - backcasting, forecasting, policy experiments under different scenarios - there exists each an interface that allows to easily replicate the various experiments described in the main document. Also for the conducted model tests - extreme conditions tests and sensitivity analysis – an interface facilitates the replication. The following table shows the fives views that can be found:

Interfaces for policy analysis and model testing	Views
Interfaces for policy analysis	• View 01 "Back-casting policy-experiments 1987" • View 02 "Forecasting policy-experiments 2004-2020" • View 03 "Policy-experiments under diff scenarios"
Interfaces for model testing	• View 04 "Extreme condition tests" • View 05 "Sensitivity analysis"

Table: Interfaces for policy analysis and model testing

The main views representing the model-structure

The views representing the model structure can be clustered according to the main sectors included in the model: The household decision sector, the household waste separation sector and the local SWM sector. The following tables emphasize the views with core elements of the model and those that have rather a supportive character. The core elements include the main stock and flow structure and main concepts of the model. Contrarily, the supportive elements are those structure that mainly compute auxiliary-variables.

Model sector	Core elements of the model structure	Supportive model structure elements
The household decision sector	• View 1 “Flows of people” • View 2 “Fraction becoming willing” • View 3 “Fraction becoming unwilling”	• View 11 “Time on moving from iep to ep • View 31 “Pool for effects on flow people”
The household waste separation sector	• View 4 “Separation behavior wep” • View 5 “Separation behavior wiep” • View 6 “Separation behavior nwiep” • View 7 “Separation behavior nwep”	• View 61 “Inappropriately separated per nwiep” • View 8 “Fractions and amounts”
The local SWM sector	• View 9 “Computed garbage bag charge” • View 94 “Policy prepaid disposal tax” • View 95 “Economic growth”	• View 91 “Cost solid waste management • View 911 “Profit solid waste management” • View 92 “Impurity” • View 93 “Prices separation an prepaid tax revenue • View 96 “Real data variables”

Table: Views of the model

Example interfaces for policy analysis and model testing: View 01 "Back-casting policy-experiments 1987"

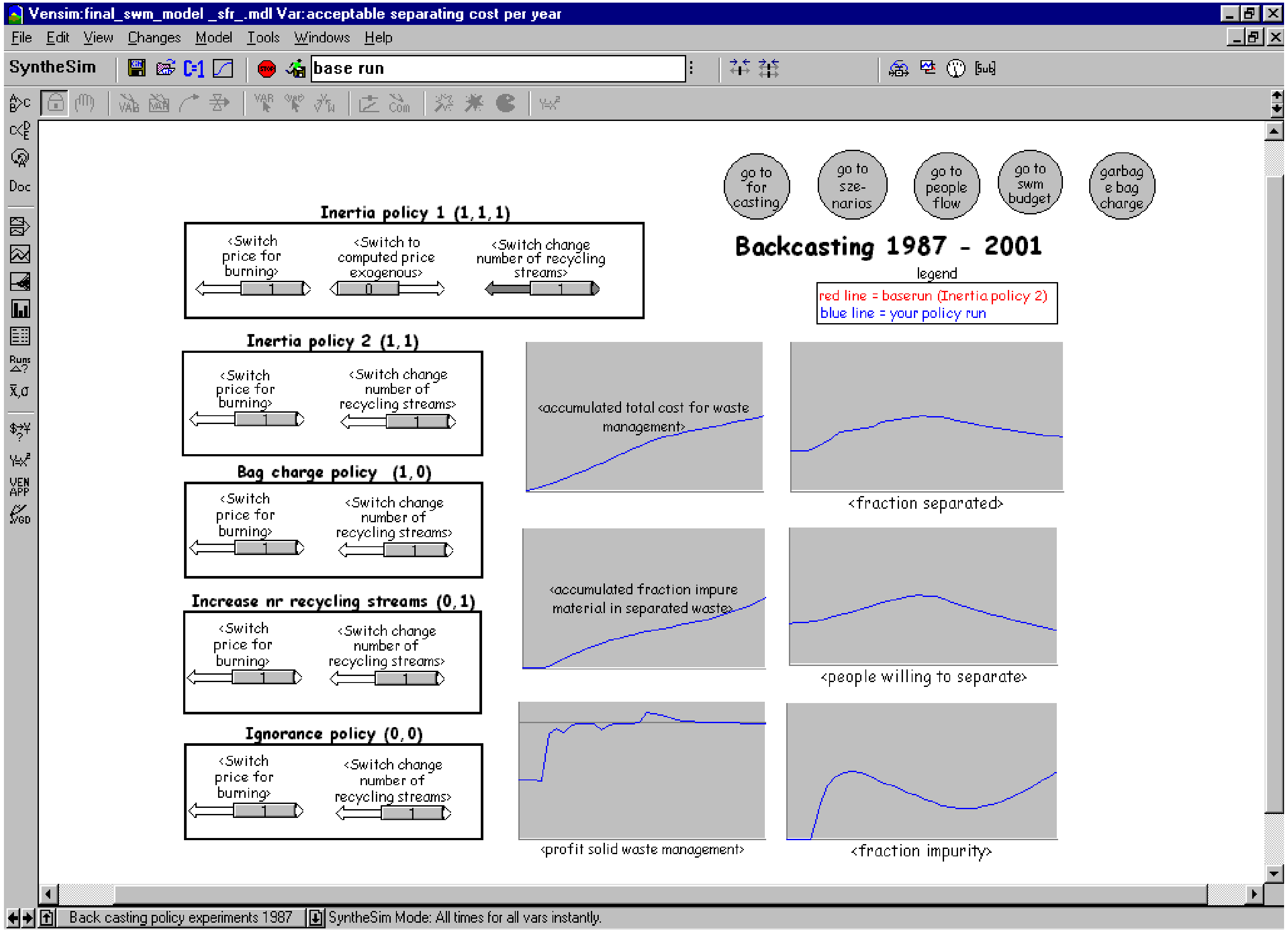


Figure: View 01 "Back-casting policy-experiments 1987"

Example core elements of the model structure : View 1 “Flows of people”

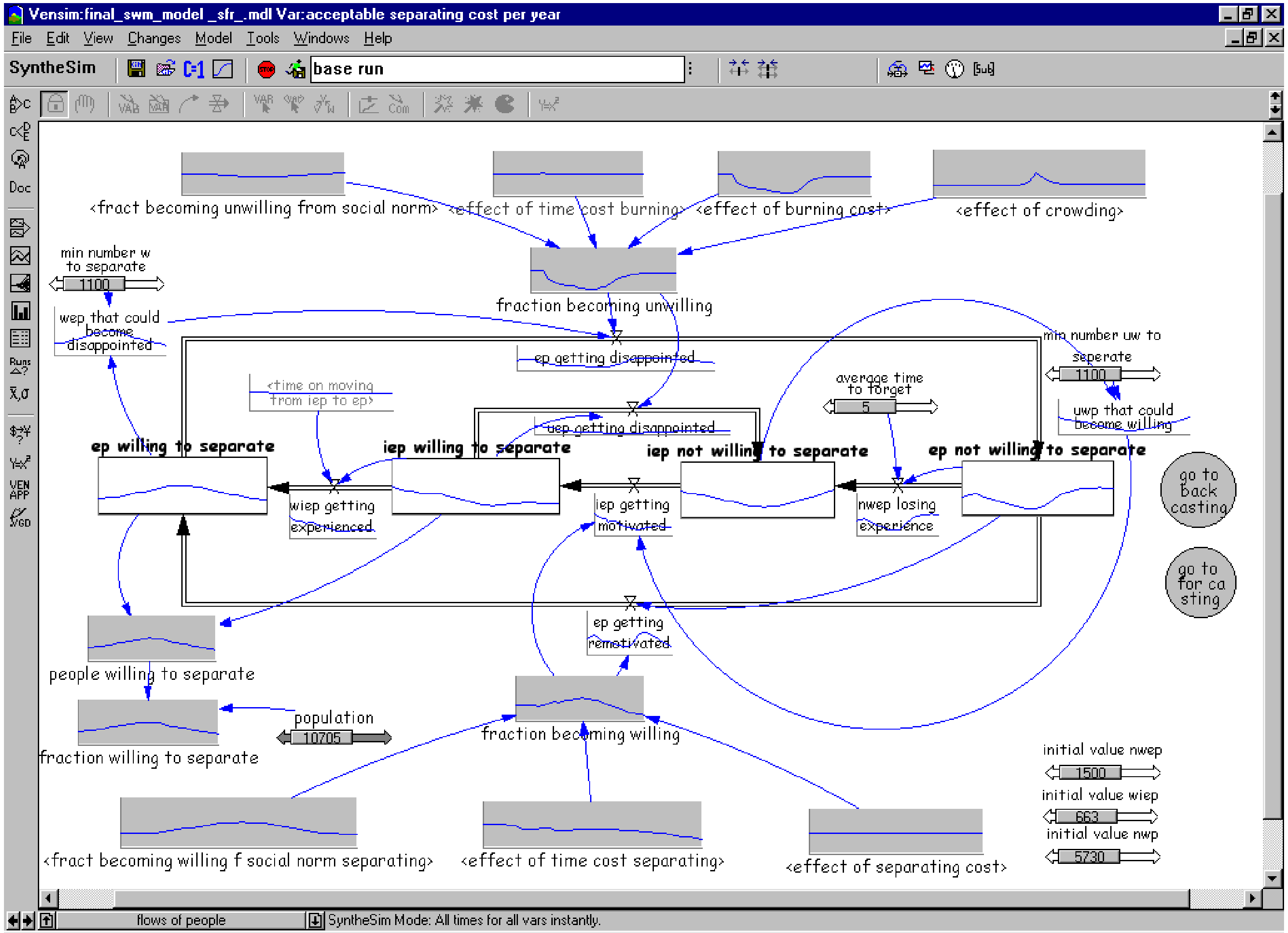


Figure: View 1 “Flows of people”

