EABSS Workshop 2023

Co-Creation of Agent-Based Social Simulation Models

Case Study (Siebers et al 2020)

Multi-Method Integrated Assessment Modelling of Global Climate Change

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

The Context

- Modelling and simulation play an increasingly significant role in **exploratory studies for informing policy makers** on climate change mitigation strategies

- There is considerable research being done in creating **Integrated Assessment Models** (IAMs), which focus on examining the human impacts on climate change

The Problem

- IAMs are often created as **steady state optimisation models**, holding **aggregate views** on variables, and hence are unable to capture a finer level of details of the underlying system components

- This presents a problem as the **risks and impacts** associated with climate change are **unevenly distributed**, geographically and demographically.

Alternatives

- An **alternative approach** that allows modelling populations as a collection of individual and unevenly distributed entities is **Agent-Based Modelling** (ABM) but simulating huge numbers of individual entities can quickly become an issue, as it **requires large amounts of computational resources**.

What about taking the best of both worlds and come up with a hybrid approach that overcomes the limitations of the individual approaches?

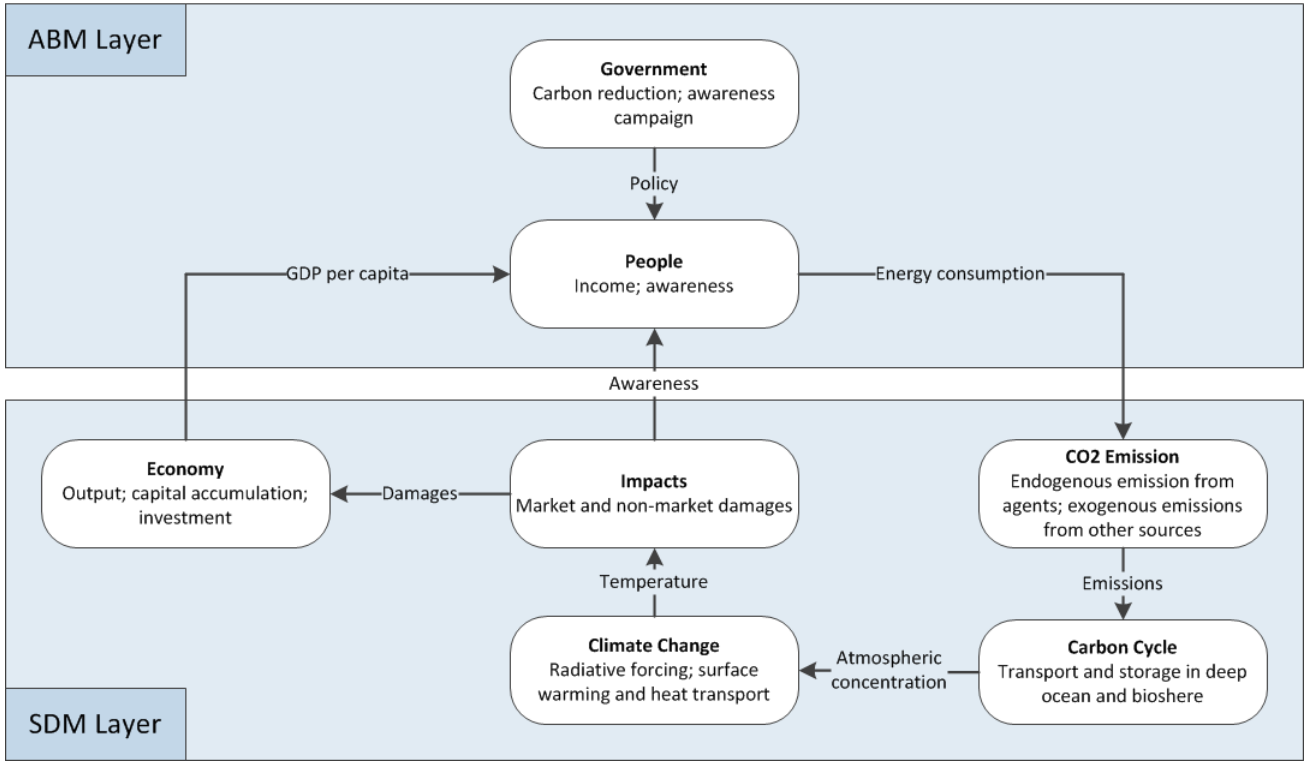
HCAM: Our Hybrid Approach

- We represent the **physical and economic environments** we use parts of a well-established **System Dynamics** (SD) interpretation of a well-established IAM called DICE (Nordhaus 1992)

- Social units and the **population** are embedded into this SD model in form of a hierarchical agent-based model.
  - At the top end we represents social units (nation; region; state) and at the bottom end we represent the population as a collection of **Collective Person Agent** (CPA) units
  - These CPA units are endowed with an **internal SD model** to track their collective psychological state, which influences their decision making

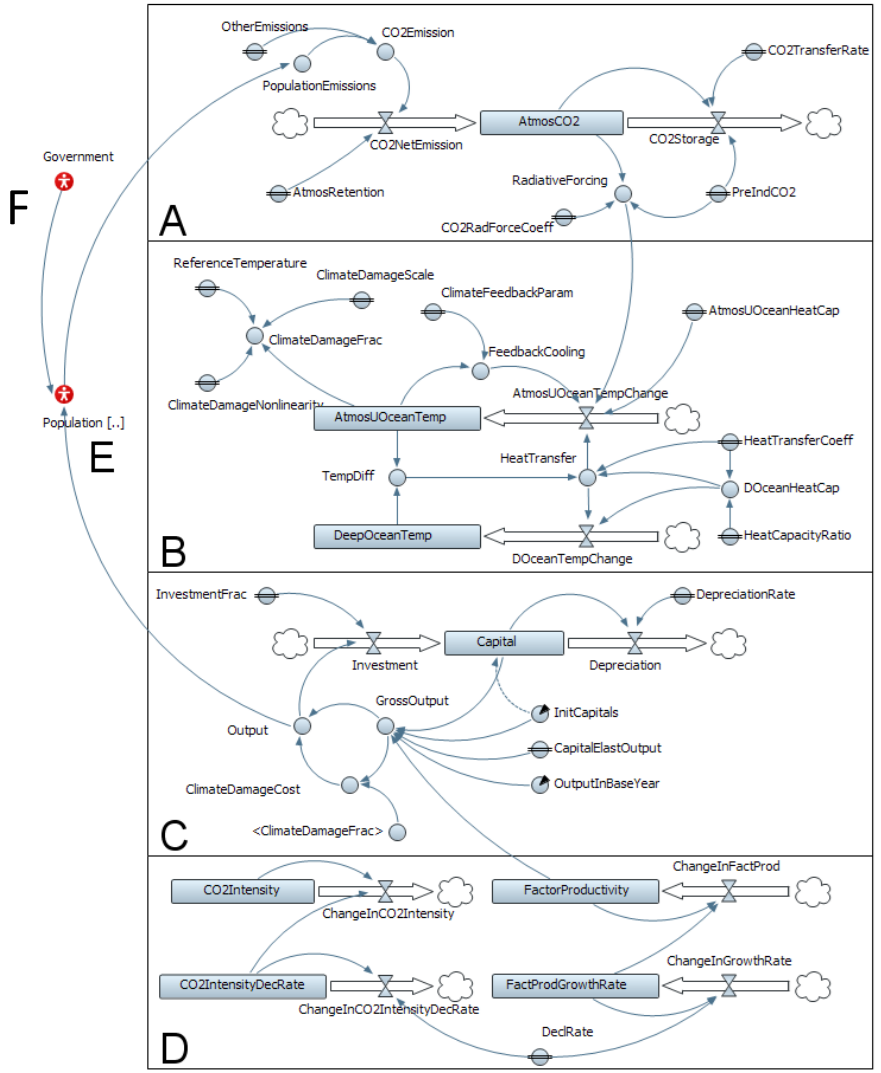
Conceptual Modelling

- Sector Boundary Map (showing feedback structure)



Conceptual Modelling

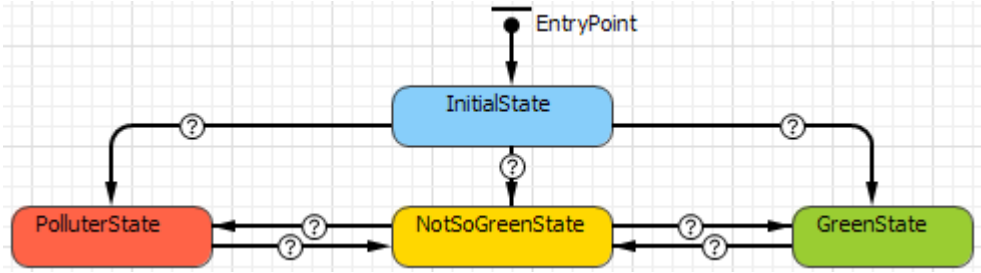
- Base Model
  - A = Carbon Cycle
  - B = Climate Subsystem
  - C = Economy Subsystem
  - D = Exogenous Drivers
  - E = Population
  - F = Government (Policy Makers)



Conceptual Modelling

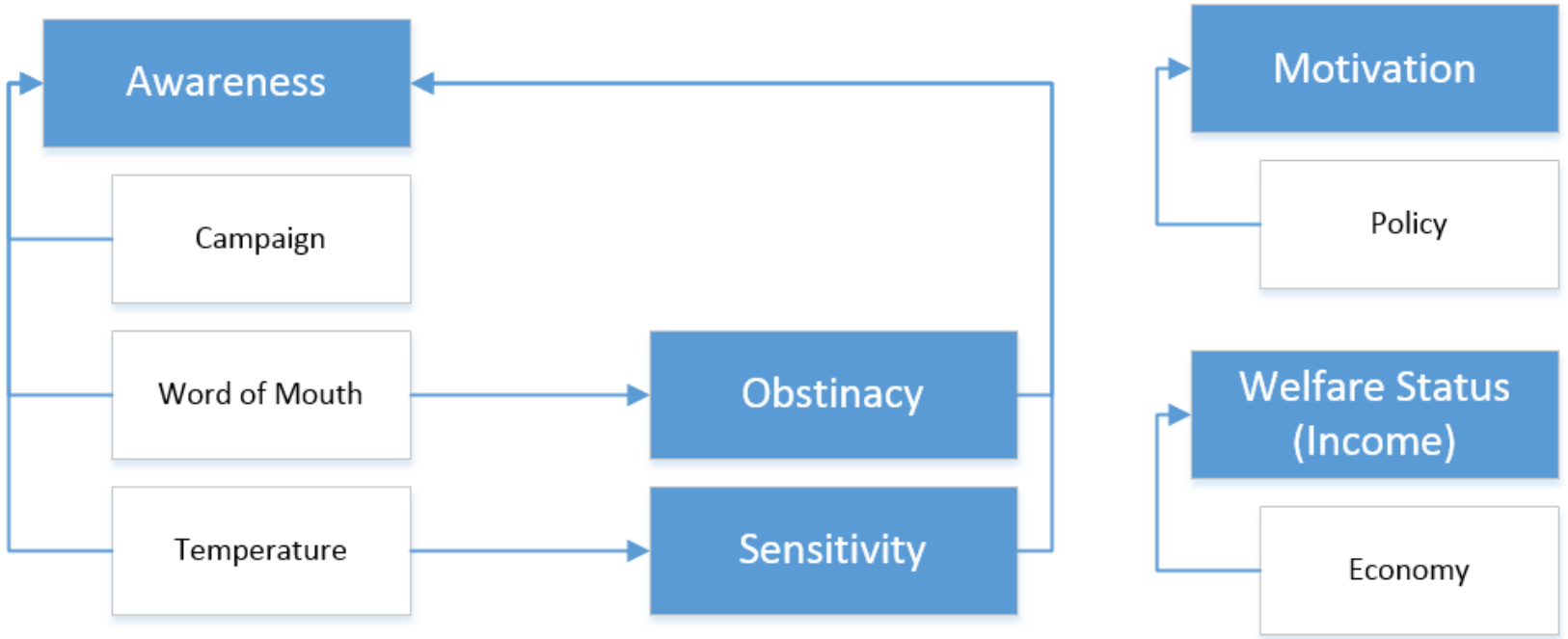
- Collective Person Agents (CPAs)
  - Capturing large populations through scaling (e.g. 1:250,000)
  - Activities of CPAs
    - Consume energy; produce emissions; network with other CPAs

