



# **Integration of GCAM-USA into GLIMPSE: Update and demonstration**

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GCAM Community Modeling Meeting  
Joint Global Change Research Institute, College Park, MD  
October 13, 2016

- **Objectives of this presentation**

- Describe enhancements to GCAM-USA to support environmental-climate-energy decision support
- Demonstrate Scenario Builder and Enhanced Model Interface graphical user interface components

- **Intended audience**

- The Global Change Assessment Model (GCAM) modeling community

- **Acknowledgments**

- The GLIMPSE team includes the authors, as well as Samaneh Babaei, Raj Bhandar, Troy Hottle, and Carol Lenox

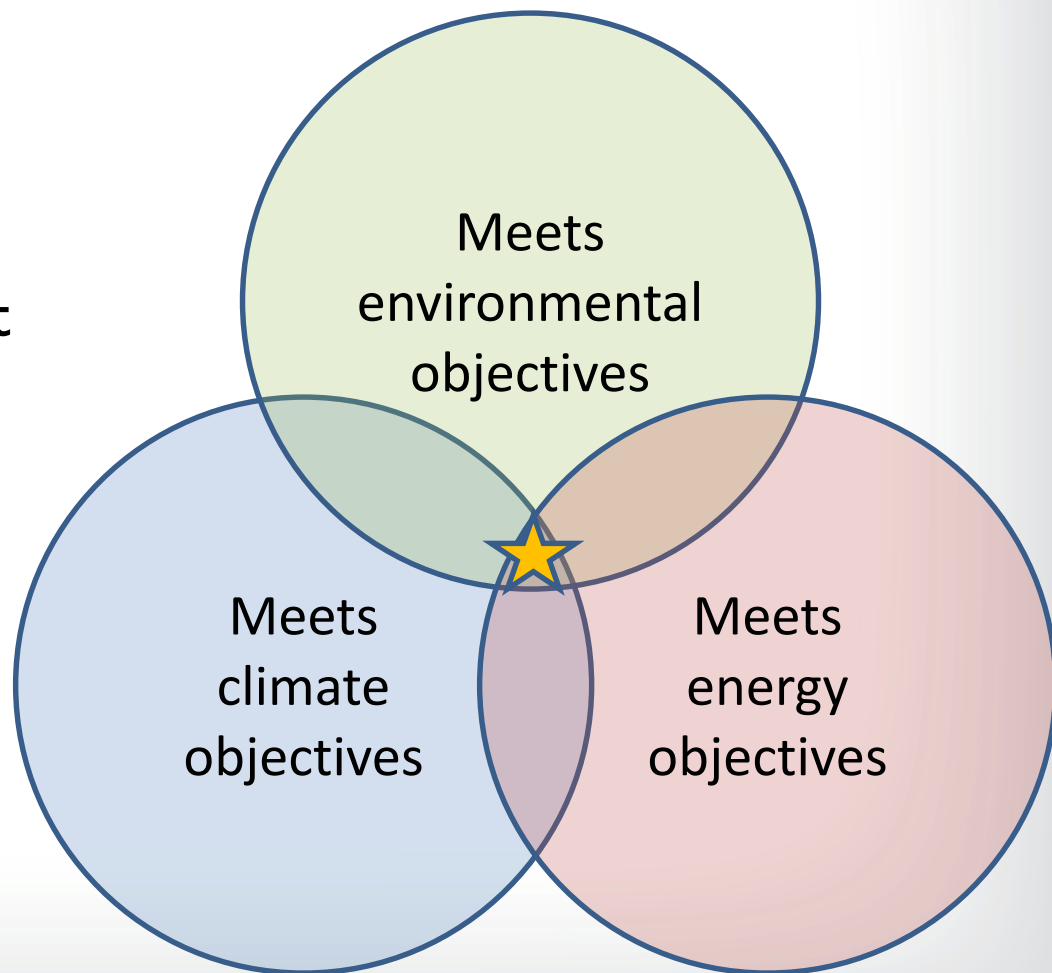
- **Disclaimers**

- The views expressed in this presentation are those of the author and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.
- All results are provided for illustrative purposes only.

## Develop decision support tools for:

- Evaluating how candidate management strategies meet environmental, climate and energy objectives
- Characterizing tradeoffs among objectives
- Identifying strategies that efficiently meet all objectives

## Management strategy space



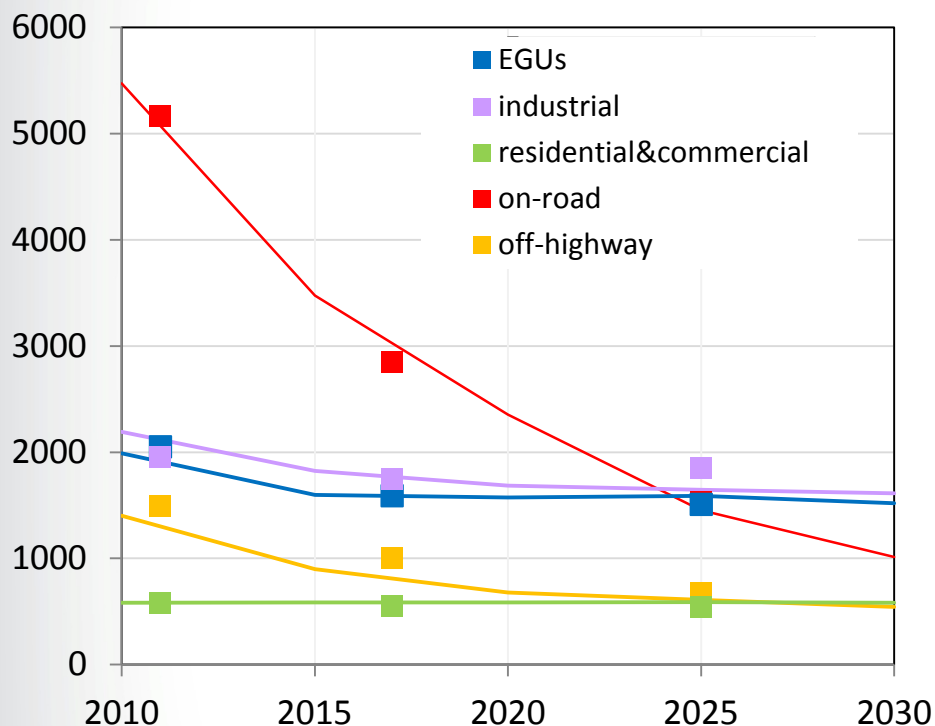
- **GCAM-USA is being enhanced by:**
  - harmonizing emission factors with U.S. estimates
  - incorporating characterizations of air pollutant controls
  - including representations of U.S. regulations
    - CAFE, CSAPR, CPP, NSPSs, RPSs
  - enhancing the industrial sector representation
    - regionality, source categories
  - prototyping decision support tools
    - Scenario Builder (front-end)
    - Enhanced Model Interface (back-end)