Example core elements of the model structure: View 2 "Fraction becoming willing"

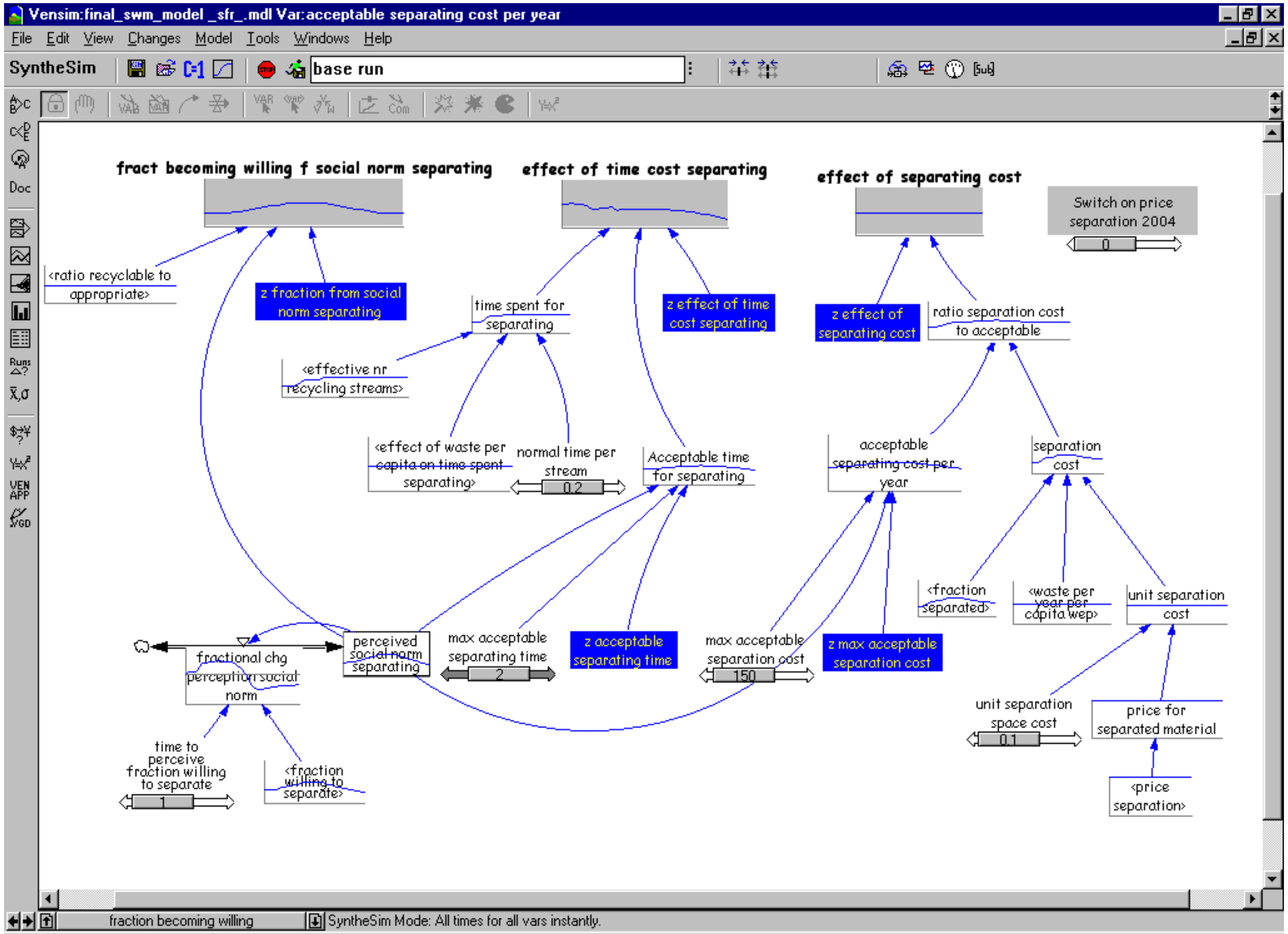
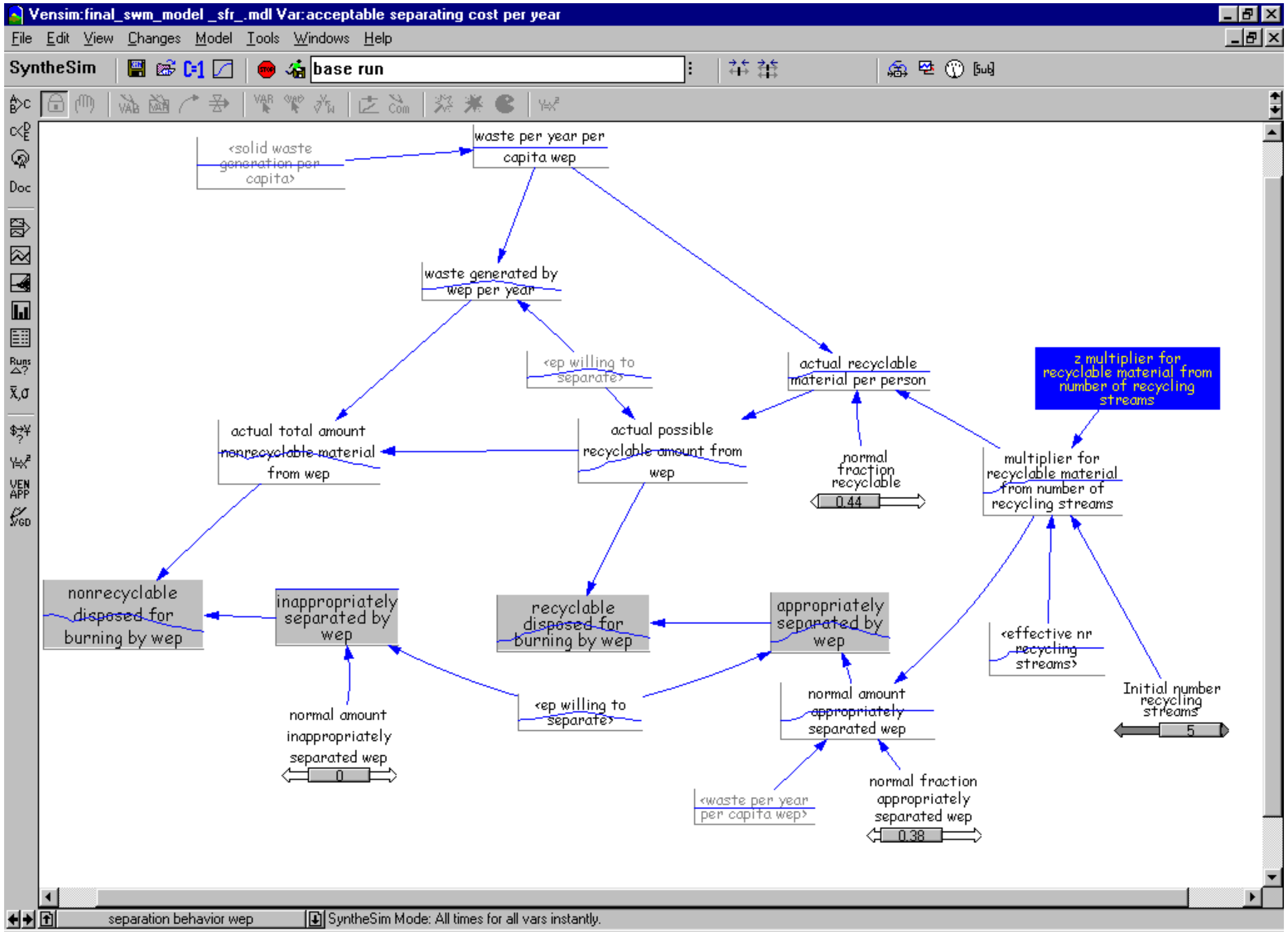