- Classifications of CPAs
  - They are classified into different stereotypes, based on their emission levels; these range from "green" to "polluter"



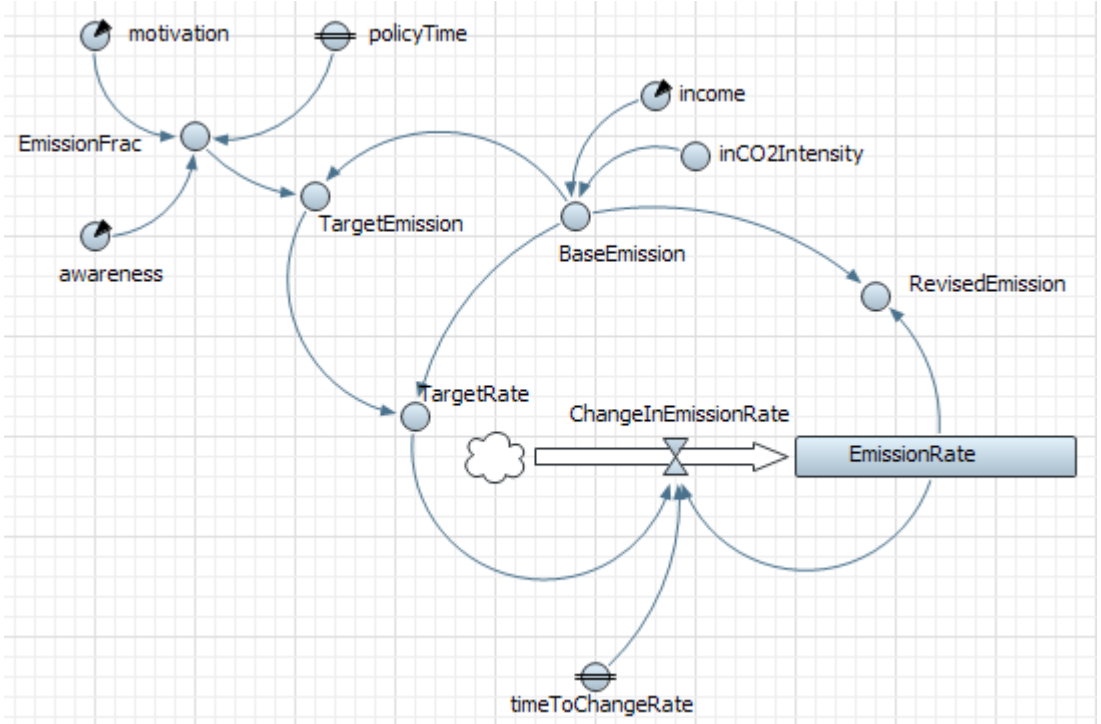
Conceptual Modelling

- Mental model of CPAs
  - Blue boxes: Mental model attributes
  - White boxes: External influences



Conceptual Modelling

- Behaviour model of CPAs
  - Emission rate SD model inside the CPAs



Conceptual Modelling

- Multi-level modelling of social structures
  - CPA $\subset$ State $\subset$ Region $\subset$ Nation

- Networking
  - All CPAs are equipped with networking modules, enabling them to communicate with each other by passing time-stamped InfluenceAction objects to each other

Conceptual Modelling

- Policies
  - Carbon reduction policy
    - Induces **motivation** on the people to cut down on their emissions
  - Awareness campaign policy
    - Raise public **awareness** on environmental issues

An Illustrative Example

- Our test case takes the settings of the USA
  - USA contributes to the majority of the global carbon footprints and is the largest economic power in the world
  - We investigate the carbon emissions and its relevant economic impacts on the nation

Given a constant amount of capital allocated for the climate mitigation sector, what is/are the most effective policy(s) that the federal government can invest the funds in to leverage the available resources?

climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]

x1 | experiment: climat... | AnyLogic

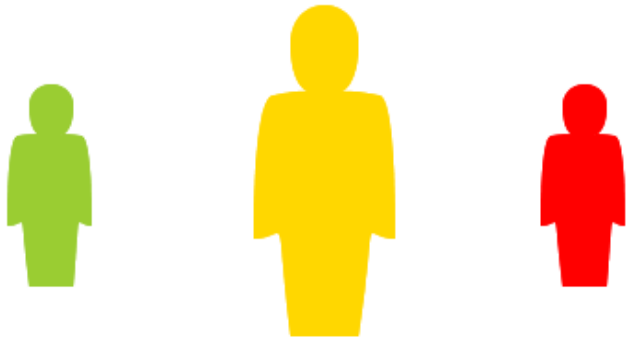
Hybrid Climate Assessment Model

This is an integrated climate assessment model. The model simulates the population, climate and economy of the United States. Population of people can be seen on the map as small dots. Red people produce the highest emissions while green people produce the lowest emissions.

This model is designed for policy analysis. You can implement different types of policies - carbon reduction policy and campaigns. You can also set how often the people talk to each other.

Scaling Factor: 250,000
Population represented by each Collective Person Agent
100,000 — 500,000

Run



People

Green Threshold: 30
Upper emission boundary for Green archetype
0 — 50

Contact Influence: 0.05
Influence weight of contact
0 — 0.1

Polluter Threshold: 50
Lower emission boundary for Polluter archetype
50 — 100

Contact Rate: 0
People contacted per month
0 — 50

Climate Sensitivity: 0.5 °C
Responsiveness to temperature anomaly
0 — 3

Contact Duration: 5
Duration of contact in days
5 — 50

Policy

Base Year: 2,019
Year to start implement policy
2,019 — 2,119

Campaign Rate: 0
Campaign organised per year
0 — 8

Carbon Reduction: 0
Target percentage reduction in carbon emissions
0 — 100

Campaign Duration: 2
Duration of campaign in weeks
0 — 4

Policy Influence: 0.5
Influence weight of policy
0 — 1

Campaign Influence: 2.5
Influence weight of campaign
0 — 5

Run: 0 Idle | Time: - | Simulation: Stop time not set | Date: - | Memory: 18M of 227M

climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]

Admin | Model | Statistics

Hybrid Climate Assessment Model

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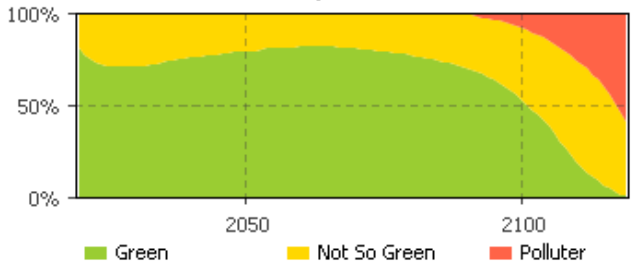
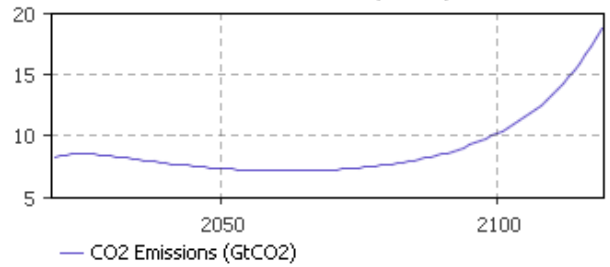
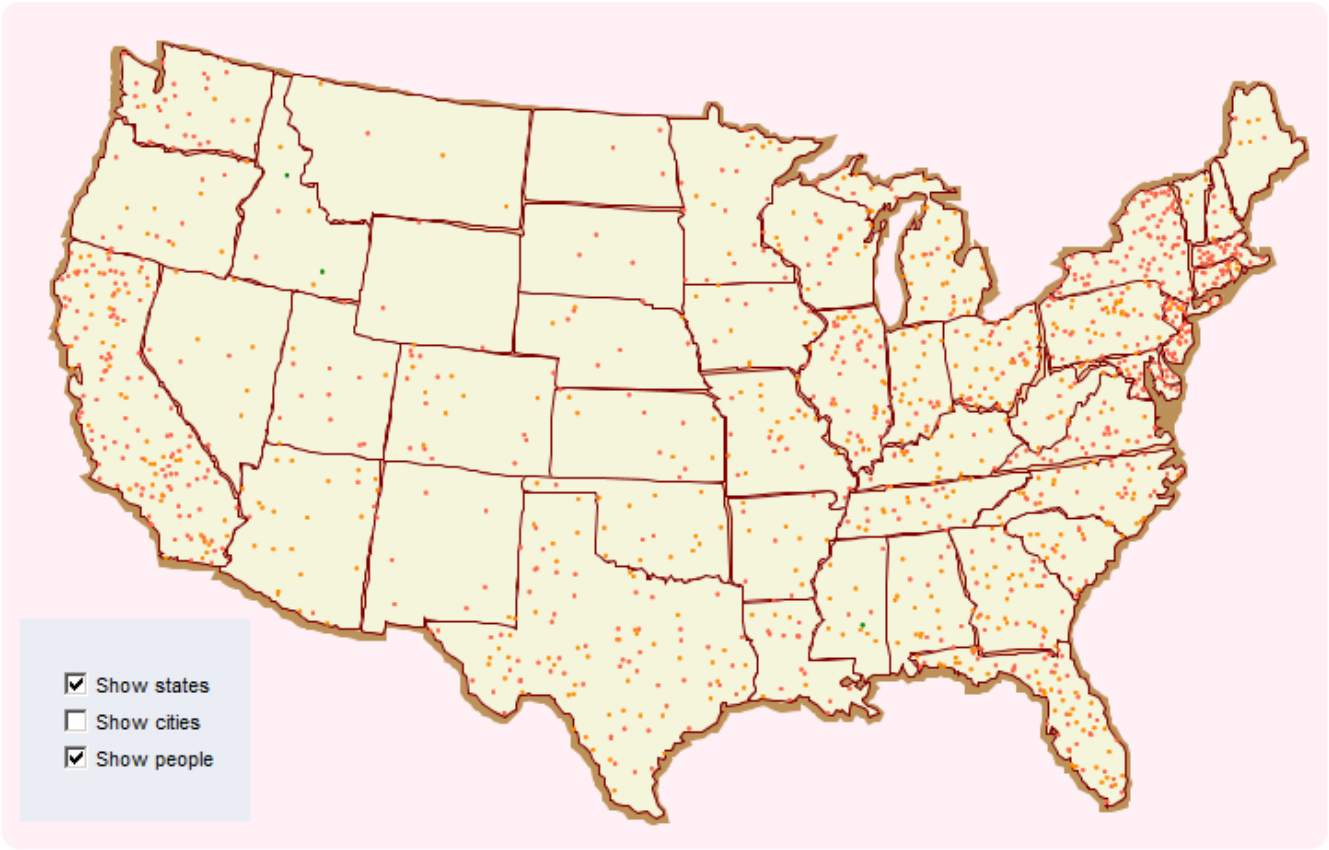
People State