# Evaluation of emissions

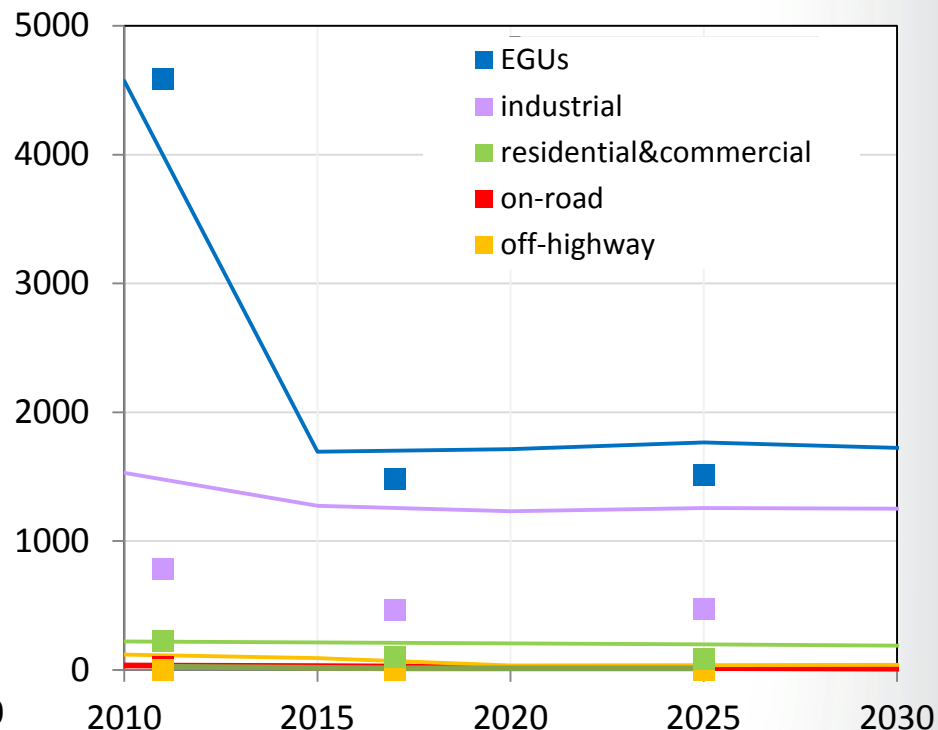
## NO<sub>x</sub> emissions (tons x1000)

GCAM-USA (lines) vs. EPA 2011eh platform (squares)



## SO<sub>2</sub> emissions (tons x1000)

GCAM-USA (lines) vs. EPA 2011eh platform (squares)



- Off-highway NO<sub>x</sub> is low relative to the inventory, but this could be because of discrepancies in what is being compared
- Industrial sector SO<sub>2</sub> from GCAM-USA are two times higher than the inventory. A hypothesis we are testing is that offroad mobile emissions included GCAM's industrial sector may not reflect mobile source fuel sulfur content limits. We also need to examine the assumed mix of industrial boilers, turbines, and engines in GCAM-USA.



# Decision Support System integration

## Scenario Builder: Managing scenarios

Creating a  
new scenario  
from existing  
components

**Candidate Scenario Components**

File Name	Address	Created
CO2CapNortheast.txt	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:49:54 ...
CO2CapUSA.txt	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:47:41 ...
CO2TaxNortheast.txt	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:35:14 ...
CO2TaxUSA.txt	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:33:19 ...
SolarPVSubsidyUSA.txt	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:53:27 ...
SolarPVSubsidyWest....	C:\Projects\GCAM-GUI\io\ScenarioComponen...	Mon Oct 26 16:52:17 ...

**Construct or Edit Scenario**

Name: CO2CapNE\_update

Components:

File Name
CO2CapNortheast.txt

**Working Scenarios**

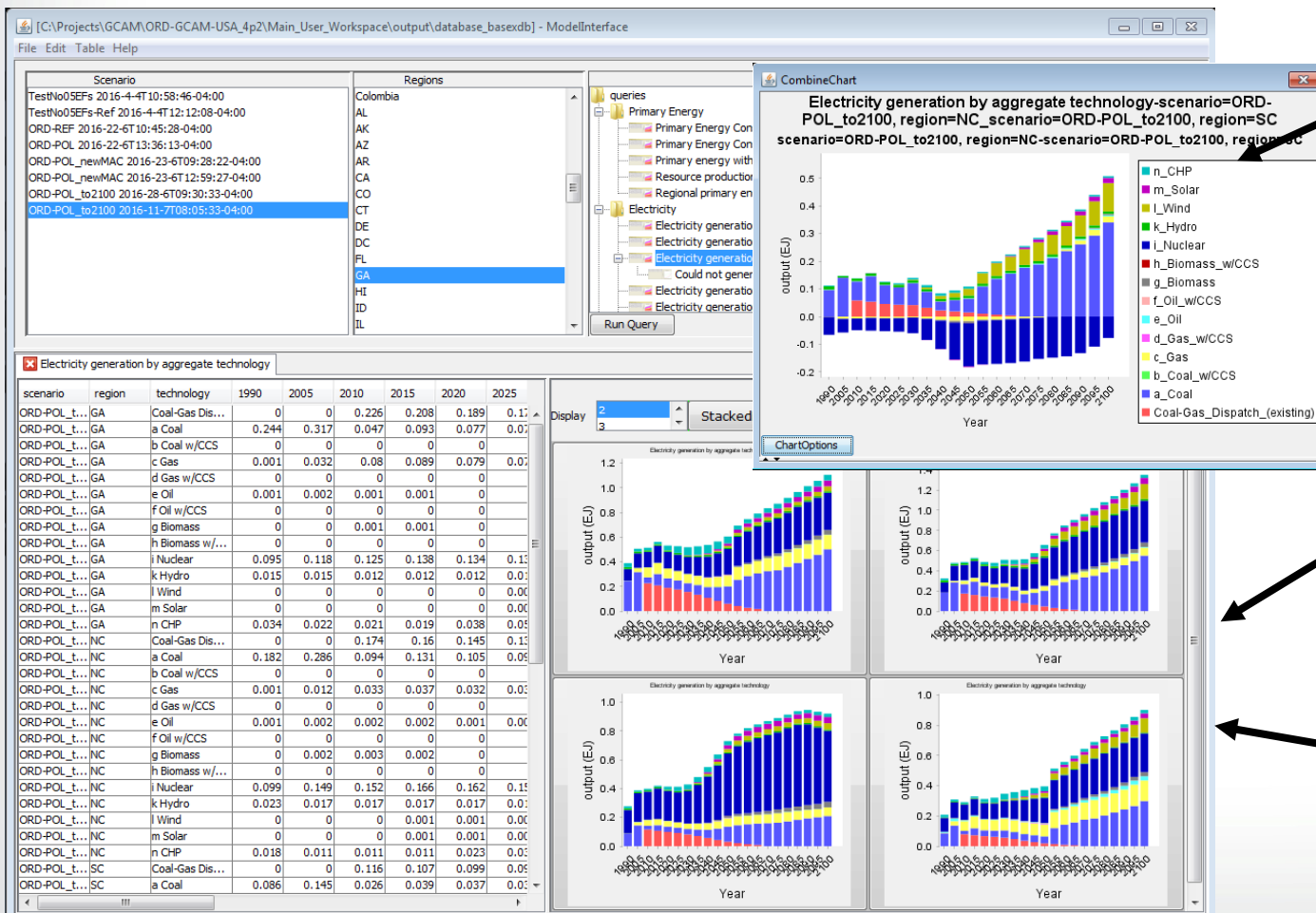
Run Name	Components	Run Date
CO2TaxUSA	CO2TaxUSA.txt;	Mon Oct 26 16:57:34 EDT 2015
CO2TaxNortheast	CO2TaxNortheast.txt;	Mon Oct 26 16:57:34 EDT 2015
CO2CapUSA	CO2CapUSA.txt;	Mon Oct 26 16:57:34 EDT 2015
CO2CapNortheast	CO2CapNortheast.txt;	Mon Oct 26 16:57:34 EDT 2015
SolarPVSubsidyWest	SolarPVSubsidyWest.txt;	Mon Oct 26 16:57:34 EDT 2015
SolarPVSubsidyUSA	SolarPVSubsidyUSA.txt;	Mon Oct 26 16:57:34 EDT 2015

Management  
and execution  
of scenarios



# Decision Support System integration

## Enhancements to the Model Interface



Easily sum over regions and estimate differences across scenarios

Show results separate plots

Choose from line, bar, and pie charts

- **Types**

- Air pollutant taxes or caps\*
- GHG taxes or caps\*
- CAFE standard<sup>+</sup>
- Renewable Electricity Standard<sup>+</sup>
- Technology subsidies
- Forced technology penetration
- High-efficiency technology end-use requirements

- **Geographic application**

- Global, global region, or national\*
- Group of states or individual state\*





# Demo



GCAM-USA Scenario Creator

Candidate Scenario Components

filter:

File Name	Address	Created
30pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:57:30
40pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:57:45
50pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:57:55
60pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:04
70pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:14
80pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:23
90pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:32

N

Edit

Delete

Construct or Edit Scenario

Name:

Components:

File Name

No content in table

Run

Create

Working Scenarios

filter:

Run Name	Components	Run Date
Ref4p2	Reference4p2.txt;	Mon Feb 08 14:04:24 EST 2016
30pctCO2RdxUSA	30pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
40pctCO2RdxUSA	40pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
50pctCO2RdxUSA	50pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
60pctCO2RdxUSA	60pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
70pctCO2RdxUSA	70pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
80pctCO2RdxUSA	80pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016


Analyze

Run Selected

Delete Selected

Options

Help



Creating a new scenario component

New Scenario Component

Preset Custom

Component:

Action: Emission Cap (Mt)

Sector: System Wide

Parameter: CO2

Populate:

Type: Initial w/% Growth

Start Year: 2020

End Year: 2100

Initial Amount:

Growth (%):

Values: Populate Delete Clear

Year	Value
No content in table	

Applied to:

► world

Add

Save Close

New Scenario Component window

New Scenario Component

Preset Custom

Component:

Action: Emission Cap (Mt)

Sector: System Wide

Parameter: CO2

Populate:

Type: Initial w/% Growth

Start Year: 2020

End Year: 2100

Initial Amount:

Growth (%):

Values: Populate Delete Clear

Year	Value
No content in table	

Applied to:

► ☐ world

Add

Save Close

Choosing the type of the component

New Scenario Component

Preset Custom

Component:

Action: Emission Cap (Mt)

Sector: Emission Cap (Mt)

Parameter: Emission Tax (\$/t)  
Renewable Elec Std (%)  
CAFE (MPG)

Populate:

Type: Initial w/% Growth

Start Year: 2020

End Year: 2100

Initial Amount:

Growth (%):

Values: Populate Delete Clear

Year	Value
No content in table	

Applied to:

► ☐ world

Add

Save Close

Menu of component types (to be expanded)

New Scenario Component

Preset Custom

Component:

Action: Emission Tax (\$/t)

Sector: Emission Cap (Mt)

Parameter: Emission Tax (\$/t)

Populate: Renewable Elec Std (%)

Type: Initial w/% Growth

Start Year: 2020

End Year: 2100

Initial Amount:

Growth (%):

Values: Populate Delete Clear

Year	Value
No content in table	

Applied to:

world

Save Close

Choosing to apply an emission tax

New Scenario Component

Preset Custom

Component:

Action: Emission Tax (\$/t)

Sector: System Wide

Parameter: CO2

Populate:

Type: Initial w/% Growth

Start Year: 2020

End Year: 2100

Initial Amount:

Growth (%):

Values: Populate Delete Clear

Year	Value
No content in table	

Applied to:

▶ ☐ world

Add

Save Close

Applied system-wide to CO2



New Scenario Component

Preset Custom

Component:

Action: Emission Tax (\$/t)

Sector: System Wide

Parameter: CO2

Populate:

Type: Initial w/% Growth

Start Year: 2020

End Year: 2100

Initial Amount:

Growth (%):

Values: Populate Delete Clear

Year	Value
No content in table	

Applied to:

- world

Add

Save Close

Defining the tax magnitude and timing

New Scenario Component

Preset Custom

Component:

Action: Emission Tax (\$/t)

Sector: System Wide

Parameter: CO2

Populate:

Type: Initial w/% Growth

Start Year: Initial w/% Growth

End Year: Initial w/Delta

Initial Amount: Initial and Final

Growth (%): Table w/% Change

Table w/Delta

Values: Populate Delete Clear

Year	Value
No content in table	

Applied to:

world

Add

Save Close

New Scenario Component

Preset Custom

Component:

Action: Emission Tax (\$/t)

Sector: System Wide

Parameter: CO2

Values: Populate Delete Clear

Applied to:

► world

Populate:

Type: Initial and Final

Start Year: Initial w/% Growth

End Year: Initial w/Delta

Initial Amount: Initial and Final

Growth: Table w/% Change

Table w/Delta

Year Value

No content in table

Add

Save Close

Selecting starting and ending tax – Intermediate values are interpolated

New Scenario Component

Preset

Custom

Component:

Action:

Emission Tax (\$/t)

Sector:

System Wide

Parameter:

CO2

Populate:

Type:

Initial and Final

Start Year:

2020

End Year:

2100

Initial Amount:

Final Amount:

Values:

Populate

Delete

Clear

Year	Value
No content in table	

Add

Applied to:

▶

world

Save

Close

New Scenario Component

Preset Custom

Component:

Action: Emission Tax (\$/t)

Sector: System Wide

Parameter: CO2

Populate:

Type: Initial and Final

Start Year: 2020

End Year: 2100

Initial Amount: 50

Final Amount: 500

Values: Populate Delete Clear

Year	Value
No content in table	

Applied to:

- ☐ world

Save Close

Tax increases linearly from \$50/tCO<sub>2</sub> in 2020 to \$500/tCO<sub>2</sub> in 2100

New Scenario Component

Preset Custom

Component:

Action: Emission Tax (\$/t)

Sector: System Wide

Parameter: CO2

Populate:

Type: Initial and Final

Start Year: 2020

End Year: 2100

Initial Amount: 50

Final Amount: 500

Values: Populate Delete Clear

	Value
2020	50.00
2025	78.12
2030	106.25
2035	134.38
2040	162.50
2045	190.62
2050	218.75
2055	246.88
2060	275.00
2065	303.12
2070	331.25
2075	359.38

Applied to:

world

Save Close

Populating the table of values

New Scenario Component

Preset Custom

Component:

Action: Emission Tax (\$/t)

Sector: System Wide

Parameter: CO2

Populate:

Type: Initial and Final

Start Year: 2020

End Year: 2100

Initial Amount: 50

Final Amount: 500

Values: Populate Delete Clear

Year	Value
2020	50.00
2025	78.12
2030	106.25
2035	134.38
2040	162.50
2045	190.62
2050	218.75
2055	246.88
2060	275.00
2065	303.12
2070	331.25
2075	359.38

Applied to:

- ☒ world
- ☐ USA
- ☐ Canada
- ☐ EU-15
- ☐ Europe\_Non\_EU
- ☐ European Free Trade Association
- ☐ Japan
- ☐ Australia\_NZ
- ☐ Central Asia
- ☐ Russia
- ☐ China
- ☐ Middle East
- ☐ Africa\_Eastern

Save Close

Selecting to which regions the tax is applied

# New Scenario Component

Preset Custom

Component:

Action: Emission Tax (\$/t)

Sector: System Wide

Parameter: CO2

Populate:

Type: Initial and Final

Start Year: 2020

End Year: 2100

Initial Amount: 50

Final Amount: 500

Values:

Populate

Delete

Clear

Year	Value
2020	50.00
2025	78.12
2030	106.25
2035	134.38
2040	162.50
2045	190.62
2050	218.75
2055	246.88
2060	275.00
2065	303.12
2070	331.25
2075	359.38