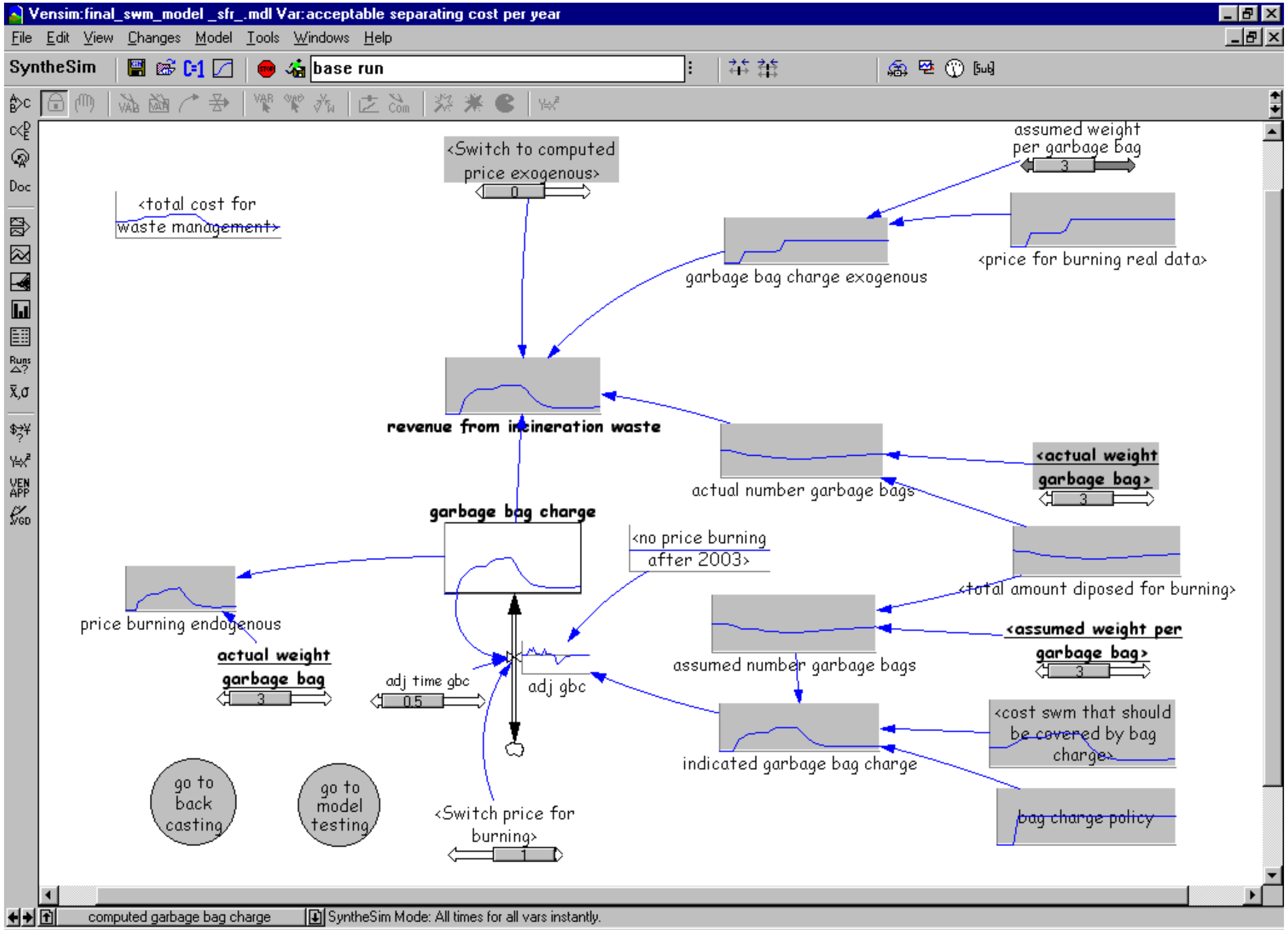
Figure: View 2 "Fraction becoming willing"

Example core elements of the model structure: View 4 "separation behavior wep"



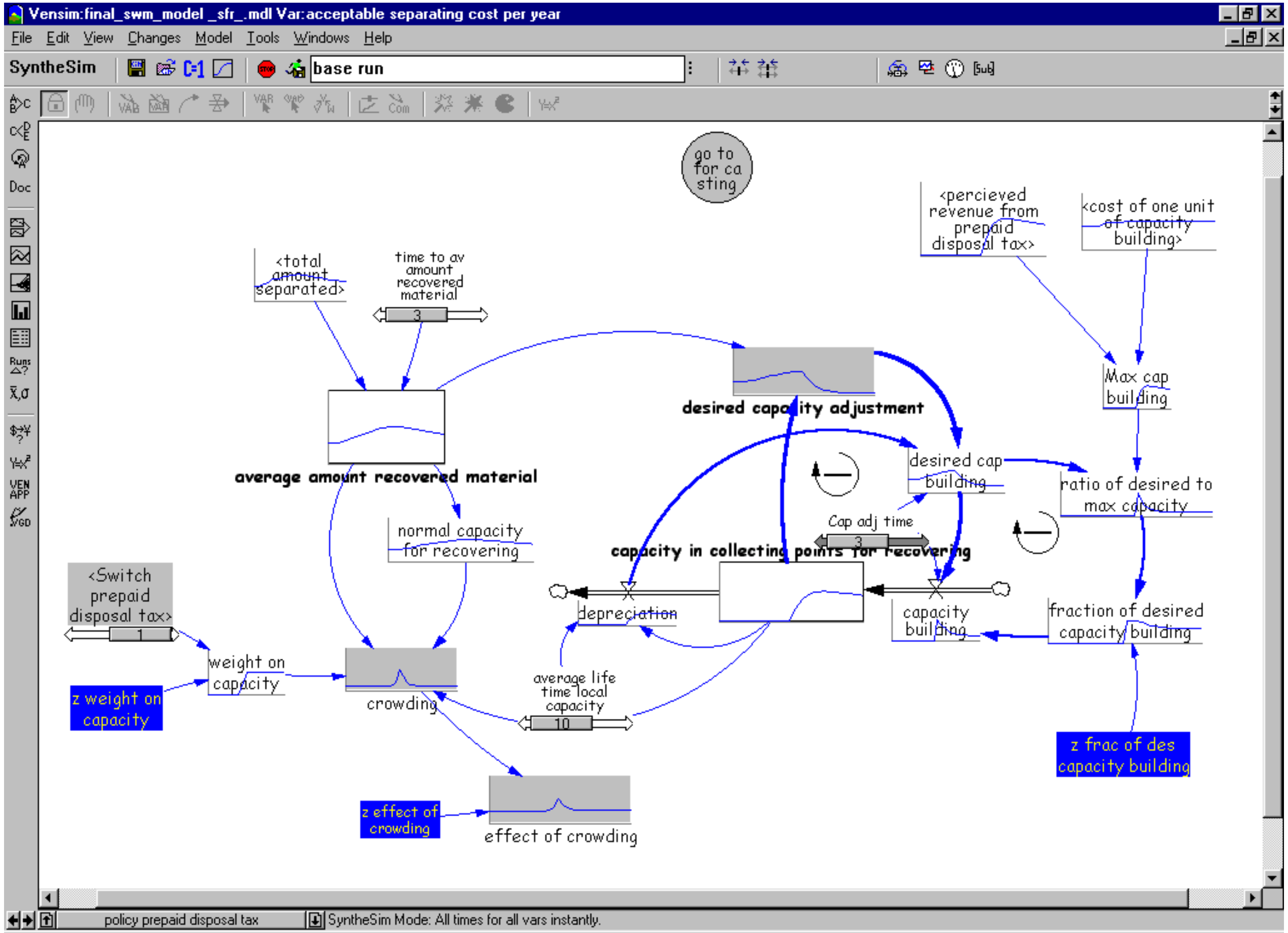
View 4 "separation behavior wep"

Example core elements of the model structure: View 9 “Computed garbage bag charge”



View 9 “Computed garbage bag charge”

Example core elements of the model structure: View 94 “Policy prepaid disposal tax”



View 94 “Policy prepaid disposal tax”

A2 Model structure and equations

****
."1 Flows of people"
****

(007) average time to forget = 5
Units: year

(008) ep getting disappointed =
wep that could become disappointed*fraction becoming unwilling
Units: people/year

(009) ep getting remotivated=
ep not willing to separate*fraction becoming willing
Units: people/year

(010) fraction becoming unwilling=
fract becoming unwilling from social norm*effect of time cost burning*effect of burning cost* effect of crowding
Units: Dmnl/year

(011) fraction becoming willing=
(fract becoming willing f social norm separating*effect of time cost separating*effect of separating cost)
Units: Dmnl/year

(012) iep getting motivated=
uwp that could become willing*fraction becoming willing
Units: people/year

(013) initial value nwep = 1500
Units: people

(014) initial value nwp = 5730
Units: people

(015) initial value wiep = 663
Units: people

(016) min number uw to separate = 1100
Units: people

(017) min number w to separate = 1100
Units: people

(018) nwep losing experience=
ep not willing to separate/average time to forget
Units: people/year

(019) people willing to separate=
ep willing to separate+iep willing to separate
Units: people

(020) uep getting disappointed=
iep willing to separate*fraction becoming unwilling
Units: people/year

(021) uwp that could become willing=
MAX(0,(iep not willing to separate-min number uw to seperate))
Units: people

(022) wep that could become disappointed=
MAX(0,(ep willing to separate-min number w to separate))
Units: people

(023) wiep getting experienced=
iep willing to separate*time on moving from iep to ep
Units: people/year

****
."11 time on moving from iep to ep"
****

(025) average amount appropriately separated nwiep=
SMOOTH(normal amount appropriately separated nwiep*effect of change in nr streams on normal amount appropriately separated nwiep , time to average amount appropriately separated)
Units: kg/(year*person)

(026) effect of experience witch separation on time for moving from wiep to wep=
z effect of experience with separation on time for moving from wiep to wep(ratio av app separated nwiep to wep)
Units: Dmnl

(027) normal time constant on moving from iep to ep = 1
Units: Dmnl/year [1,6,1]

(028) ratio av app separated nwiep to wep=
zidz (average amount appropriately separated nwiep,normal amount appropriately separated wep)
Units: Dmnl

(029) time on moving from iep to ep=
normal time constant on moving from iep to ep*effect of experience witch separation on time for moving from wiep to wep
Units: Dmnl/years

(030) time to average amount appropriately separated = 3
Units: year

(031) z effect of experience with separation on time for moving from wiep to wep(
[(0,0)-(1,1)],(0,0),(0.1,0.35),(0.25,0.7),(0.4,0.85),(0.7,0.95),(1,1))
Units: Dmnl