CO2 Emissions (GtCO2)





Temperature: 3.716 °C

Carbon: 1,031.099 ppm

United States of America

People

Population	308,876,366	
Emission per capita	60.701	
Contact rate (per month)	0	0 – 50
Climate change sensitivity (°C)	0.5	0 – 3

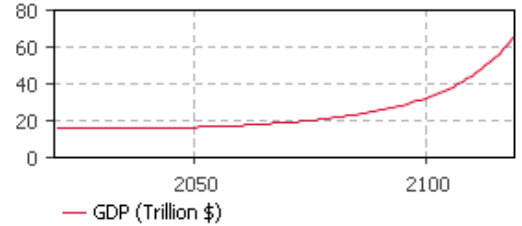
Climate Policy

Scale	◉ National ○ Regional	
National Emission	1.875E10	
Base year	2,019	2,019 – 2,119
Carbon reduction (%)	0	0 – 100
Campaign rate (per year)	0	0 – 8

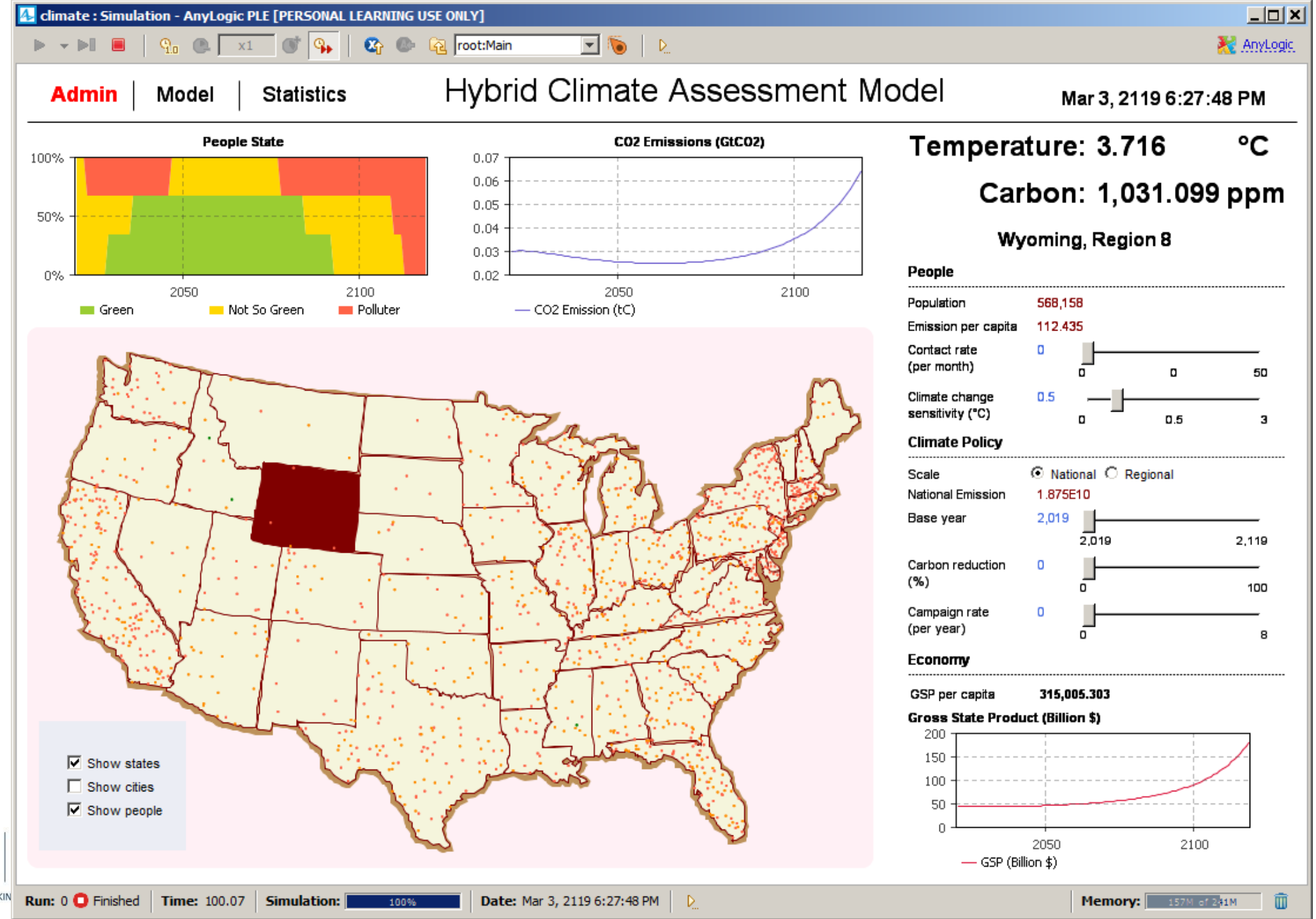
Economy

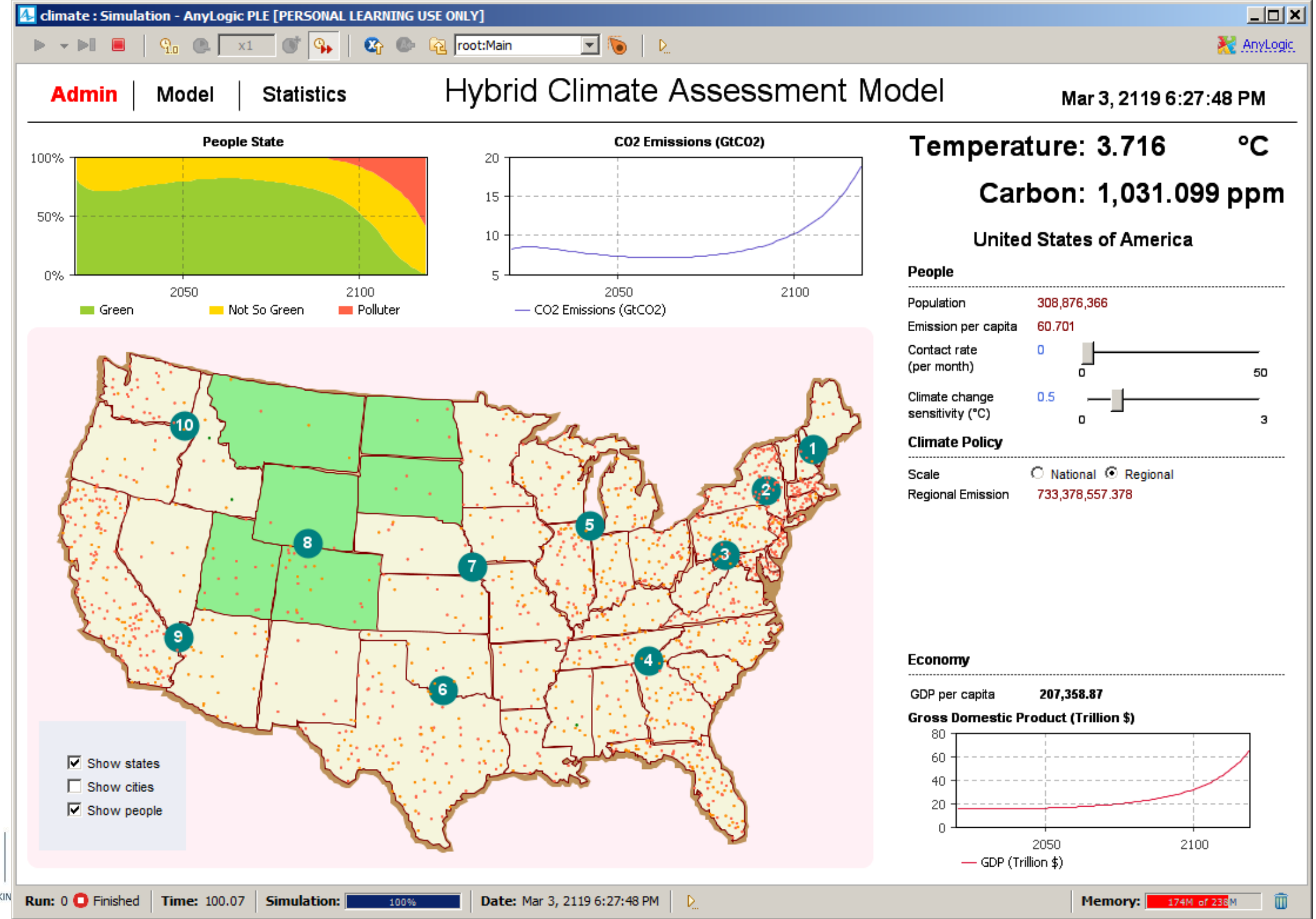
GDP per capita **207,358.87**

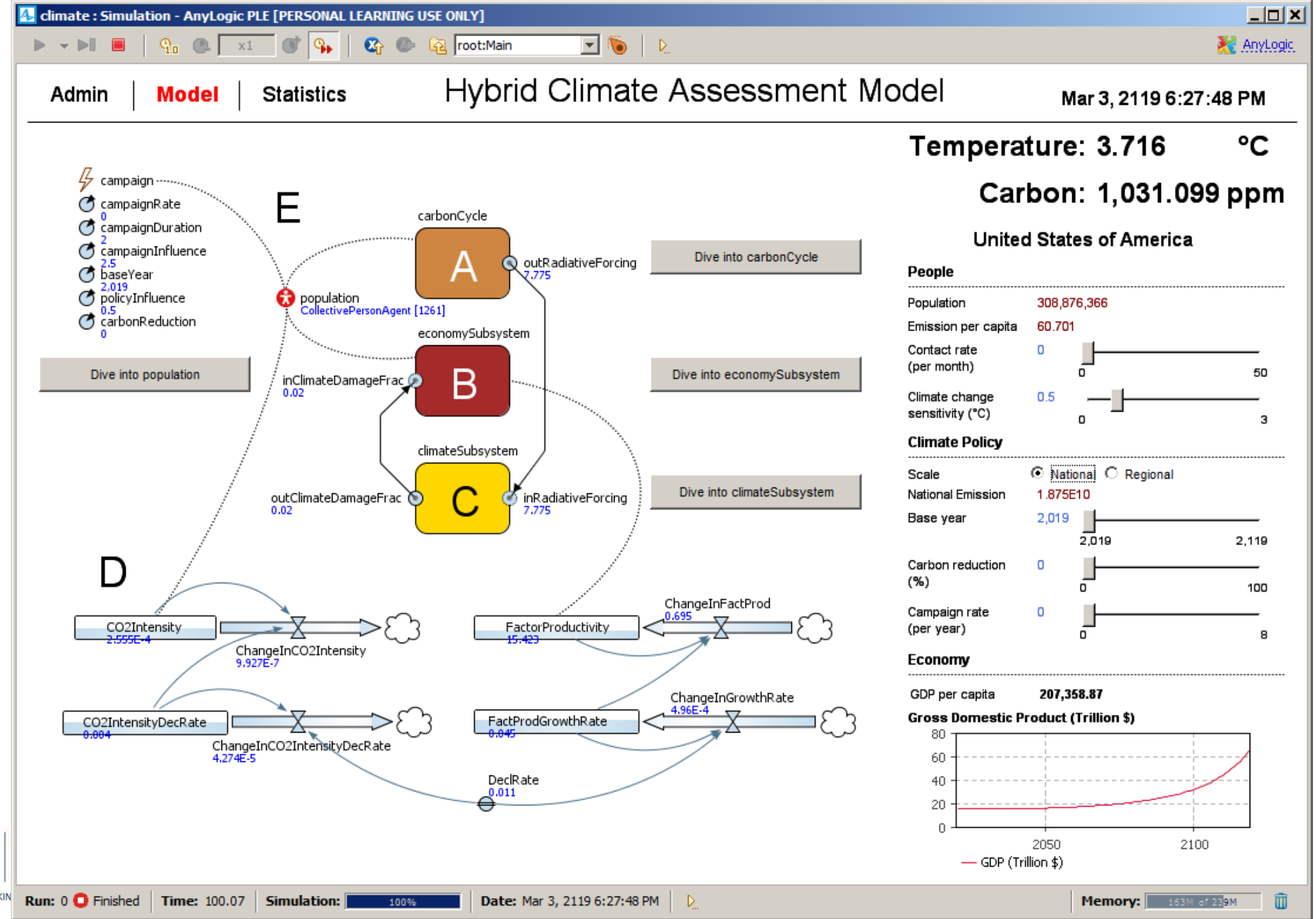
Gross Domestic Product (Trillion $)

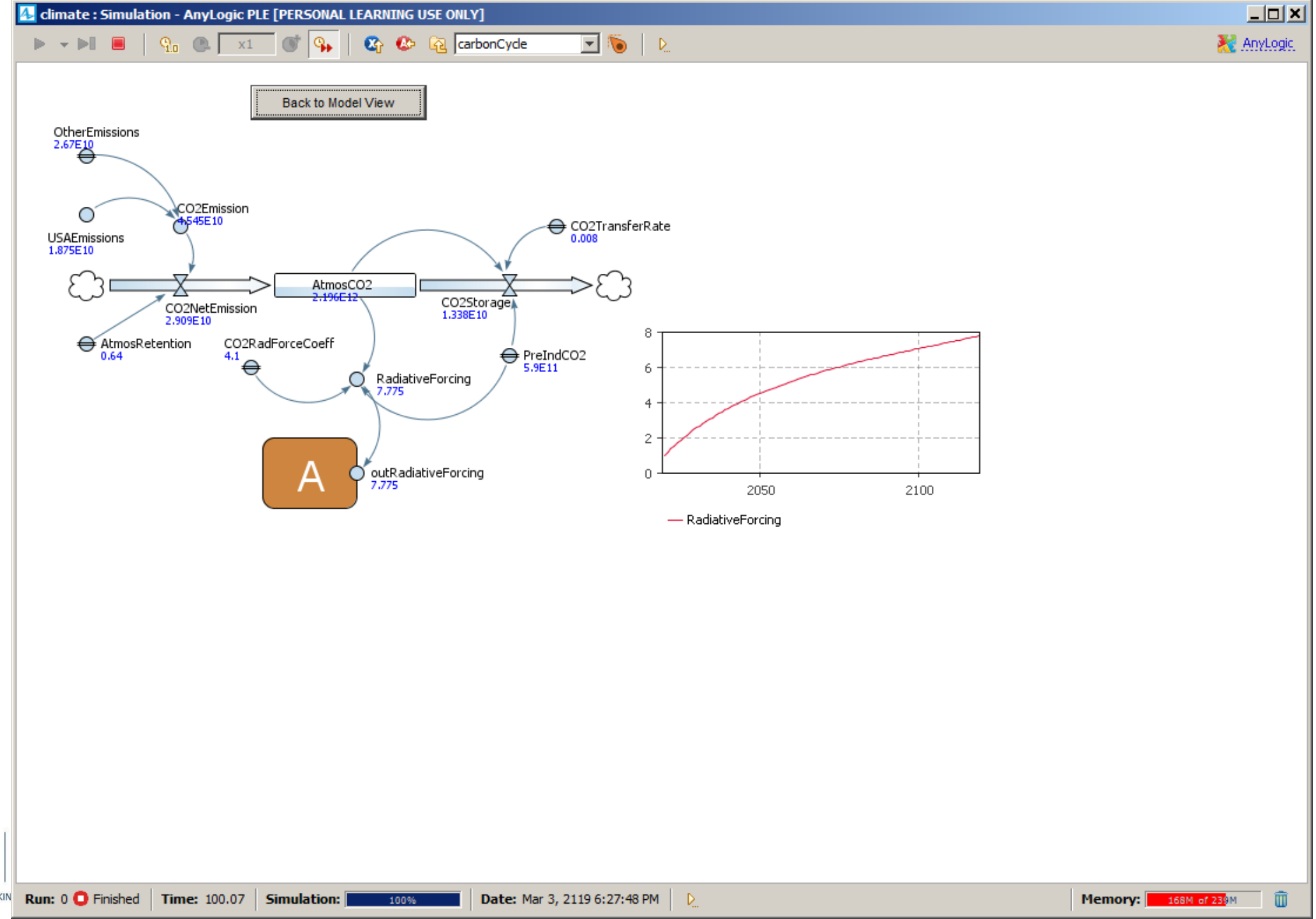


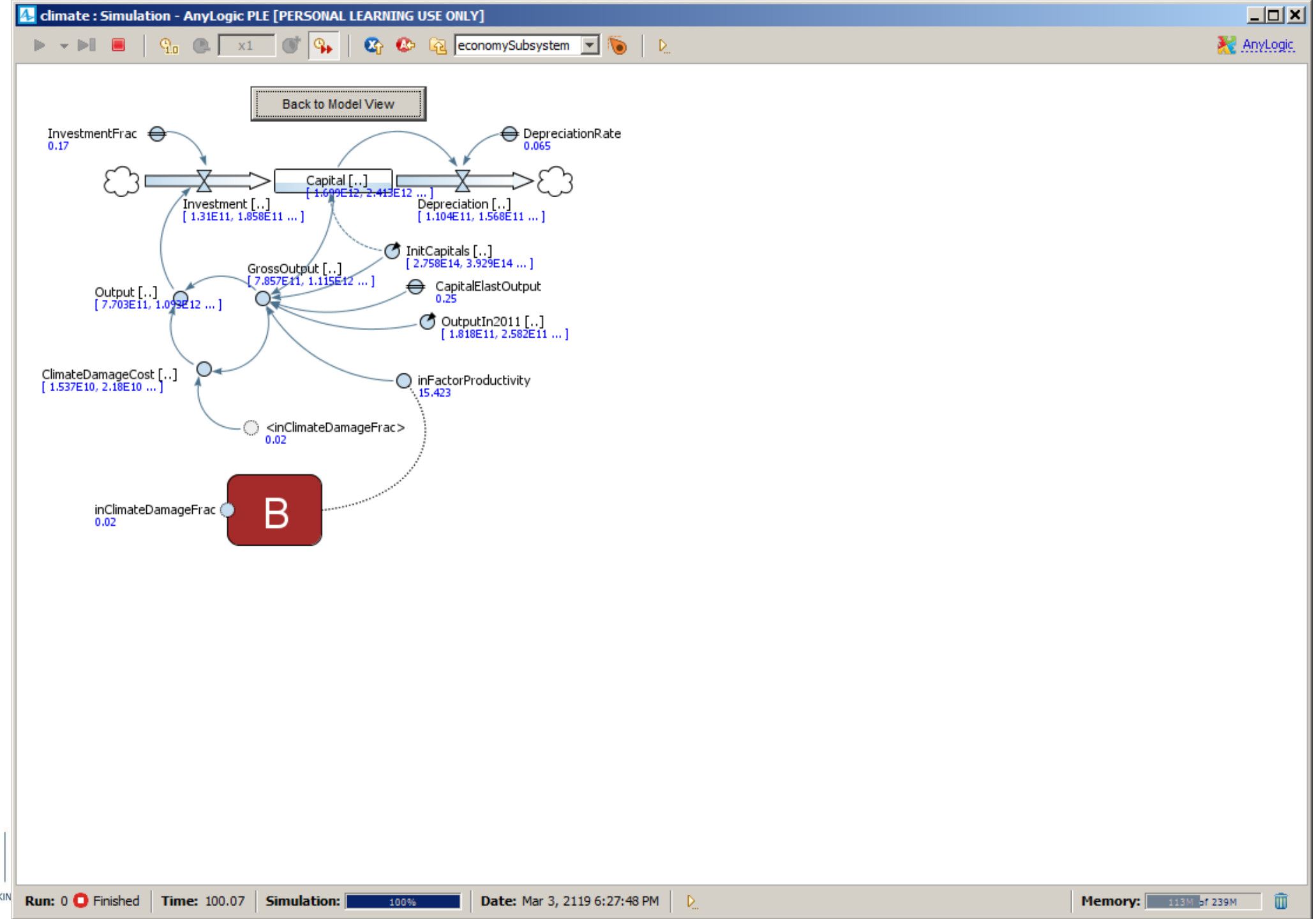
Run: 0 Finished | Time: 100.07 | Simulation: 100% | Date: Mar 3, 2119 6:27:48 PM | Memory: 151M of 239M