Add

Applied to:

- world
  - ☒ USA
  - ☒ Canada
  - ☒ EU-15
  - ☐ Europe\_Non\_EU
  - ☐ European Free Trade Association
  - ☐ Japan
  - ☐ Australia\_NZ
  - ☐ Central Asia
  - ☒ Russia
  - ☒ China
  - ☐ Middle East
  - ☐ Africa\_Eastern

Save

Close



New Scenario Component

Preset Custom

Component:

Action: Emission Tax (\$/t)

Sector: System Wide

Parameter: CO2

Populate:

Type: Initial and Final

Start Year: 2020

End Year: 2100

Initial Amount: 50

Final Amount: 500

Values: Populate Delete Clear

Year	Value
2020	50.00
2025	78.12
2030	106.25
2035	134.38
2040	162.50
2045	190.62
2050	218.75
2055	246.88
2060	275.00
2065	303.12
2070	331.25
2075	359.38

Applied to:

- world
  - ☒ USA
  - ☒ Canada
  - ☒ EU-15
  - ☐ Europe\_Non\_EU
  - ☐ European Free Trade Association
  - ☐ Japan
  - ☐ Australia\_NZ
  - ☐ Central Asia
  - ☒ Russia
  - ☒ China
  - ☐ Middle East
  - ☐ Africa\_Eastern

Save Close



Saving the scenario component

GCAM-USA Scenario Creator

Candidate Scenario Components

filter:

File Name	Address	Created
50pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:57:55
60pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:04
70pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:14
80pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:23
90pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:32
Reference4p2.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 13:56:54
SysTaxCO2Reg.txt	C:\Projects\GCAM-GUI\version\GCAM-Core\i...	Mon Oct 03 21:55:07

New Edit Delete

Construct or Edit Scenario

Name:

Components:

File Name
No content in table

Run

Create

Working Scenarios

filter:

Run Name	Components	Run Date
Ref4p2	Reference4p2.txt;	Mon Feb 08 14:04:24 EST 2016
30pctCO2RdxUSA	30pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
40pctCO2RdxUSA	40pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
50pctCO2RdxUSA	50pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
60pctCO2RdxUSA	60pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
70pctCO2RdxUSA	70pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
80pctCO2RdxUSA	80pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016

Analyze

Run Selected

Delete Selected

Options

Help

GCAM-USA Scenario Creator

Candidate Scenario Components

filter:

File Name	Address	Created
50pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:57:55
60pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:04
70pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:14
80pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:23
90pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:32
Reference4p2.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 13:56:54
SysTaxCO2Reg.txt	C:\Projects\GCAM-GUI\version\GCAM-Core\i...	Mon Oct 03 21:55:07

New

Edit

Delete

Construct or Edit Scenario

Name:

Components:

File Name
SysTaxCO2Reg.txt

Run

Create

▲

▼

Working Scenarios

filter:

Run Name	Components	Run Date
Ref4p2	Reference4p2.txt;	Mon Feb 08 14:04:24 EST 2016
30pctCO2RdxUSA	30pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
40pctCO2RdxUSA	40pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
50pctCO2RdxUSA	50pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
60pctCO2RdxUSA	60pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
70pctCO2RdxUSA	70pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
80pctCO2RdxUSA	80pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016

Analyze

Run Selected

Delete Selected

Options

Help

Selecting which components to include in the scenario

GCAM-USA Scenario Creator

Candidate Scenario Components

filter:

File Name	Address	Created
50pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:57:55
60pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:04
70pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:14
80pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:23
90pctCO2RdxUSA.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 14:58:32
Reference4p2.txt	c:\projects\gcam-gui\version\gcam-core\io\s...	Mon Feb 08 13:56:54
SysTaxCO2Reg.txt	C:\Projects\GCAM-GUI\version\GCAM-Core\i...	Mon Oct 03 21:55:07

New

Edit

Delete

Construct or Edit Scenario

Name:

Component

File Name
SysTaxCO2Reg.txt

Run

Create

▲

▼

Working Scenarios

filter:

Run Name	Components	Run Date
Ref4p2	Reference4p2.txt;	Mon Feb 08 14:04:24 EST 2016
30pctCO2RdxUSA	30pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
40pctCO2RdxUSA	40pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
50pctCO2RdxUSA	50pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
60pctCO2RdxUSA	60pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
70pctCO2RdxUSA	70pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016
80pctCO2RdxUSA	80pctCO2RdxUSA.txt;	Mon Feb 08 15:01:31 EST 2016