****
."2 Fraction becoming willing"
****

(033) acceptable separating cost per year=
z max acceptable separation cost(perceived social norm separating)*max acceptable separation cost
Units: CHF/(year*person)

(034) Acceptable time for separating=
z acceptable separating time(perceived social norm separating)*max acceptable separating time
Units: hours/week

(035) effect of separating cost=
z effect of separating cost(ratio separation cost to acceptable)
Units: Dmnl

(036) effect of time cost separating=
z effect of time cost separating(time spent for separating/Acceptable time for separating)
Units: Dmnl

(037) fract becoming willing f social norm separating=
z fraction from social norm separating(perceived social norm separating)*ratio recyclable to appropriate
Units: Dmnl/year

(038) fraction willing to separate=
people willing to separate/population
Units: Dmnl

(039) fractional chg perception social norm=
((fraction willing to separate-perceived social norm separating)/time to perceive fraction willing to separate)
Units: Dmnl/year

(040) max acceptable separating time = 2
Units: hours/week [0.8,3,0.1]

(041) max acceptable separation cost = 150
Units: CHF/(years*person)

(042) normal time per stream = 0.2
Units: hours/(week*streams) [0,0.3,0.01]

(043) price for separated material=
price separation
Units: CHF/kg

(044) ratio separation cost to acceptable=
separation cost/acceptable separating cost per year
Units: Dmnl

(045) separation cost=
unit separation cost*(fraction separated*waste per year per capita wep)
Units: CHF/year/person

(046) time spent for separating=
effective nr recycling streams * normal time per stream * effect of waste per capita on time spent separating
Units: hours/week

(047) time to perceive fraction willing to separate = 1
Units: year

(048) unit separation space cost = 0.1
Units: CHF/kg

(049) z acceptable separating time(
[(0,0)-(1,1)],(0,0),(0.0917431,0.122807),(0.183486,0.328947),(0.284404,0.587719),(0.357798,0.692982),
(0.422018,0.763158),(0.538226,0.864035),(0.669725,0.942982),(0.83792,0.991228),(1,1))
Units: Dmnl

(050) z effect of separating cost(
[(0,0)-(5,1.4)],(0,1.4),(0.2,1.4),(0.366972,1.35702),(0.458716,1.28333),(0.932722,0.35614),(1.16208,
0.166667), (1.57492,0.0701754),(2.49235,0),(5,0))
Units: Dmnl

(051) z effect of time cost separating(
[(0,0)-(2,2)],(0,1.5),(0.6,1.5),(0.782875,1.41228),(0.868502,1.27193),(1,1),(1.3,0.3),(1.45,0.13),
(1.7,0.04),(1.9,0),(2,0))
Units: Dmnl

(052) z fraction from social norm separating(
[(0,0.1)-(1,0.2)],(0,0.1),(0.45,0.1),(0.5,0.105),(0.56,0.125),(0.64,0.15),(0.7,0.17),(0.8,0.19),

(0.88,0.2),(1,0.2))
Units: Dmnl/year

(053) z max acceptable separation cost(
[(0,0)-(1,1)],(0,0.00438596),(0.0795107,0.267544),(0.180428,0.495614),(0.281346,0.644737),
(0.394495,0.758772),(0.525994,0.855263),(0.654434,0.934211),(0.807339,0.982456),(0.990826,1))
Units: Dmnl

****
."3 Fraction becoming unwilling"
****

(055) Acceptable time burning=
z acceptable time burning(perceived fraction social norm burning)*max acceptable time for burning
Units: hours/(person*week)

(056) Acceptable unit cost for burning=
z acceptable cost for burning(perceived fraction social norm burning)*max acceptable cost for burning
Units: CHF/year/person

(057) amount for burning per capita=
fraction for burning*waste per year per capita wep
Units: kg/(year*person)

(058) cost for burning=
unit cost for burning*amount for burning per capita
Units: CHF/year/person

(059) effect of burning cost=
z effect of acceptable cost burning gbc endogenous(ratio cost for burning to acceptable)*(1-Switch to computed price exogenous)+z effect of acceptable cost burning gbc exogenous(ratio cost for burning to acceptable)*Switch to computed price exogenous
Units: Dmnl

(060) effect of time cost burning=
z effect of time burning(time spent burning/Acceptable time burning)
Units: Dmnl

(061) fract becoming unwilling from social norm=
z fraction f social norm burning(perceived fraction social norm burning)
Units: Dmnl/year

(062) max acceptable cost for burning = 180
Units: CHF/year/person

(063) max acceptable time for burning = 1
Units: hours/(week*person)

(064) perceived social norm separating= INTEG (fractional chg perception social norm, fraction willing to separate)
Units: Dmnl

(065) perceived fraction social norm burning=
1-perceived social norm separating
Units: Dmnl

(066) ratio cost for burning to acceptable=
cost for burning/Acceptable unit cost for burning
Units: Dmnl

(067) time per kg burning waste=
0.1

Units: hours/kg

(068) time spent burning=
(amount for burning per capita/weeks per year)*time per kg burning waste
Units: hours/(person*week)

(069) weeks per year=
52
Units: weeks/year

(070) z acceptable cost for burning(
[(0,0)-(1,1)],(0.0030581,0.394737),(0.088685,0.508772),(0.211009,0.666667),(0.379205,0.811404),
(0.587156,0.907895),(0.776758,0.973684),(1,1))
Units: Dmnl

(071) z acceptable time burning(
[(0,0)-(1,1)],(0,0),(0.0519878,0.263158),(0.165138,0.635965),(0.357798,0.890351),(0.584098,0.964912),
(1,1))
Units: Dmnl

(072) z effect of acceptable cost burning gbc endogenous(
[(0,0)-(5,1)],(0,1),(0.7,0.31),(0.8,0.2),(1,0.1),(1.2,0.06),(1.5,0.03),(2.5,0),(5,0))
Units: Dmnl

(073) z effect of acceptable cost burning gbc exogenous(
[(0,0)-(5,1)],(0,1),(0.5,0.32),(0.65,0.2),(0.95,0.1),(1.2,0.06),(1.5,0.03),(2.5,0),(5,0))
Units: Dmnl

(074) z effect of time burning(
[(0,0)-(2,1.2)],(0,1.1),(0.2,1.1),(0.7,1.05),(1,1),(1.15,0.85),(1.4,0.1),(1.6,0),(2,0))
Units: Dmnl

(075) z fraction f social norm burning(
[(0,0.1)-(1,0.4)],(0,0.19),(0.1,0.19),(0.3,0.2),(0.45,0.22),(0.55,0.23),(1,0.23))
Units: Dmnl/year

****
."31 Pool for effects on flow people"
****

(077) effect of waste per capita on time spent separating=
z effect of waste per capita on time spent separating(zidz(waste per year per capita wep,Solid waste generation per capita normal))
Units: Dmnl

(078) ratio recyclable to appropriate=
z effect or ratio recyclable to appropriately separated(zidz(total amount recyclable material
,total amount appropriately separated))
Units: Dmnl

(079) Switch on no price burning after 2003 = 0
Units: Dmnl [0,1,1]

(080) unit space cost for burnable material = 0.05
Units: CHF/kg

(081) z effect of number recycling streams on unit cost(
[(0,0)-(4,10)],(0.03,10),(0.25,5),(0.36,3.5),(0.5,2.4),(0.7,1.5),(1,1),(1.5,0.6),(2.5,0.2),(3 ,0.09),(4,0))
Units: Dmnl

(082) z effect of waste per capita on time spent separating(

[(0,0)-(4,1.2)],(0,0),(0.3,0.49),(0.5,0.73),(0.7,0.9),(1,1),(1.4,1.1),(2.2,1.16),(2.7,1.18),(4,1.2))
Units: Dmnl

(083) z effect of ratio recyclable to appropriately separated(
[(0,0)-(2,1)],(0,0),(0.07,0.03),(0.2,0.9),(0.26,0.97),(0.33,1),(2,1))
Units: Dmnl

****
."4 Separation behavior wep"
****

(085) actual possible recyclable amount from wep=
actual recyclable material per person*ep willing to separate
Units: kg/year

(086) actual total amount nonrecyclable material from wep=
waste generated by wep per year-actual possible recyclable amount from wep
Units: kg/year

(087) ep willing to separate= INTEG (wiep getting experienced+ep getting remotivated-ep getting disappointed,
(population - initial value nwp-initial value wiep))
Units: people

(088) normal amount appropriately separated wep=
waste per year per capita wep*normal fraction appropriately separated wep*multiplier for recyclable material from number of recycling streams
Units: kg/(people*year)

(089) normal amount inappropriately separated wep = 0
Units: kg/(people*year)

(090) normal fraction appropriately separated wep = 0.38
Units: Dmnl

(091) normal fraction recyclable = 0.44
Units: Dmnl [0.44,1]

(092) waste generated by wep per year=
ep willing to separate*waste per year per capita wep
Units: kg/year

(093) waste per year per capita wep=
solid waste generation per capita
Units: kg/(person*year)

(094) z multiplier for recyclable material from number of recycling streams(
[(0,0)-(4,2)],(0,0),(0.75,0.75),(1.2,1.2),(1.6,1.45),(1.9,1.6),(2.29969,1.7),(2.9,1.75),(4,1.85))
Units: Dmnl