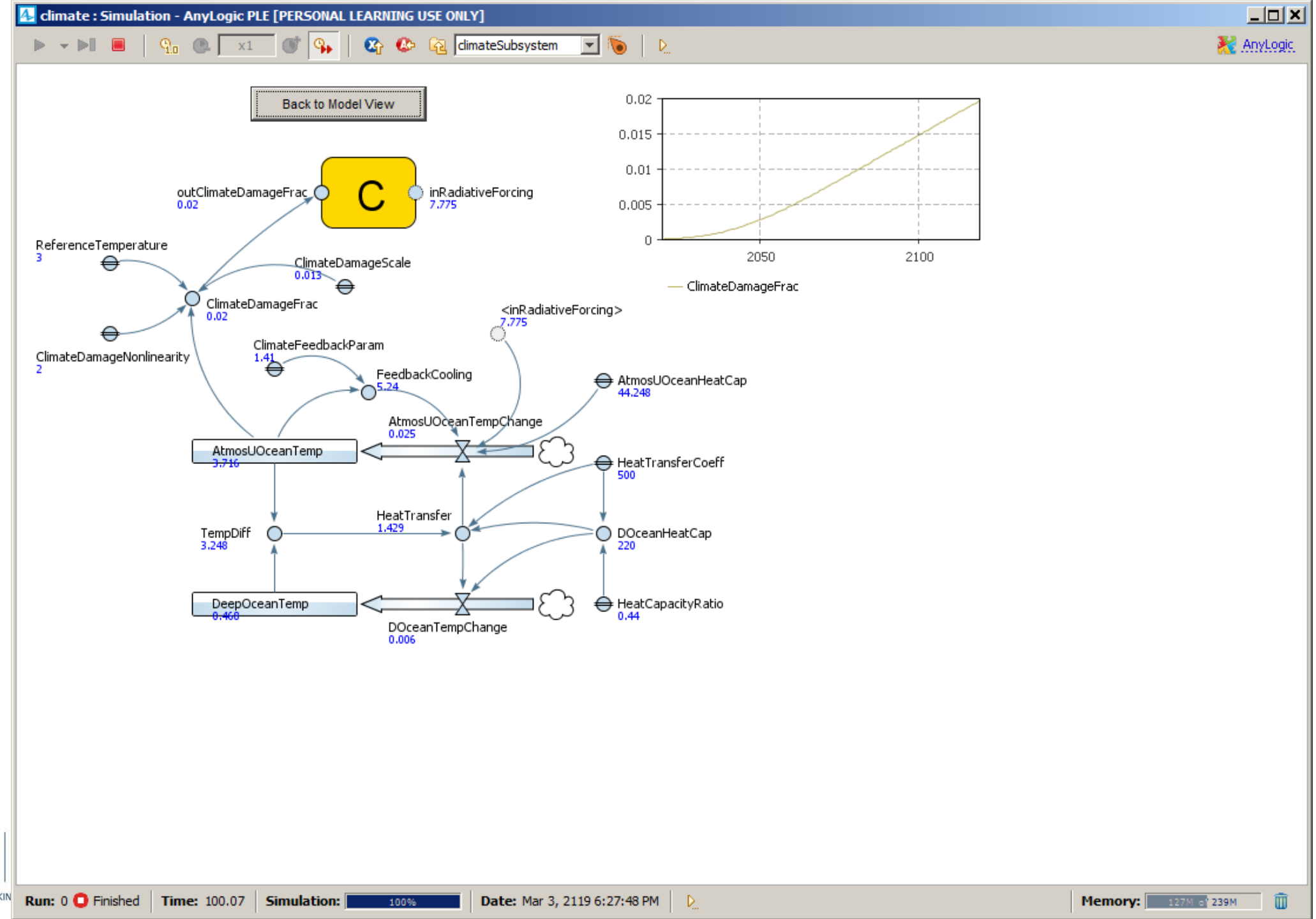

climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
root:Main
AnyLogic
Admin
Model
Statistics
Hybrid Climate Assessment Model
Mar 3, 2119 6:27:48 PM
People State
100%
50%
0%
2050
2100
Green
Not So Green
Polluter
CO2 Emissions (GtCO2)
0.07
0.06
0.05
0.04
0.03
0.02
2050
2100
CO2 Emission (tC)
Temperature: 3.716 °C
Carbon: 1,031.099 ppm
Wyoming, Region 8
People
Population 568,158
Emission per capita 112.435
Contact rate (per month) 0
0 0 50
Climate change sensitivity (°C) 0.5
0 0.5 3
Climate Policy
Scale National Regional
National Emission 1.875E10
Base year 2,019
2,019 2,119
Carbon reduction (%) 0
0 100
Campaign rate (per year) 0
0 8
Economy
GSP per capita 315,005.303
Gross State Product (Billion $)
200
150
100
50
0
2050
2100
GSP (Billion $)
Show states
Show cities
Show people
Run: 0 Finished
Time: 100.07
Simulation: 100%
Date: Mar 3, 2119 6:27:48 PM
Memory:

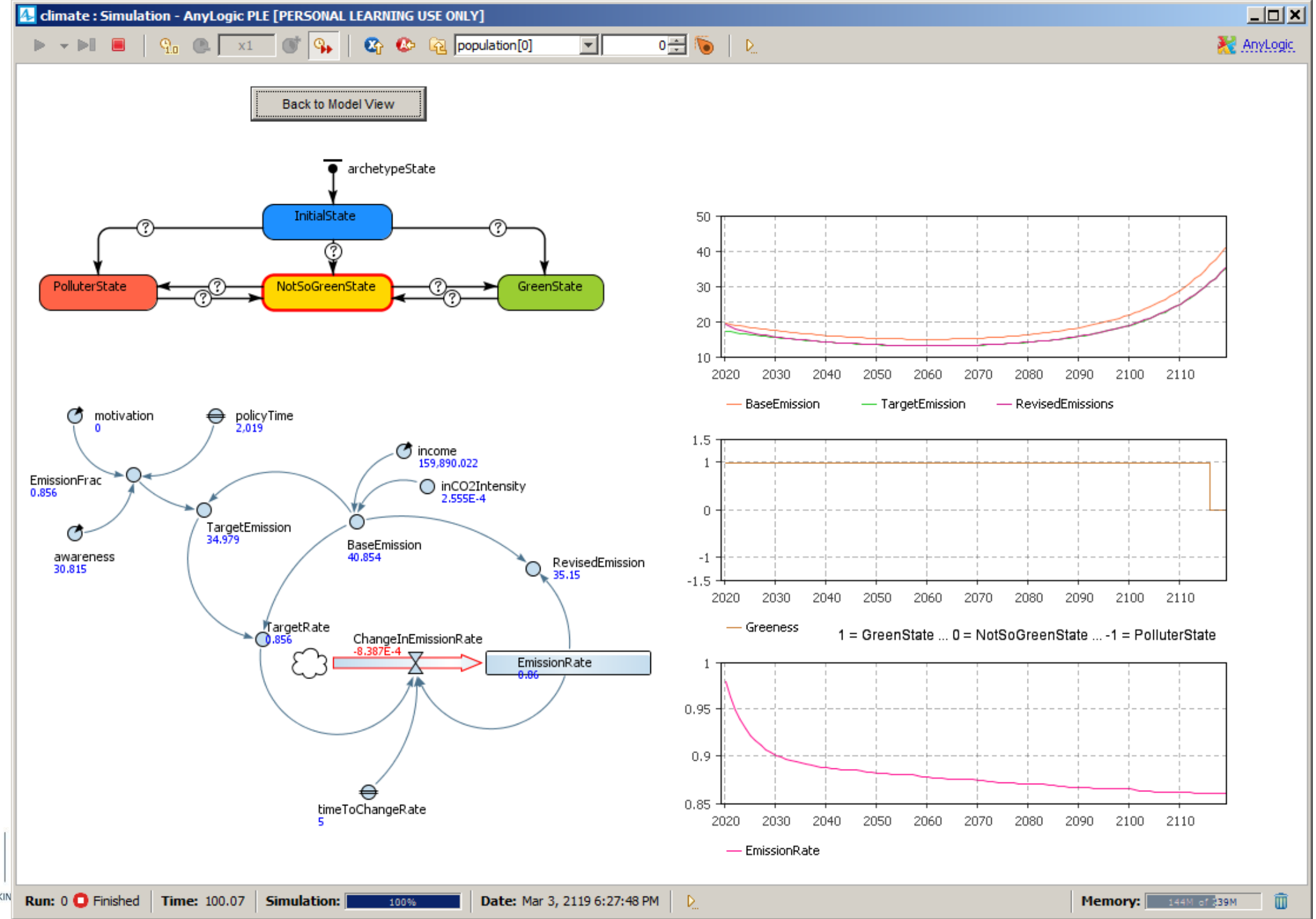

climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
root:Main
AnyLogic
Admin
Model
Statistics
Hybrid Climate Assessment Model
Mar 3, 2119 6:27:48 PM
People State
100%
50%
0%
2050
2100
Green
Not So Green
Polluter
CO2 Emissions (GtCO2)
20
15
10
5
2050
2100
CO2 Emissions (GtCO2)
Temperature: 3.716 °C
Carbon: 1,031.099 ppm
United States of America
People
Population 308,876,366
Emission per capita 60.701
Contact rate (per month) 0
0
50
Climate change sensitivity (°C) 0.5
0
3
Climate Policy
Scale National Regional
Regional Emission 733,378,557.378
Economy
GDP per capita 207,358.87
Gross Domestic Product (Trillion $)
80
60
40
20
0
2050
2100
GDP (Trillion $)
Show states
Show cities
Show people
Run: 0 Finished
Time: 100.07
Simulation: 100%
Date: Mar 3, 2119 6:27:48 PM
Memory: 174M of 238M