Analyze

Run Selected

Delete Selected

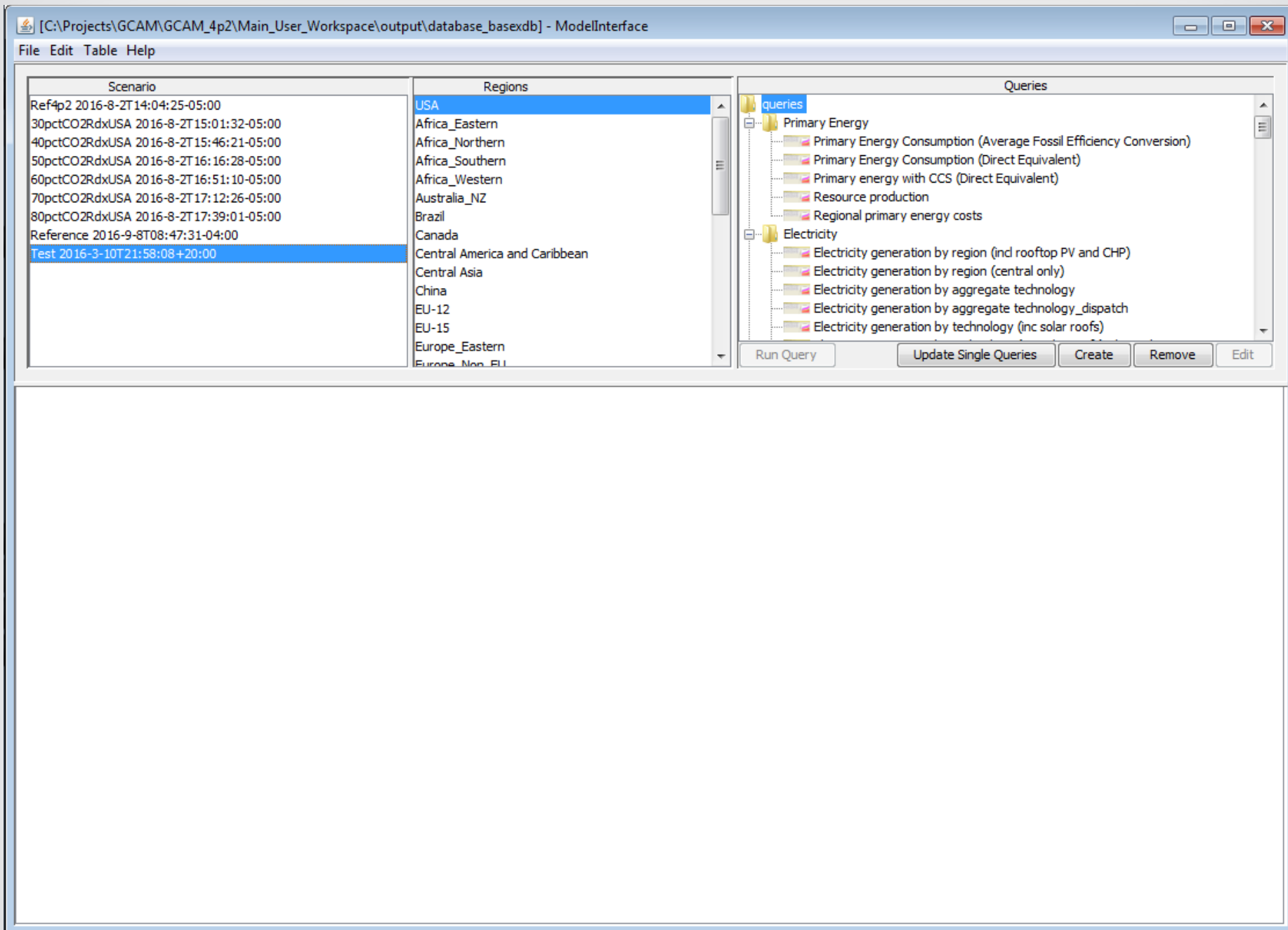
Options

Help

Naming the scenario







Enhanced Model Interface, showing scenarios that have been run, regions, and outputs



Scenario	Regions
Ref4p2 2016-8-2T14:04:25-05:00	USA
30pctCO2RdxUSA 2016-8-2T15:01:32-05:00	Africa_Eastern
40pctCO2RdxUSA 2016-8-2T15:46:21-05:00	Africa_Northern
50pctCO2RdxUSA 2016-8-2T16:16:28-05:00	Africa_Southern
60pctCO2RdxUSA 2016-8-2T16:51:10-05:00	Africa_Western
70pctCO2RdxUSA 2016-8-2T17:12:26-05:00	Australia_NZ
80pctCO2RdxUSA 2016-8-2T17:39:01-05:00	Brazil
Test 2016-4-10T07:44:25-04:00	Canada
	Central America and Caribbean
	Central Asia
	China
	EU-12
	EU-15
	Europe_Eastern
	Europe_Neg_EU

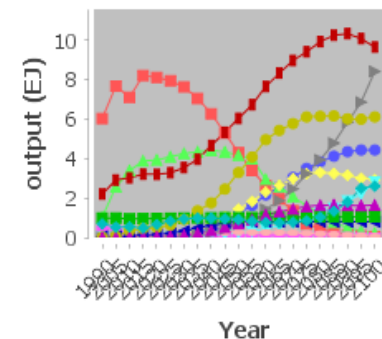
Queries
queries
Primary Energy
Primary Energy Consumption (Average Fossil Efficiency Conversion)
Primary Energy Consumption (Direct Equivalent)
Primary energy with CCS (Direct Equivalent)
Resource production
Regional primary energy costs
Electricity
Electricity generation by region (incl rooftop PV and CHP)
Electricity generation by region (central only)
Electricity generation by aggregate technology
Could not generate list.
Electricity generation by aggregate technology_dispatch