****
."5 separation behavior wiep"
****

(096) actual possible recyclable amount from wiep=
actual recyclable material per person*iep willing to separate
Units: kg/year

(097) actual total amount nonrecyclable material from wiep=
waste generated by wiep per year-actual possible recyclable amount from wiep
Units: kg/year

(098) iep willing to separate= INTEG (iep getting motivated-uep getting disappointed-wiep getting experienced, initial value wiep)
Units: people

(099) multiplier for recyclable material from number of recycling streams=
z multiplier for recyclable material from number of recycling streams(zidz(effective nr recycling streams, Initial number recycling streams))
Units: Dmnl

(100) normal amount appropriately separated wiep=
normal fraction appropriately separated wiep*waste per capita per year wiep*multiplier for recyclable material from number of recycling streams
Units: kg/(people*year)

(101) normal amount inappropriately separated wiep = 0
Units: kg/(people*year)

(102) normal fraction appropriately separated wiep = 0.24
Units: Dmnl

(103) waste generated by wiep per year =
waste per capita per year wiep*iep willing to separate
Units: kg/year

(104) waste per capita per year wiep=
solid waste generation per capita
Units: kg/(year*people)

****
."6 Separation behavior nwiep"
****

(106) actual possible recyclable amount from nwiep=
actual recyclable material per person*iep not willing to separate
Units: kg/year

(107) actual total amount nonrecyclable material from nwiep=
waste generated by nwiep per year-actual possible recyclable amount from nwiep
Units: kg/year

(108) iep not willing to separate= INTEG (nwep losing experience+uep getting disappointed-iep getting motivated, initial value nwp-initial value nwep)
Units: people

(109) waste generated by nwiep per year=
iep not willing to separate*waste per capita per year nwiep
Units: kg/year

****
."61 Inappropriately separated per nwiep"
****

(111) effect of change in nr streams=
z effect of change in nr streams(effect of change in nr streams on normal amount appropriately separated nwiep)
Units: Dmnl

(112) inappropriately separated per nwiep=
normal amount inappropriately separated nwiep*multiplier for inappropriately separated from relative price burning to separation *effect of change in nr streams
Units: kg/(people*year)

(113) multiplier for inappropriately separated from relative price burning to separation=
z multiplier for inappropriately separated from relative price burning(relative price burning to separation)
Units: Dmnl

(114) normal amount appropriately separated nwiep=
waste per capita per year nwiep*normal fraction appropriately separated nwiep*effect of change in nr streams on normal amount appropriately separated nwiep
Units: kg/(people*year)

(115) normal amount inappropriately separated nwiep = 10
Units: kg/(people*year)

(116) normal fraction appropriately separated nwiep = 0.2
Units: Dmnl

(117) relative price burning to separation=
unit cost for burning/unit separation cost
Units: Dmnl

(118) unit cost for burning=
((price for burning real data+unit space cost for burnable material)* (Switch to computed price exogenous)) +
((unit space cost for burnable material+price burning endogenous*Switch price for burning)*
(1-Switch to computed price exogenous))*no price burning after 2003
Units: CHF/kg

(119) unit separation cost=
unit separation space cost+price for separated material
Units: CHF/kg

(120) waste per capita per year nwiep=
solid waste generation per capita
Units: kg/(year*people)

(121) z effect of change in nr streams(
[(0,0)-(5,3)],(0,0),(1,1),(5,2))
Units: Dmnl

(122) z effect of change in nr streams on normal amount appropriately separated(
[(0,0)-(4,1.1)],(0,0),(1,1),(1.16,1.04),(1.45,1.07),(4,1.1))
Units: Dmnl

(123) z multiplier for inappropriately separated from relative price burning(
[(0,0)-(15,10)],(0,0),(0.5,0),(0.7,0.2),(1,1),(10,2),(15,3))
Units: Dmnl

****
."7 Separation behavior nwep"
****

(125) actual possible recyclable amount from nwep=
actual recyclable material per person*ep not willing to separate
Units: kg/year

(126) actual total amount nonrecyclable material from nwep=
waste generated by nwep per year-actual possible recyclable amount from nwep
Units: kg/year

(127) effect of change in nr streams on normal amount appropriately separated nwiep=
z effect of change in nr streams on normal amount appropriately separated(zidz
(effective nr recycling streams, Initial number recycling streams))

Units: Dmnl

(128) ep not willing to separate= INTEG (
ep getting disappointed-nwep losing experience-ep getting remotivated, initial value nwep)
Units: people

(129) normal amount appropriately separated nwep=
normal fraction appropriately separated nwep*waste per capita per year nwep*effect of change in nr streams on normal amount appropriately separated nwiep
Units: kg/(people*year)

(130) normal amount inappropriately separated nwep = 0
Units: kg/(people*year)

(131) normal fraction appropriately separated nwep = 0.2
Units: Dmnl

(132) waste generated by nwep per year = ep not willing to separate*waste per capita per year nwep
Units: kg/year

****
."8 Fractions and amounts"
****

(134) accumulated fraction impure material in separated waste= INTEG (
fractional rate impurity, 0)
Units: Dmnl

(135) actual recyclable material per person=
normal fraction recyclable*waste per year per capita wep*multiplier for recyclable material from number of recycling streams
Units: kg/(people*year)

(136) adj time frac rate impure material in sep waste = 1
Units: year

(137) appropriately separated by newp=
normal amount appropriately separated nwep*ep not willing to separate
Units: kg/year

(138) appropriately separated by nwiep=
normal amount appropriately separated nwiep*iep not willing to separate
Units: kg/year

(139) appropriately separated by wep=
normal amount appropriately separated wep*ep willing to separate
Units: kg/year

(140) appropriately separated by wiep=
normal amount appropriately separated wiep*iep willing to separate
Units: kg/year

(141) control separated waste=
zidz((total amount appropriately separated+tot amount inappropriately separated), total amount separated)
Units: Dmnl

(142) control total waste=
zidz((population*waste per capita per year nwep),total amount solid waste)
Units: Dmnl

(143) fraction for burning=

zidz(total amount diposed for burning , total amount solid waste)
Units: Dmnl

(144) fraction separated=
zidz(total amount separated,total amount solid waste)
Units: Dmnl

(145) fractional rate impurity=
ratio impure material in separated waste/adj time frac rate impure material in sep waste
Units: Dmnl/year

(146) inappropriately separated by nwep=
normal amount inappropriately separated nwep*ep not willing to separate
Units: kg/year

(147) inappropriately separated by nwiep=
inappropriately separated per nwiep*iep not willing to separate
Units: kg/year

(148) inappropriately separated by wep=
normal amount inappropriately separated wep*ep willing to separate
Units: kg/year

(149) inappropriately separated by wiep=
normal amount inappropriately separated wiep*iep willing to separate
Units: kg/year

(150) nonrecyclable disposed for burning by nwep=
actual total amount nonrecyclable material from nwep-inappropriately separated by nwep
Units: kg/year

(151) nonrecyclable disposed for burning by nwiep=
actual total amount nonrecyclable material from nwiep-inappropriately separated by nwiep
Units: kg/year

(152) nonrecyclable disposed for burning by wep=
actual total amount nonrecyclable material from wep-inappropriately separated by wep
Units: kg/year

(153) nonrecyclable disposed for burning by wiep=
actual total amount nonrecyclable material from wiep-inappropriately separated by wiep
Units: kg/year

(154) population = 10705
Units: people

(155) ratio impure material in separated waste=
zidz(tot amount inappropriately separated , total amount separated)
Units: Dmnl

(156) recyclable disposed for burning by nwep=
actual possible recyclable amount from nwep-appropriately separated by nwep
Units: kg/year

(157) recyclable disposed for burning by nwiep=
actual possible recyclable amount from nwiep-appropriately separated by nwiep
Units: kg/year

(158) recyclable disposed for burning by wep=
actual possible recyclable amount from wep-appropriately separated by wep
Units: kg/year

(159) recyclable disposed for burning by wiep=
actual possible recyclable amount from wiep-appropriately separated by wiep
Units: kg/year

(160) total amount recyclable material=
actual recyclable material per person*population
Units: kg/year

(161) total amount solid waste=
total amount diposed for burning+total amount separated
Units: kg/year

(162) waste per capita per year nwep=
solid waste generation per capita
Units: kg/(year*people)

****
."9 Computed garbage bag charge"
****

(164) actual number garbage bags=
total amount diposed for burning/actual weight garbage bag
Units: bag/years

(165) adj gbc=
((indicated garbage bag charge*no price burning after 2003-garbage bag charge)/adj time gbc)*
Switch price for burning
Units: CHF/(years*bag)

(166) adj time gbc = 0.5
Units: years

(167) assumed number garbage bags=
total amount diposed for burning/assumed weight per garbage bag
Units: bag/years

(168) assumed weight per garbage bag = 3
Units: kg/bag

(169) bag charge policy = IF THEN ELSE(Time>1990,1 , 0)
Units: Dmnl

(170) garbage bag charge= INTEG (
adj gbc, 0)
Units: CHF/bag

(171) garbage bag charge exogenous=
(price for burning real data*assumed weight per garbage bag)
Units: CHF/bag

(172) indicated garbage bag charge=
(zidz(cost swm that should be covered by bag charge,assumed number garbage bags))*bag charge policy
Units: CHF/bag

(173) no price burning after 2003=
(IF THEN ELSE(Time > 2003, 0 , 1))*Switch on no price burning after 2003 + 1*(1-Switch on no price burning after 2003)
Units: Dmnl