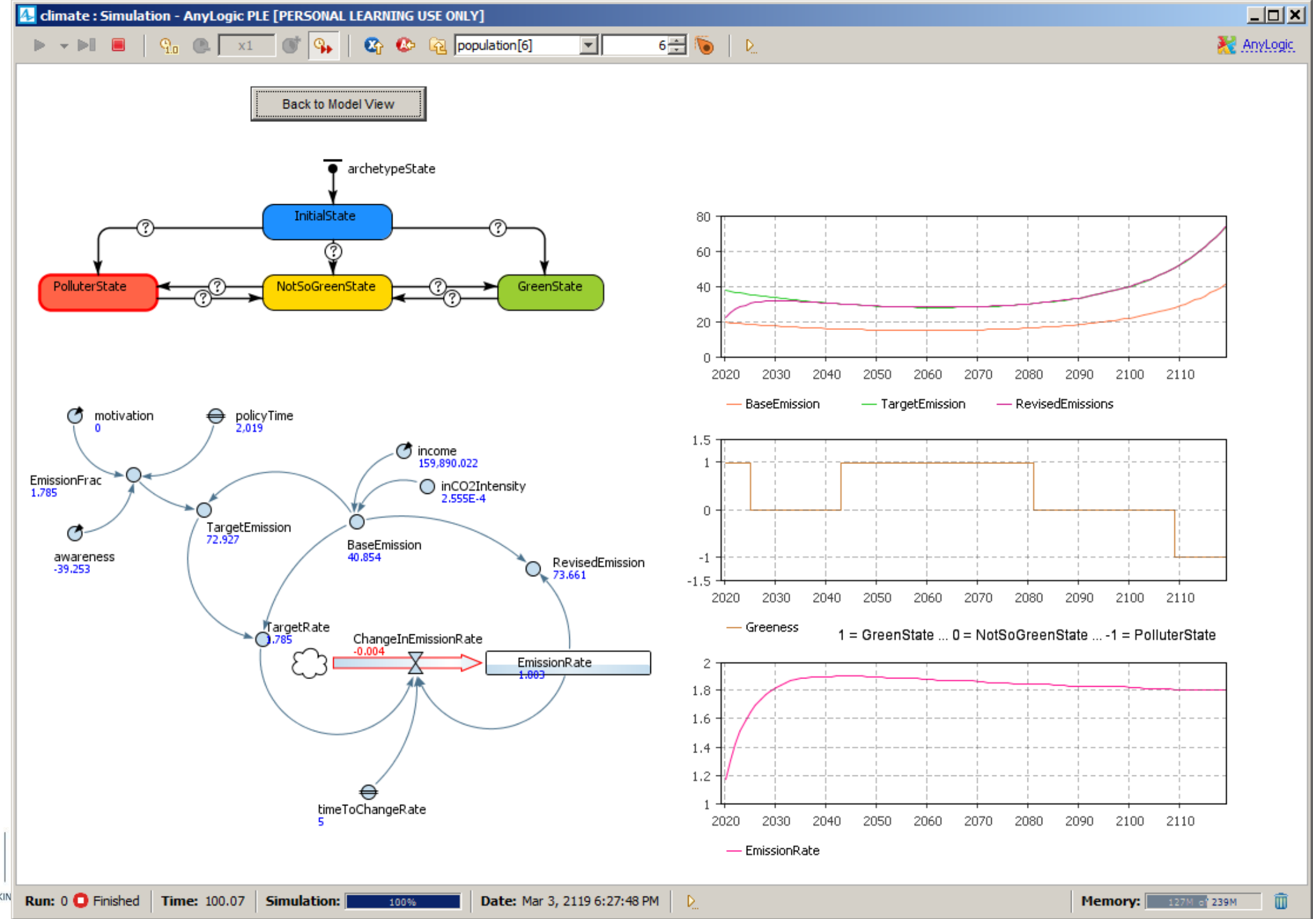

climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
root:Main
AnyLogic
Admin
Model
Statistics
Hybrid Climate Assessment Model
Mar 3, 2119 6:27:48 PM
Temperature: 3.716 °C
Carbon: 1,031.099 ppm
campaign
campaignRate
0
campaignDuration
2
campaignInfluence
2.5
baseYear
2,019
policyInfluence
0.5
carbonReduction
0
E
carbonCycle
A
outRadiativeForcing
7.775
Dive into carbonCycle
population
CollectivePersonAgent [1261]
economySubsystem
B
Dive into population
inClimateDamageFrac
0.02
Dive into economySubsystem
climateSubsystem
C
outClimateDamageFrac
0.02
inRadiativeForcing
7.775
Dive into climateSubsystem
D
CO2Intensity
2.555E-4
ChangeInCO2Intensity
9.927E-7
FactorProductivity
15.423
ChangeInFactProd
0.695
CO2IntensityDecRate
0.004
ChangeInCO2IntensityDecRate
4.274E-5
FactProdGrowthRate
0.045
ChangeInGrowthRate
4.96E-4
DeclRate
0.011
United States of America
People
Population 308,876,366
Emission per capita 60.701
Contact rate (per month) 0
0
50
Climate change sensitivity (°C) 0.5
0
3
Climate Policy
Scale National Regional
National Emission 1.875E10
Base year 2,019
2,019
2,119
Carbon reduction (%) 0
0
100
Campaign rate (per year) 0
0
8
Economy
GDP per capita 207,358.87
Gross Domestic Product (Trillion $)
80
60
40
20
0
2050
2100
GDP (Trillion $)
Run: 0 Finished
Time: 100.07
Simulation: 100%
Date: Mar 3, 2119 6:27:48 PM
Memory:

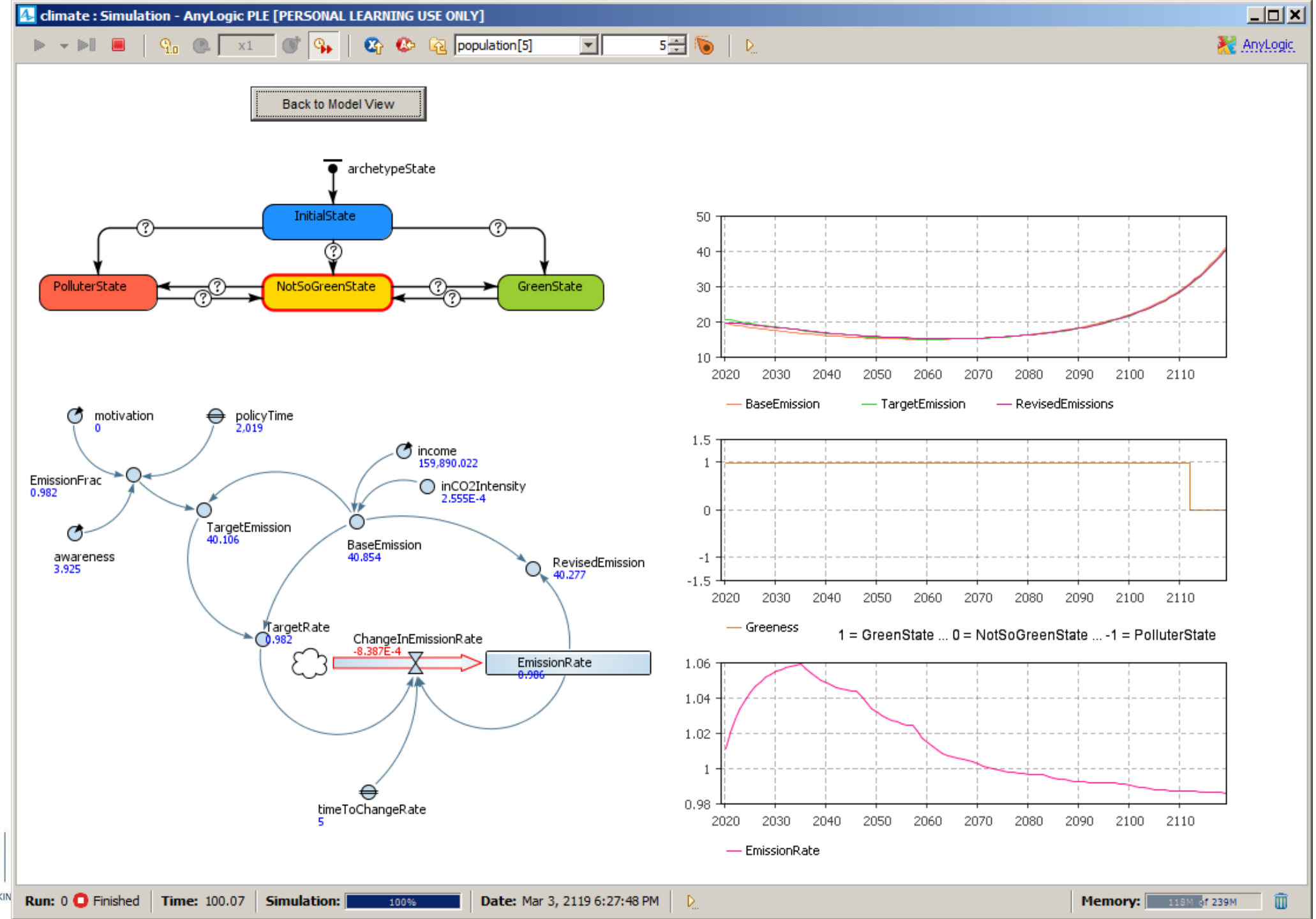

climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x1
carbonCycle
AnyLogic
Back to Model View
OtherEmissions
2.67E10
CO2Emission
4.545E10
USAEmissions
1.875E10
CO2TransferRate
0.008
AtmosCO2
2.196E12
CO2Storage
1.338E10
CO2NetEmission
2.909E10
AtmosRetention
0.64
CO2RadForceCoeff
4.1
PreIndCO2
5.9E11
RadiativeForcing
7.775
A
outRadiativeForcing
7.775
8
6
4
2
0
2050
2100
RadiativeForcing
Run: 0 Finished
Time: 100.07
Simulation:
100%
Date: Mar 3, 2119 6:27:48 PM
Memory:
168M of 239M


climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
economySubsystem
AnyLogic
Back to Model View
InvestmentFrac
0.17
DepreciationRate
0.065
Capital [..]
[1.609E12, 2.413E12 ...]
Investment [..]
[1.31E11, 1.858E11 ...]
Depreciation [..]
[1.104E11, 1.568E11 ...]
InitCapitals [..]
[2.758E14, 3.929E14 ...]
GrossOutput [..]
[7.857E11, 1.115E12 ...]
Output [..]
[7.703E11, 1.093E12 ...]
CapitalElastOutput
0.25
OutputIn2011 [..]
[1.818E11, 2.582E11 ...]
ClimateDamageCost [..]
[1.537E10, 2.18E10 ...]
inFactorProductivity
15.423
<inClimateDamageFrac>
0.02
inClimateDamageFrac
0.02
B
Run: 0 Finished
Time: 100.07
Simulation: 100%
Date: Mar 3, 2119 6:27:48 PM
Memory:


climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
climateSubsystem
AnyLogic
Back to Model View
C
outClimateDamageFrac
0.02
inRadiativeForcing
7.775
ReferenceTemperature
3
ClimateDamageScale
0.013
ClimateDamageFrac
0.02
ClimateDamageNonlinearity
2
<inRadiativeForcing>
7.775
ClimateFeedbackParam
1.41
FeedbackCooling
5.24
AtmosUOceanHeatCap
44.248
AtmosUOceanTempChange
0.025
AtmosUOceanTemp
3.716
HeatTransferCoeff
500
HeatTransfer
1.429
TempDiff
3.248
DOceanHeatCap
220
DeepOceanTemp
0.468
HeatCapacityRatio
0.44
DOceanTempChange
0.006
0.02
0.015
0.01
0.005
0
2050
2100
ClimateDamageFrac
Run: 0 Finished
Time: 100.07
Simulation: 100%
Date: Mar 3, 2119 6:27:48 PM
Memory: 127M of 239M


climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
population[0]
AnyLogic
Back to Model View
archetypeState
InitialState
PolluterState
NotSoGreenState
GreenState
motivation
0
policyTime
2,019
income
159,890.022
EmissionFrac
0.856
inCO2Intensity
2.555E-4
TargetEmission
34.979
BaseEmission
40.854
awareness
30.815
RevisedEmission
35.15
TargetRate
0.856
ChangeInEmissionRate
-8.387E-4
EmissionRate
0.86
timeToChangeRate
5
50
40
30
20
10
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
BaseEmission
TargetEmission
RevisedEmissions
1.5
1
0
-1
-1.5
Greeness
1 = GreenState ... 0 = NotSoGreenState ... -1 = PolluterState
0.95
0.9
0.85
EmissionRate
Run: 0 Finished
Time: 100.07
Simulation:
100%
Date: Mar 3, 2119 6:27:48 PM
Memory:


climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
population[6]
6
AnyLogic
Back to Model View
archetypeState
InitialState
PolluterState
NotSoGreenState
GreenState
motivation
0
policyTime
2,019
income
159,890.022
EmissionFrac
1.785
inCO2Intensity
2.555E-4
TargetEmission
72.927
BaseEmission
40.854
awareness
-39.253
RevisedEmission
73.661
TargetRate
.785
ChangeInEmissionRate
-0.004
EmissionRate
1.003
timeToChangeRate
5
80
60
40
20
0
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
BaseEmission
TargetEmission
RevisedEmissions
1.5
1
0
-1
-1.5
Greeness
1 = GreenState ... 0 = NotSoGreenState ... -1 = PolluterState
2
1.8
1.6
1.4
1.2
1
EmissionRate
Run: 0 Finished
Time: 100.07
Simulation: 100%
Date: Mar 3, 2119 6:27:48 PM
Memory: 127M of 239M


climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x1
population[5]
5
AnyLogic
Back to Model View
archetypeState
InitialState
PolluterState
NotSoGreenState
GreenState
motivation
0
policyTime
2,019
income
159,890.022
EmissionFrac
0.982
inCO2Intensity
2.555E-4
TargetEmission
40.106
BaseEmission
40.854
awareness
3.925
RevisedEmission
40.277
TargetRate
0.982
ChangeInEmissionRate
-8.387E-4
EmissionRate
0.986
timeToChangeRate
5
50
40
30
20
10
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
BaseEmission
TargetEmission
RevisedEmissions
1.5
1
0
-1
-1.5
Greeness
1 = GreenState ... 0 = NotSoGreenState ... -1 = PolluterState
1.06
1.04
1.02
1
0.98
EmissionRate
Run: 0 Finished
Time: 100.07
Simulation: 100%
Date: Mar 3, 2119 6:27:48 PM
Memory: 118M of 239M

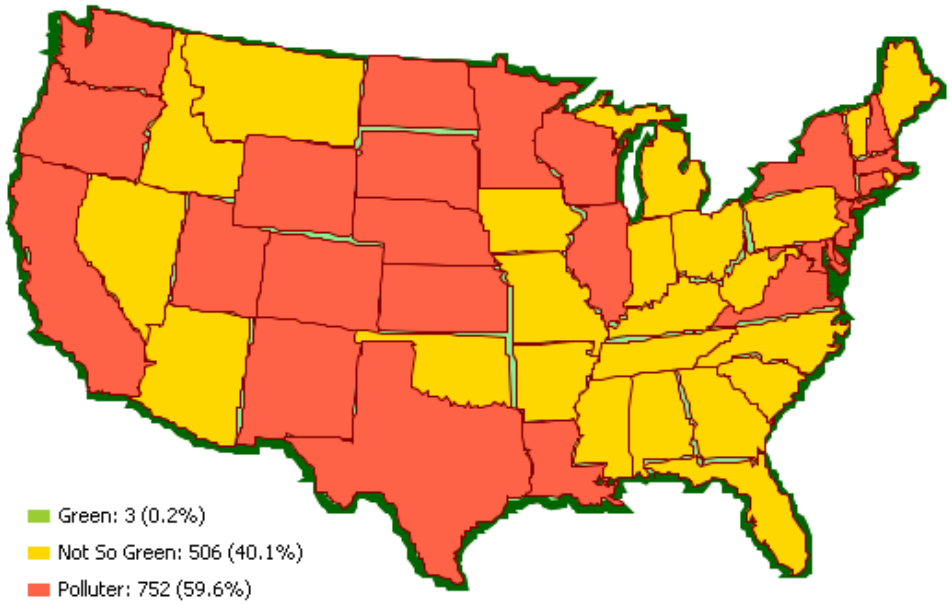
climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]

Admin | Model | Statistics

Hybrid Climate Assessment Model

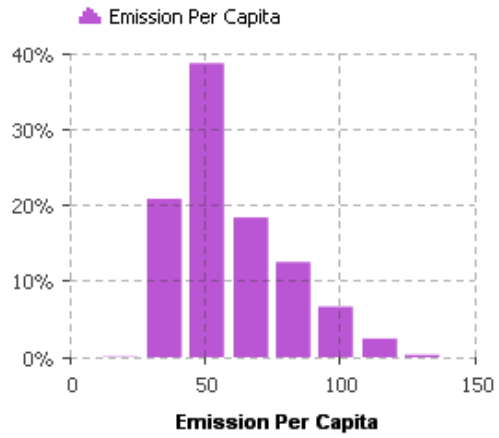
Mar 3, 2119 6:27:48 PM

United States



Green: 3 (0.2%)
Not So Green: 506 (40.1%)
Polluter: 752 (59.6%)

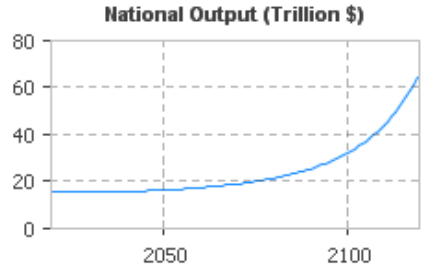
People State

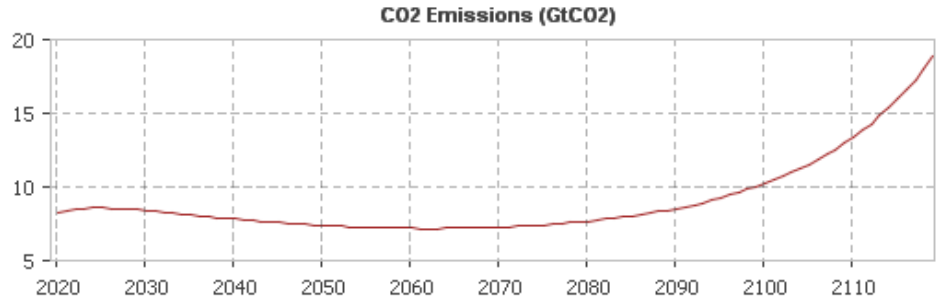


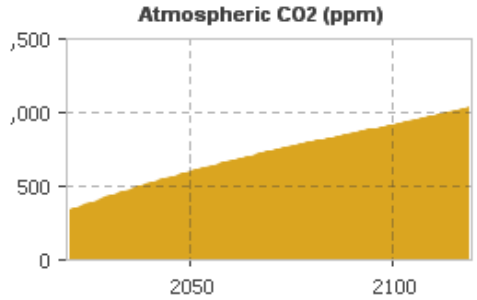
Emission Per Capita

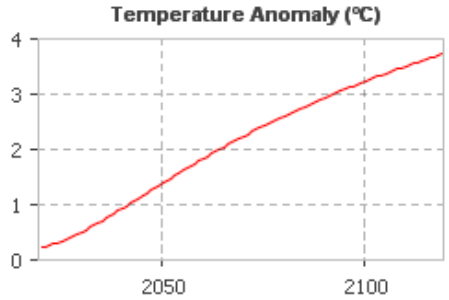
Temperature Anomaly:	3.716	°C
Atmospheric Carbon Dioxide:	1,031.099	ppm
National Emissions:	18.749	GtCO2
Percentage to Target:	None	%

Most polluted state:	California
Greenest state:	Vermont
Max emission p.c. (tCO2):	131.428
Min emission p.c. (tCO2):	25.92
Mean emission p.c. (tCO2):	59.474
GDP per capita ($):	207,358.87









Run: 0 Finished | Time: 100.07 | Simulation: 100% | Date: Mar 3, 2119 6:27:48 PM | Memory: 134M of 239M

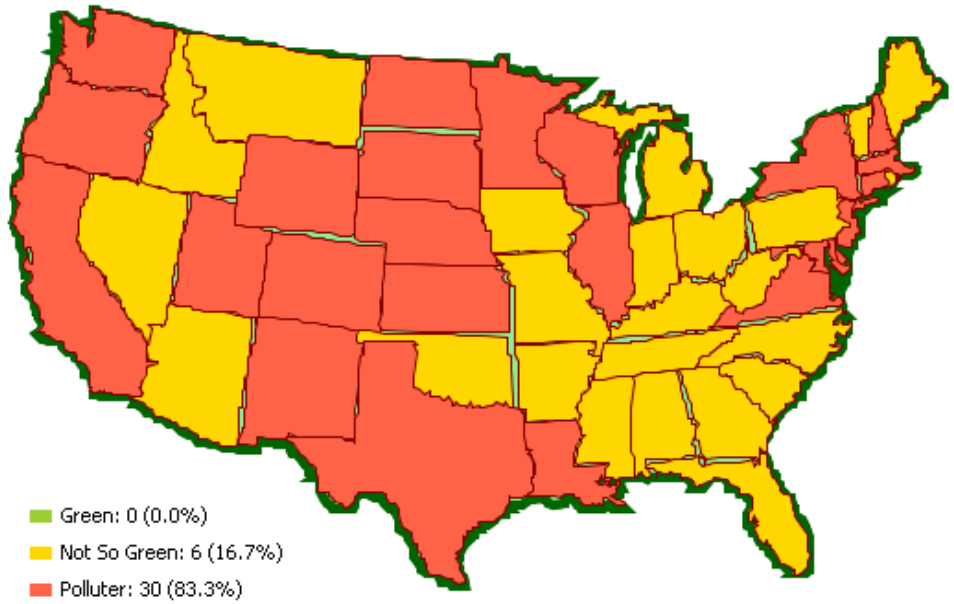
climate : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]

Admin | Model | Statistics

Hybrid Climate Assessment Model

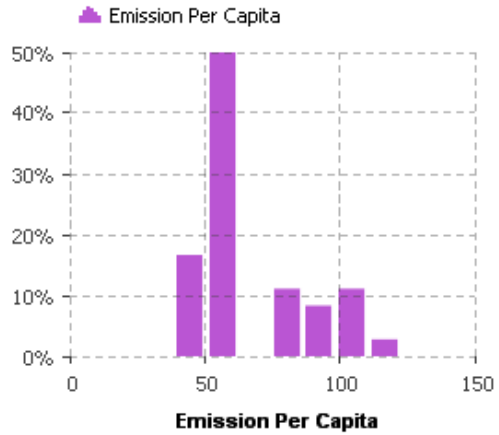
Mar 3, 2119 6:27:48 PM

NewJersey



Green: 0 (0.0%)
Not So Green: 6 (16.7%)
Polluter: 30 (83.3%)