### Electricity generation by aggregate technology

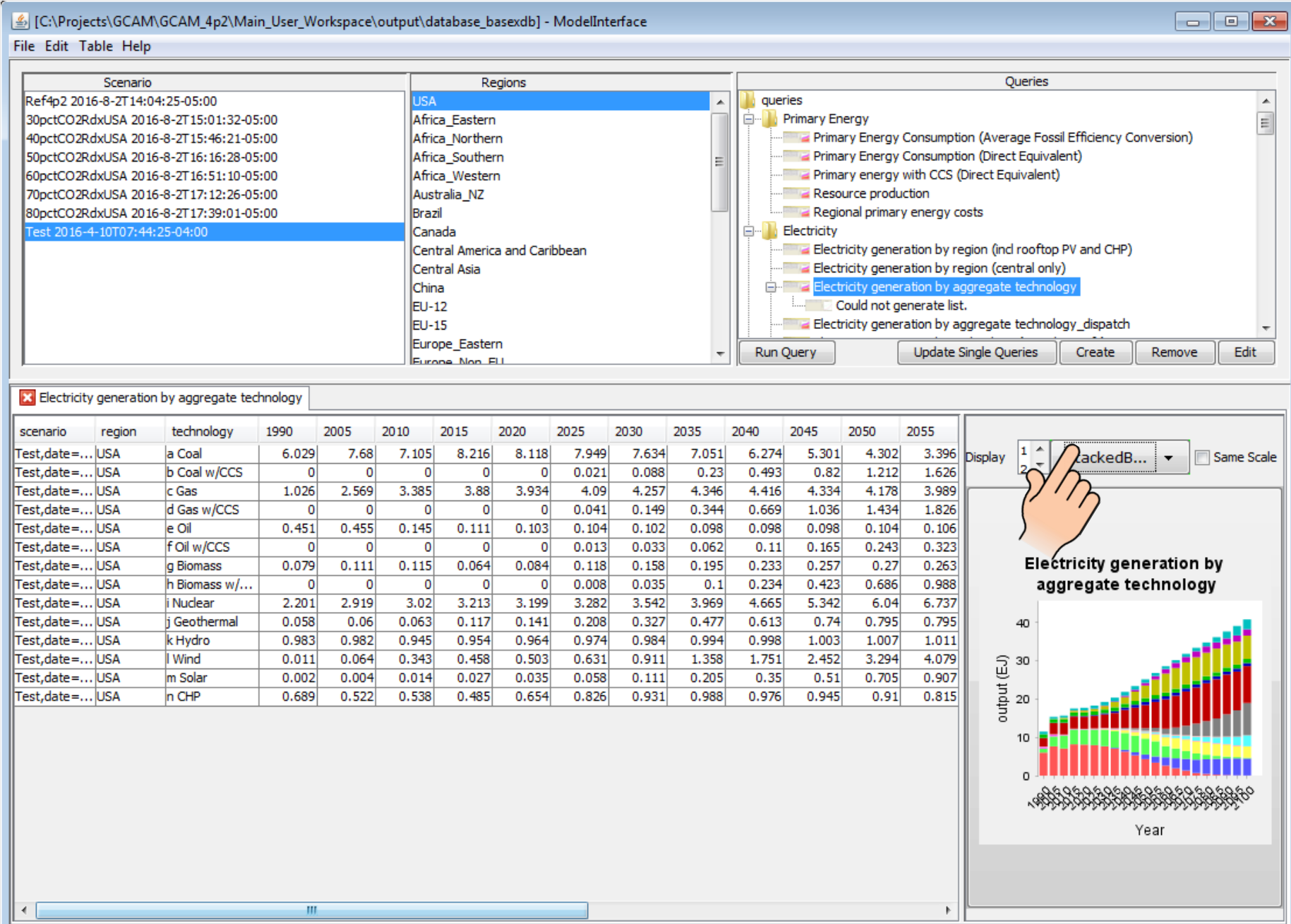
scenario	region	technology	1990	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055
Test,date=...	USA	a Coal	6.029	7.68	7.105	8.216	8.118	7.949	7.634	7.051	6.274	5.301	4.302	3.396
Test,date=...	USA	b Coal w/CCS	0	0	0	0	0	0.021	0.088	0.23	0.493	0.82	1.212	1.626
Test,date=...	USA	c Gas	1.026	2.569	3.385	3.88	3.934	4.09	4.257	4.346	4.416	4.334	4.178	3.989
Test,date=...	USA	d Gas w/CCS	0	0	0	0	0	0.041	0.149	0.344	0.669	1.036	1.434	1.826
Test,date=...	USA	e Oil	0.451	0.455	0.145	0.111	0.103	0.104	0.102	0.098	0.098	0.098	0.104	0.106
Test,date=...	USA	f Oil w/CCS	0	0	0	0	0	0.013	0.033	0.062	0.11	0.165	0.243	0.323
Test,date=...	USA	g Biomass	0.079	0.111	0.115	0.064	0.084	0.118	0.158	0.195	0.233	0.257	0.27	0.263
Test,date=...	USA	h Biomass w/...	0	0	0	0	0	0.008	0.035	0.1	0.234	0.423	0.686	0.988
Test,date=...	USA	i Nuclear	2.201	2.919	3.02	3.213	3.199	3.282	3.542	3.969	4.665	5.342	6.04	6.737
Test,date=...	USA	j Geothermal	0.058	0.06	0.063	0.117	0.141	0.208	0.327	0.477	0.613	0.74	0.795	0.795
Test,date=...	USA	k Hydro	0.983	0.982	0.945	0.954	0.964	0.974	0.984	0.994	0.998	1.003	1.007	1.011
Test,date=...	USA	l Wind	0.011	0.064	0.343	0.458	0.503	0.631	0.911	1.358	1.751	2.452	3.294	4.079
Test,date=...	USA	m Solar	0.002	0.004	0.014	0.027	0.035	0.058	0.111	0.205	0.35	0.51	0.705	0.907
Test,date=...	USA	n CHP	0.689	0.522	0.538	0.485	0.654	0.826	0.931	0.988	0.976	0.945	0.91	0.815