(174) price burning endogenous=

(garbage bag charge/actual weight garbage bag)
Units: CHF/kg

(175) Switch to computed price exogenous = 0
Units: Dmnl [0,1,1]

****
."91 Cost solid waste management"
****

(177) capacity in collecting points for recovering= INTEG (
capacity building-depreciation,0)
Units: kg/year

(178) cost swm that should be covered by bag charge=
total cost for waste management-revenue from separated material-revenue from tax
Units: CHF/year

(179) effect of impurity on recycling unit cost=
z effect of impurity on recycling cost(fraction impurity)
Units: Dmnl

(180) effect of number recycling streams on recycling unit cost=
z effect of number recycling streams on unit cost (zidz (Initial number recycling streams, effective nr recycling streams))
Units: Dmnl

(181) Incineration cost per unit = 0.23
Units: CHF/kg [0.1,0.23,0.05]

(182) Recycling cost per unit = 0.1
Units: CHF/kg [0,0.5,0.05]

(183) revenue from separated material=
av amount separated*price separation
Units: CHF/year

(184) revenue from tax=
(z revenue from tax(Time))
Units: CHF/years

(185) tot var cost for separated material=
((total amount separated - capacity in collecting points for recovering) *unit cost for separated material)
Units: CHF/years

(186) tot var cost for waste disposed for burning=
(Incineration cost per unit+unit cost for collecting burnable material)*total amount disposed for burning
Units: CHF/years

(187) total amount disposed for burning=
nonrecyclable disposed for burning by nwep+nonrecyclable disposed for burning by nwiep+nonrecyclable disposed for burning by wep+nonrecyclable disposed for burning by wiep+recyclable disposed for burning by nwep+recyclable disposed for burning by nwiep+recyclable disposed for burning by wep+recyclable disposed for burning by wiep
Units: kg/year

(188) total amount separated=
appropriately separated by wep+appropriately separated by nwep+appropriately separated by nwiep
+appropriately separated by wiep+inappropriately separated by nwep+inappropriately separated by nwiep
+inappropriately separated by wep+inappropriately separated by wiep
Units: kg/year

(189) total cost for waste management=
tot var cost for waste disposed for burning+tot var cost for separated material
Units: CHF/year

(190) unit cost for collecting burnable material=
0.1
Units: CHF/kg

(191) unit cost for collecting separated material = 0.2
Units: CHF/kg [0,1]

(192) unit cost for separated material=
(unit cost for collecting separated material *effect of number recycling streams on recycling unit cost
+ Recycling cost per unit) * effect of impurity on recycling unit cost
Units: CHF/kg

****
."911 Profit solid waste management"
****

(194) accumulated total cost for waste management= INTEG (
cost for waste management,0)
Units: CHF

(195) cost for waste management=
total cost for waste management
Units: CHF/years

(196) non profit threshold=
z profit threshold(Time)
Units: CHF/year

(197) profit solid waste management=
(revenue from incineration waste+revenue from separated material+revenue from tax) –
total cost for waste management
Units: CHF/years

(198) revenue from incineration waste=
((garbage bag charge*actual number garbage bags)*(1-Switch to computed price exogenous))
+ ((garbage bag charge exogenous*actual number garbage bags) * (Switch to computed price exogenous))
Units: CHF/years

(199) z profit threshold(
[(1987,0)-(2020,10)],(0,0),(1987,0),(2020,0))
Units: CHF/year

****
."92 Impurity"
****

(201) av amount inappropriately separated= INTEG (
change in average impurity, tot amount inappropriately separated)
Units: kg/year

(202) change in average impurity=
(tot amount inappropriately separated-av amount inappropriately separated)/time to average waste amount
Units: kg/(year*year)

(203) chg in av amount separated=
(total amount separated-av amount separated)/time to average waste amount

Units: kg/(year*year)

(204) fraction impurity=
zidz(av amount inappropriately separated, av amount separated)
Units: Dmnl

(205) time to average waste amount = 2
Units: years

(206) tot amount inappropriately separated=
inappropriately separated by nwep+inappropriately separated by nwiep+inappropriately separated by wep
+inappropriately separated by wiep
Units: kg/year

(207) z effect of impurity on recycling cost(
[(0,0)-(0.2,3)],(0,1),(0.03,1.15),(0.09,1.5),(0.14,2),(0.2,3))
Units: Dmnl

****
.''93 Prices separation and prepaid tax revenue''
****

(209) adj perception unit cost for separated material=
(unit cost for separated material-perceived unit cost for separated material)/adj time separation cost and price
Units: CHF/(kg*years)

(210) adj price for separating=
(perceived unit cost for separated material - price for separating) /adj time separation cost and price
Units: CHF/(years*kg)

(211) adj time separation cost and price = 1
Units: year

(212) av amount separated= INTEG (chg in av amount separated, total amount separated)
Units: kg/year

(213) normal unit cost of one unit of capacity building = 0.14
Units: CHF/kg

(214) perceived unit cost for separated material= INTEG (
adj perception unit cost for separated material, unit cost for separated material)
Units: CHF/kg

(215) prepaid disposal tax 2004 = 0.2
Units: CHF/kg

(216) price for separating= INTEG (
adj price for separating, 0)
Units: CHF/kg

(217) price separation=
IF THEN ELSE(Time>2003, price for separating * Switch on price separation 2004, 0)
Units: CHF/kg

(218) revenue from prepaid disposal tax=
IF THEN ELSE(Time>2003, prepaid disposal tax 2004 , 0) * total amount separated * Switch prepaid disposal tax
Units: CHF/year

(219) Switch on price separation 2004 = 0
Units: Dmnl [0,1,1]

(220) time to perceive revenue from pdt = 2
Units: years

(221) total amount appropriately separated=
appropriately separated by nwep+appropriately separated by nwiep+appropriately separated by wep +appropriately separated by wiep
Units: kg/year

(222) z effect on cost of one unit of capacity building(
[(0,0)-(20,10)],(0,0),(1.45,1.3),(2.5,1.7),(3.8,1.9),(5.5,2.1),(11.2,2.8),(12.8,3),(16,4),(17.4 ,4.5),
(18.3,5.5),(20,10))
Units: Dmnl

****
."94 Policy prepaid disposal tax"
****

(224) average amount recovered material=
SMOOTH(total amount separated,time to av amount recovered material)
Units: kg/year

(225) average life time local capacity = 10
Units: year

(226) Cap adj time = 3
Units: year

(227) capacity building=
(desired cap building/Cap adj time)*fraction of desired capacity building
Units: kg/(year*year)

(228) cost of one unit of capacity building=
normal unit cost of one unit of capacity building*(z effect on cost of one unit of capacity building (effective nr recycling streams))
Units: CHF/kg

(229) crowding=
zidz(average amount recovered material , ((normal capacity for recovering
* (1-weight on capacity)) + capacity in collecting points for recovering*weight on capacity))
Units: Dmnl

(230) depreciation=
capacity in collecting points for recovering/average life time local capacity
Units: kg/(year*year)

(231) desired cap building=
(depreciation*Cap adj time)+desired capacity adjustment
Units: kg/(year)

(232) desired capacity adjustment=
(average amount recovered material-capacity in collecting points for recovering)
Units: kg/year

(233) effect of crowding=
z effect of crowding(crowding)
Units: Dmnl

(234) fraction of desired capacity building=
z frac of des capacity building(ratio of desired to max capacity)
Units: Dmnl

(235) Max cap building=
zidz(perceived revenue from prepaid disposal tax,cost of one unit of capacity building)
Units: kg/year

(236) normal capacity for recovering=
average amount recovered material
Units: kg/year

(237) perceived revenue from prepaid disposal tax=
SMOOTH(revenue from prepaid disposal tax, time to perceive revenue from pdt)
Units: CHF/year

(238) ratio of desired to max capacity=
zidz(desired cap building, Max cap building)
Units: Dmnl

(239) Switch prepaid disposal tax = 1
Units: Dmnl [0,1,1]

(240) time to av amount recovered material = 3
Units: year

(241) weight on capacity=
z weight on capacity(Time)*Switch prepaid disposal tax + (0 * (1-Switch prepaid disposal tax)
)
Units: Dmnl

(242) z effect of crowding(
[(0,0)-(80,2)],(0,0.8),(1,1),(2,1.2),(4,1.6),(5,1.8),(5.9,1.95),(7,2),(60,2))
Units: Dmnl

(243) z frac of des capacity building(
[(0,0)-(2,1)],(0,0),(0.8,0.8),(0.95,0.9),(1.05,0.93),(1.2,0.97),(1.6,1),(2,1))
Units: Dmnl

(244) z weight on capacity(
[(1987,0)-(2020,10)],(1987,0),(2000,0),(2003.65,1),(2020,1))
Units: Dmnl

****
."95 Economic growth"
****

(246) constant average income per capita = 70000
Units: CHF/(year*person)

(247) fractional change in sw generation per capita from economic growth=
(zidz((potential SW generation per capita from economic growth-solid waste generation per capita),
solid waste generation per capita))/time to adjust SW generation from economic growth
Units: Dmnl/year

(248) growth income=
income per capita/income per capita normal
Units: Dmnl

(249) income per capita=
constant average income per capita*(1-Switch to test economic growth)+Switch to test economic growth
*initial income per capita*EXP(income per capita growth rate *(Time- INITIAL TIME))
Units: CHF/(person*year)