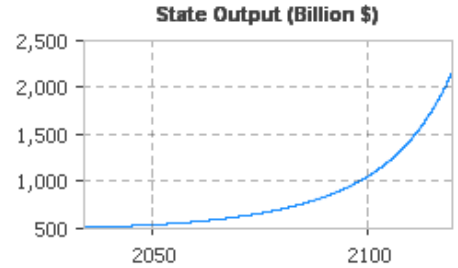
People State

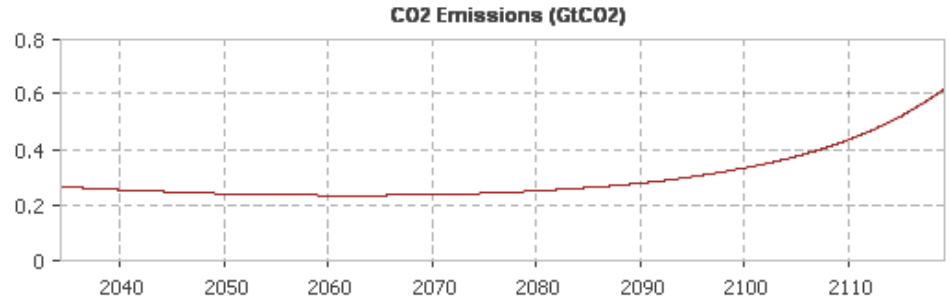


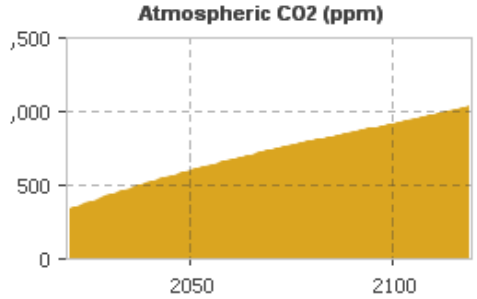
Emission Per Capita

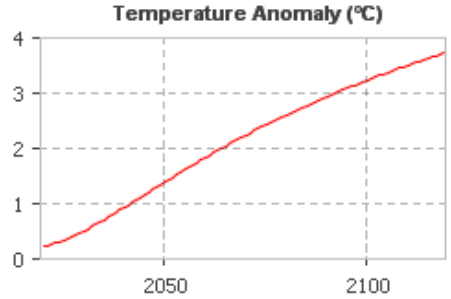
Temperature Anomaly:	3.716	°C
Atmospheric Carbon Dioxide:	1,031.099	ppm
National Emissions:	18.749	GtCO2
Percentage to Target:	None	%

Most polluted state:	California
Greenest state:	Vermont
Max emission p.c. (tCO2):	131.428
Min emission p.c. (tCO2):	25.92
Mean emission p.c. (tCO2):	59.474
GDP per capita ($):	207,358.87









Run: 0 Finished | Time: 100.07 | Simulation: 100% | Date: Mar 3, 2119 6:27:48 PM | Memory: 178M of 239M

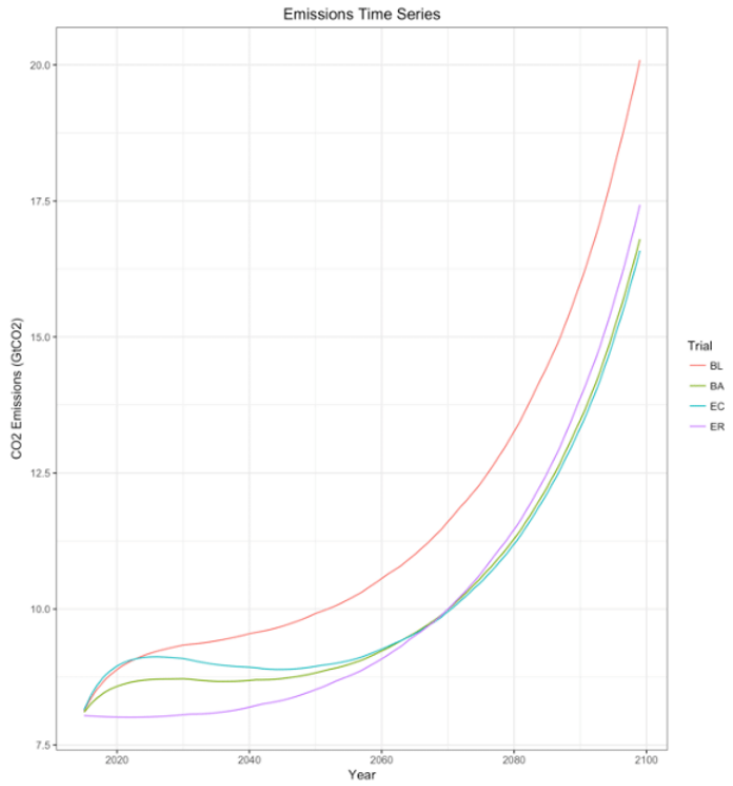
Illustrative Example

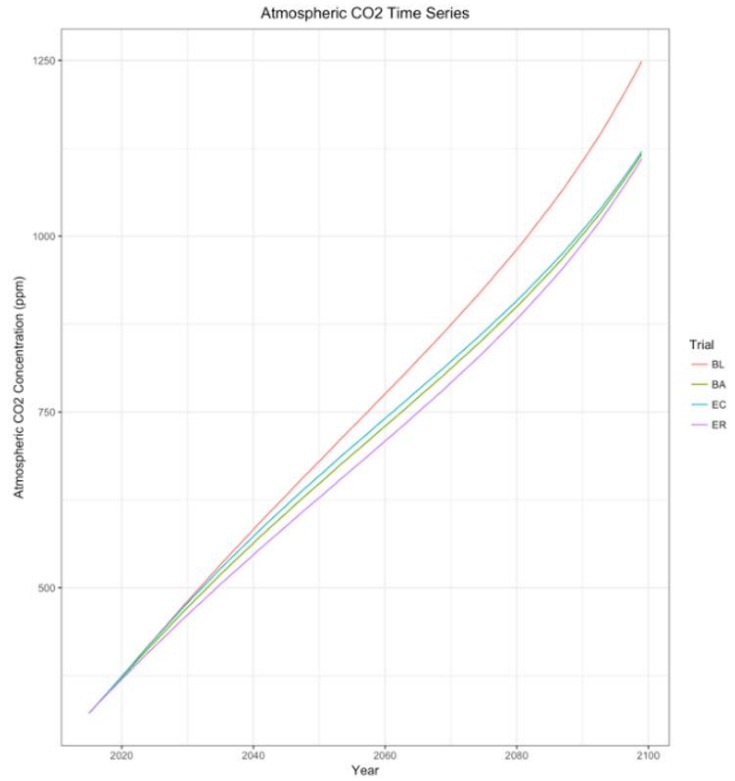
- Experimentation
  - Question: Given a constant amount of capital allocated for the climate mitigation sector, what is/are the most effective policy(s) that the federal US government can invest the funds in to leverage the available resources?
    - Baseline scenario: no mitigation actions
    - Balanced scenario: evenly-split spending
      - Carbon reduction target of 17% based on target set by Obama
    - Extreme campaign: all funding is spent on organizing campaigns
    - Extreme reduction: all funding is invested in carbon abatement

		Policy	
		Carbon reduction (%)	Campaigns (per year)
Scenario	Baseline (BL)	0	0
	Balanced (BA)	17	4
	Extreme Campaign (EC)	0	8
	Extreme Reduction (ER)	34	0

Illustrative Example

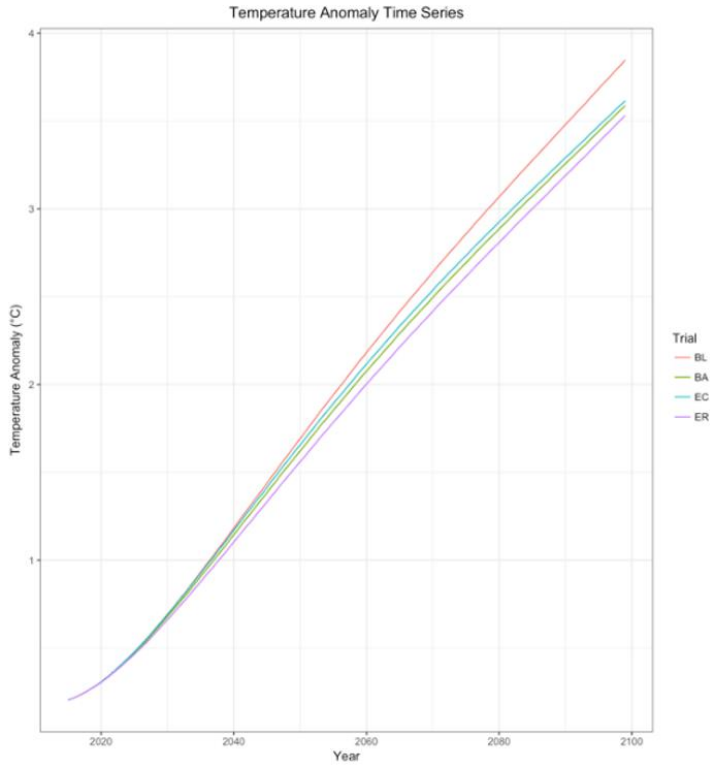
- Experimentation results

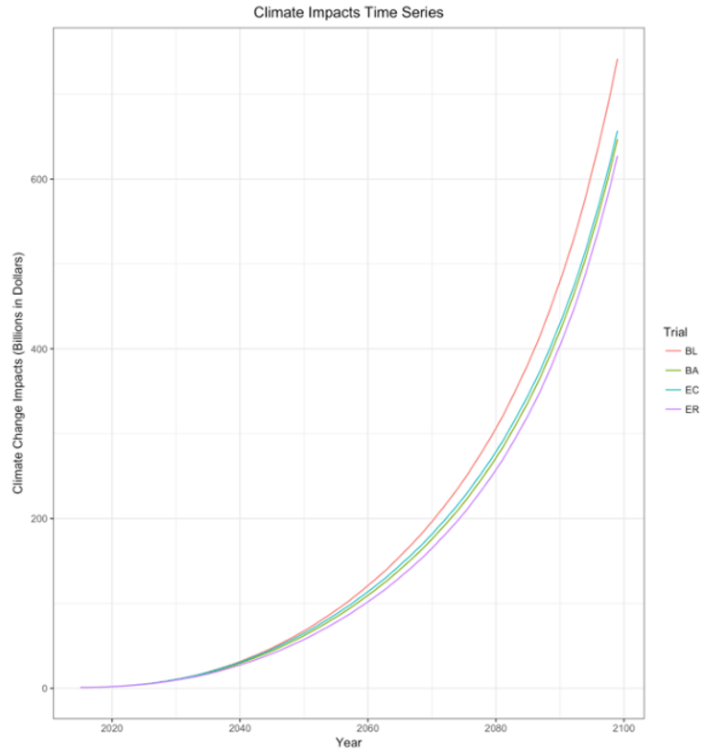




Illustrative Example

- Experimentation results





Questions / Comments

References

- Siebers PO, En Lim Z, Figueredo GP, and Hey J (2020) 'An Innovative Approach to Multi-Method Integrated Assessment Modelling of Global Climate Change', Journal of Artificial Societies and Social Simulation, 23(1)10.