(250) income per capita growth rate = 0.025
Units: Dmnl/year

(251) income per capita normal =
constant average income per capita*(1-Switch to test economic growth)+Switch to test economic growth *initial income per capita
Units: CHF/(person*year)

(252) initial income per capita = 35000
Units: CHF/(year*person)

(253) INITIAL TIME = 1987
Units: year

(254) potential SW generation per capita from economic growth=
Solid waste generation per capita normal*growth income
Units: kg/person/year

(255) rate of change of solid waste generation per capita=
fractional change in sw generation per capita from economic growth*solid waste generation per capita
Units: kg/((year*person)*year)

(256) solid waste generation per capita= INTEG (
rate of change of solid waste generation per capita, Solid waste generation per capita normal)
Units: kg/(person*year)

(257) Solid waste generation per capita normal = 339
Units: kg/(year*person) [0,339,339]

(258) Switch to test economic growth = 0
Units: Dmnl [0,1,1]

(259) time to adjust SW generation from economic growth = 2
Units: years

****
."96 Real data variables"
****

(261) actual weight garbage bag = 3
Units: kg/bag

(262) effective nr recycling streams=
(increase in recycling streams*Switch change number of recycling streams) + (Initial number recycling streams * (1-Switch change number of recycling streams))
Units: streams

(263) fraction for burning real data=
1-fraction recovered real data
Units: Dmnl

(264) fraction recovered real data=
z fraction recovered real data(Time)
Units: Dmnl

(265) increase in recycling streams=
(increase in recycling streams after 2004 * Switch on increase in recycling streams after 2004)
+ (increase number recyc stream 2000 * (1-Switch on increase in recycling streams after 2004))
Units: streams

(266) increase in recycling streams after 2004=

z increase in nr recycling streams 2020(Time)
Units: streams

(267) increase number recyc stream 2000=
z number recycling stream(Time)
Units: streams

(268) Initial number recycling streams = 5
Units: streams [0,5,5]

(269) price for burning real data=
(z garbage bag charge(Time) /actual weight garbage bag)*Switch price for burning
Units: CHF/kg

(270) recycling cost real data=
z recycling cost(Time)
Units: CHF/kg

(271) Switch change number of recycling streams = 1
Units: Dmnl [0,1,1]

(272) Switch on increase in recycling streams after 2004 = 0
Units: Dmnl [0,1,1]

(273) Switch price for burning = 1
Units: Dmnl [0,1,1]

(274) three median smooth fraction burned=
1-three median smooth fraction separated
Units: Dmnl

(275) three median smooth fraction separated=
z three median smooth fraction recycled(Time)
Units: Dmnl

(276) z fraction recovered real data(
[(1980,0)-(2025,1)],(1980,0.3),(1987,0.3),(1988,0.3),(1989,0.3),(1989.91,0.0877193),(1990,0.2),
(1991,0.4),(1992,0.4),(1993,0.4),(1994,0.4),(1995,0.4),(1996,0.4),(1997,0.5),(1998,0.4),
(1998 ,0.4),(1999,0.5),(2000,0.5),(2001,0.5),(2025,0.5))
Units: Dmnl

(277) z garbage bag charge(
[(1980,0)-(2020,2)],(1980,0),(1987,0),(1989.05,0),(1990.03,0),(1990.52,0.9),(1991.04,0.9),(1992.05,0.9),
(1996.59,0.9),(1997.9,0.9),(1998.5,1.8),(1999.51,1.8),(2000,1.8),(2000.22,1.8),(2001.33,1.8),(2020,1.8))
Units: CHF/bag

(278) z increase in nr recycling streams 2020(
[(1987,0)-(2025,15)],(1980,5),(1987,5),(1989.22,5),(1990,5),(1991.54,6),(1993,8),(1997,8),(1998,9),
(2001,9),(2004,10),(2007,11),(2010,12),(2014,13),(2017,14),(2019.7,14),(2025,14))
Units: streams

(279) z number recycling stream(
[(1980,0)-(2025,15)],(1980,5),(1987,5),(1989.22,5),(1991.54,6),(1993,8),(1997,8),(1998,9),(2001,9),
(2008.5,9),(2013.34,9),(2019.7,9),(2025,9))
Units: streams

(280) z recycling cost(
[(1987,0)-(2000,2e+006)],(1987,495551),(1988,567929),(1989,622386),(1990,667097),(1991,830192),
(1992,843181),(1993,1.02337e+006),(1994,1.0064e+006),(1995,968247),(1996,967072),
(1997,1.01862e+006),(1998,1.08543e+006),(2000,1.1653e+006),(1.09955e+006,1999))
Units: CHF/kg

(281) z revenue from tax(
[(1987,0)-(2020,2e+006)],(1987,500000),(1988.61,500000),(1990.03,500000),(2020,500000))
Units: CHF/years

(282) z three median smooth fraction recycled(
[(1980,0)-(2025,1)],(1980,0.27),(1987,0.27),(1988,0.27),(1989,0.26),(1990,0.26),(1991,0.37),(1992,0.41),
(1993,0.41),(1994,0.44),(1995,0.44),(1996,0.45),(1997,0.45),(1998,0.46),(1999,0.47),(2000,0.49),(2001,0.5),
(2001,0.5),(2025,0.5))
Units: Dmnl

****
.Control
****

Simulation Control Parameters

(284) FINAL TIME = 2020
Units: year

(285) SAVEPER = 1
Units: year [0,?]

(286) TIME STEP = 0.03125
Units: year [0,?]

A3 List of parameters, initial values and graphs

S: Stock; C: Constant; G: Graph

	Variable name	Unit	Value	Qualification	Sens. Control
	View Flows of people				
S	Initial value not willing people	People	5730	Modeler defined, calibrated, tipping point	Yes
S	Initial value not willing experienced people	People	1500	Modeler defined, calibrated	No
S	Initial value willing inexperienced people	People	663	Modeler defined, calibrated	No
C	Min number unwilling to separate	People	1’100	Modeler defined, not too influential	No
C	Min number willing people to separate	People	1’100	Modeler defined, not too influential	No
C	Average time to forget	Years	5	Modeler defined, not too influential	No
C	Population	People	10705	Given data	No
	View Time on moving from iep to ep				
C	Min time constant on moving form iep to ep	Years	1	Modeler defined, calibrated	No
C	Time to average amount appropriately separated	Years	3	Modeler defined	No
G	Z effect of experience with separation on fime for moving from wiep to wep	Dmnl	Non-linear	Modeler defined, calibrated	-
	View Fraction becoming willing				
C	Max acceptable separating time	Hours/week	2	Modeler defined, highly influential and uncertain	Yes
C	Max acceptable separation cost	CHF/(year*person)	150	Modeler defined, highly influential and uncertain but not critical	No
C	Normal time per stream	Hours/(week*streams)	0.2	Modeler defined, highly influential and uncertain, Policy parameter	Yes
C	Time to perceive fraction willing to separate	Year	1	Modeler defined	No
C	Unit separation space cost	CHF/kg	0.1	Modeler defined	No
G	Z fraction from social norm	1/year	Non-linear	Modeler defined, calibrated	-
G	Z acceptable separating time	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z effect of time cost recycling	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z max acceptable separation cost	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z effect of separating cost	Dmnl	Non-linear	Modeler defined, calibrated	-

	View Fraction becoming unwilling				
C	Max acceptable time for burning	Hours/(person*week)	1	Modeler defined, not critical	No
C	Max acceptable cost for burning	CHF/(year*person)	180	Based on empirical evidence, influential but certain	No
C	Time per kg burning waste	Hours/kg	0.1	Modeler defined, not critical	No
G	Z fraction f social norm burning	Dmnl/year	Non-linear	Modeler defined, uncertain and relative influential	-
G	Z acceptable time burning	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z acceptable cost for burning	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z effect of time burning	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z effect of acceptable cost burning	Dmnl	Non-linear	Modeler defined, calibrated	-
	View Pool for effects on flow of people				
C	Unit space cost for burnable material	CHF/kg	0.05	Modeler defined, not critical	No
G	Z effect of waste per capita on time spent separating	Dmnl	Non-linear	Modeler defined, calibrated	-
G	Z effect of ratio recyclable to appropriate separated	Dmnl	Non-linear	Modeler defined	-
G	Z effect of number recycling streams on unit cost	Dmnl	Non-linear	Modeler defined, calibrated, very sensitive	-
	View Separation behavior wep				
C	Normal fraction appropriately separated wep	Dmnl	0.38	Modeler defined, calibrated to real data	No
C	Normal amount inappropriately separated wep	Kg/(people*year)	0	Modeler defined, calibrated to real data	No
C	Normal fraction recyclable	Dmnl	0.44	Modeler defined, calibrated to real data	No
G	Z multiplier for recyclable material from number of recycling streams	Dmnl	Non-linear	Modeler defined, calibrated	-
	View Separation behavior wiep				
C	Normal fraction appropriately separated wiep	Dmnl	0.24	Modeler defined, calibrated to real data	-
C	Normal amount inappropriately separated wiep	Kg/(people*year)	0	Modeler defined, calibrated to real data	-
	View Inappropriately separated per nwiep				
C	Normal fraction appropriately separated nwiep	Dmnl	.2	Modeler defined, calibrated to real data	No
C	Normal amount inappropriately separated nwep	Kg/(people*year)	10	Modeler defined, calibrated to real data	No
C	Initial number recycling streams	Streams	5	Real data, policy parameter	No
G	Z multiplier for inappropriately separated from relative price burning	Dmnl	Non-linear	Modeler defined, calibrated to real data	-
G	Z effect of change in nr streams	Dmnl	Non-linear	Modeler defined, calibrated to real data	-
G	Z effect of change in nr streams on normal amount appropriately separated	Dmnl	Non-linear	Modeler defined, calibrated to real data	-

	View Separation behavior nwep				
C	Normal fraction appropriately	Dmnl	0.2	Modeler defined, calibrated to real data	No

	separated nwep				
C	Normal amount inappropriately separated nwep	Kg/(people*year)	0	Modeler defined, calibrated to real data	No
	View Computed garbage bag charge				
C	Actual weight garbage bag charge	Kg/bag	3	Modeler defined, relevant	No
C	Assumed weight per garbage bag	Kg/bag	3	Modeler defined	No
C	Adj time garbage bag charge (gbc)	Year	0.5	Modeler defined	No
c	View Cost solid waste management				
C	Unit cost for collecting burnable material	CHF/kg	0.1	Modeler defined, policy parameter	Yes
C	Incineration cost per unit	CHF/kg	0.23	Modeler defined, scenario parameter	Yes
C	Unit cost for collecting separated material	CHF/kg	0.2	Modeler defined, policy parameter	Yes
C	Recycling cost per unit	CHF/kg	0.1	Modeler defined, scenario parameter	Yes
	View Impurity				
C	Time to average waste amount	Years	2	Modeler defined, scenario parameter	No
G	Z effect of impurity on recycling cost	Dmnl	Non-linear	Modeler defined, calibrated to real data, critical	-
	View Price separation and prepaid tax revenue				
C	Normal unit cost of one unit of capacity building	CHF/kg	0.14	Modeler defined, policy parameter	Yes
C	Prepaid disposal tax 2004	CHF/kg	0.2	Modeler defined, policy parameter	Yes
C	Time to perceive revenue from prepaid tax (pdt)	Years	2	Modeler defined, not critical	No
C	Adj. Time separation cost and price	Year	1	Modeler defined, not critical	No
G	Z effect on cost of one unit of capacity building	Dmnl	Non-linear	Modeler defined	-
	View Policy prepaid disposal tax				
C	Time to av amount recovered material	Years	3	Modeler defined	No
C	Average lifetime local capacity	Years	10	Modeler defined, not critical	No
C	Cap adj time	Years	3	Modeler defined, not critical	No
G	Z weight on capacity	Dmnl	Non-linear	Modeler defined, not critical	-
G	Z effect of crowding	Dmnl	Non-linear	Modeler defined, not critical	-
G	Z frac of des capacity building	Dmnl	Non-linear	Modeler defined, not critical	-
	View Economic growth				
C	Time to adjust SW generation from economic growth	Years	2	Modeler defined, not critical	No
C	Solid waste generation normal	Kg/(year*person)	339	Real data	No
C	Initial income per capita	CHF/(year*person)	35000	Modeler defined, not critical	No
C	Constant average income per capita	CHF/(year*person)	70000	Modeler defined, not critical	No
C	Income per capita growth rate	Dmnl	0.025	Modeler defined, not critical	No

	View Real data variables				
G	Z number recycling streams	Streams	Non-linear	Real data	-
G	Z increase in nr recycling streams 2020	Streams	Non-linear	Scenario	-
G	Z recycling cost	CHF/kg	Non-linear	Real data	-

G	Z price for burning	CHF/kg	Non-linear	Real data	-
G	Z three median smooth fraction recycled	Dmnl		Computed based on real data	-
G	Z fraction recovered real data	Dmnl	Non-linear	Real data	-
G	Z revenue from tax (constant)	CHF/year	500'000	Modeler defined based on real data	-

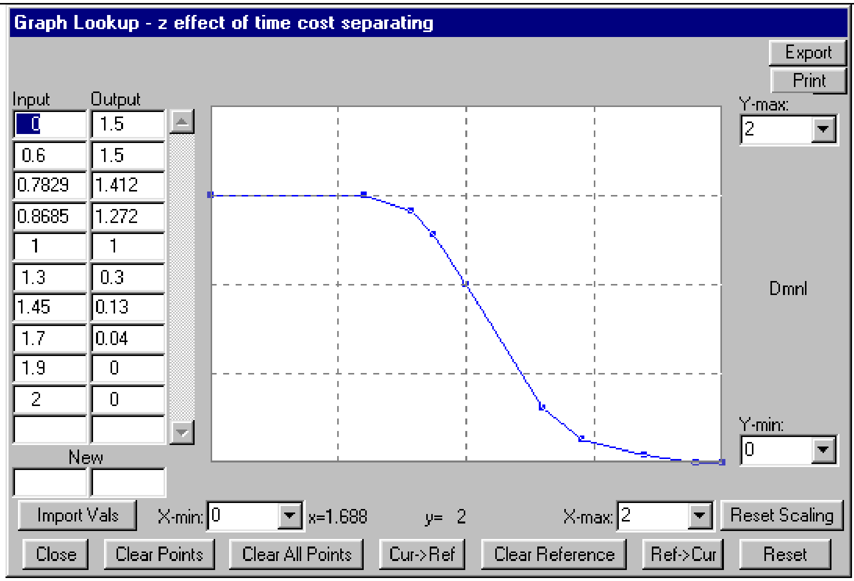
Table: Overview of input parameters and graphical functions

A4 The graphical functions

In the model 32 graphical functions are defined. In the "list graphical functions" all the graphs are displayed and explained group together according to the view in which they can be found in the simulation model.

The shape of the graphical functions is based on plausible causal assumption about the relationships between two variables. They reflect the assumption about nonlinear relationship between two variables; changes in the „input" variable (X-axis) imply nonlinear changes in the "output" variable (Y-axis). The most important reference criteria are the shape of the graph, the minimal and the maximal value. Often there is an important, well-defined reference value that the graph will pass such as the point (1,1). The "exact" values of the graph were found by calibrating the model to real data. Due to manual calibration processes some graph-values are unreasonable exact (to many digits after the comma). However the modeler tried mostly to limit those digits to two.

Example: Documentation of the graphical functions

Equation number and name	The shape of the graph	Reasoning
View "2 Fraction becoming willing		
(051) z effect of time cost separating		The graphical converter <*z effect of time cost separating*> computes the <*effect of the time cost separating*> on the diffusion process. The <*effect of the time cost separating*> is normalized; when <*time spent for separating*> equals <*acceptable time for separating*>*;* the graphical function passes the reference point (1,1). If the time cost is very low the diffusion process will be accelerated to a maximal value of 1.5. If the required <*time spent for separating*> is twice as high as the <*acceptable time for separating*> the diffusion process will be stopped.

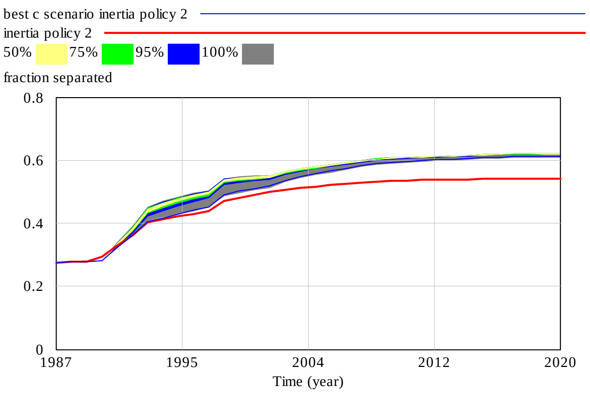
A5 Confidence bounds of the policy experiments under different scenarios

In the Table "**Confidence bounds of the policy experiments under different scenarios**" all the confidence bounds charts of the policy experiments under different scenarios are displayed, comparing the confidence bounds under best-case scenario and worst-case scenario. Confidence bounds of the following four policy-packages are available:

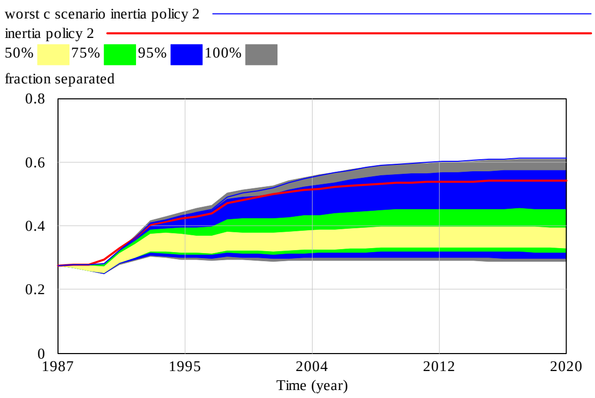
Confidence bounds of the policy experiments under different scenarios: comparing best case and worst case conditions.	Policy packages
	• Inertia policy 2 • Implement prepaid tax with flexible gbc • Implement prepaid tax with constant garbage bag charge • Implement price for burning and separated material and increase number recycling streams

Example confidence bound: Inertia policy 2

Best-case scenario



Worst-case scenario



B Documentation of the workshops from the preliminary study

B1 Cooperation and agreement & functional specification

This documents specifies the tasks of the actors involved in the workshops of the study.

B2 Selecting the experts

In this documents the raster is represented that was used for identifying the main experts for the group model building workshops.

B3 Schedule of the first two workshops

The detailed schedule is represented of the first two workshops.

B4 Scripts for the first two workshops

In this document the main course of action and procedure is described. It was used as the detailed guiding script of the first two workshops.

B5 Schedule and script of the third workshop

This documents contains the schedule and script of the final workshop.