Display 1 2 LineChart Same Scale

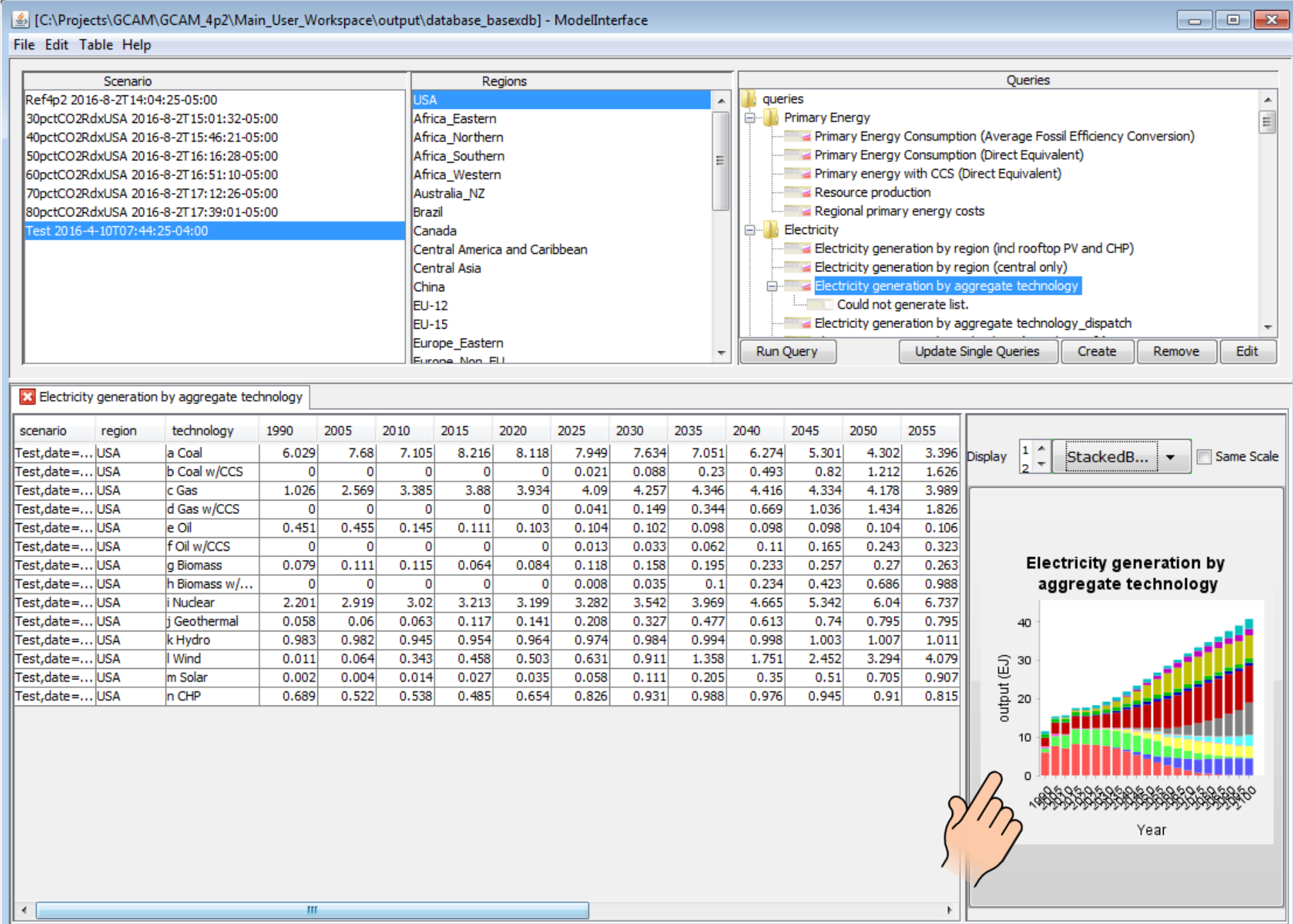
### Electricity generation by aggregate technology







Changing the thumbnail display type

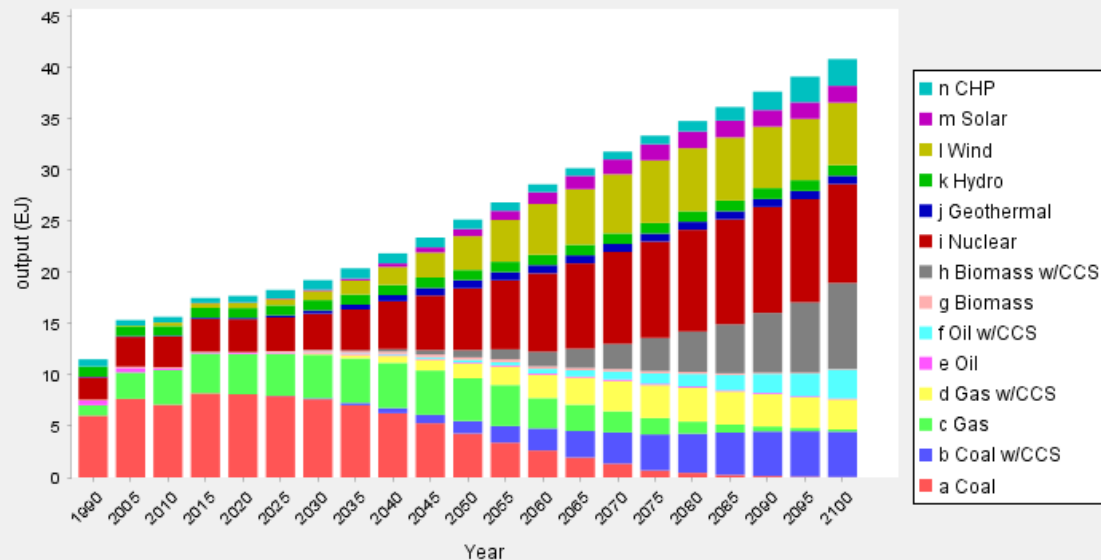


Clicking on the thumbnail...

## Electricity generation by aggregate technology

## Electricity generation by aggregate technology

Test, date=2016-4-10T07:44:25-04:00 USA



ChartOptions

Y...	1...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	
a ...	6.03	7.68	7.11	8.22	8.12	7.95	7.63	7.05	6.27	5.3	4.3	3.4	2.63	1.95	1.35	0.69	0.44	0.26	0.14	0.07	0.03	
b ...	0.0	0.0	0.0	0.0	0.0	0.02	0.09	0.23	0.49	0.82	1.21	1.63	2.16	2.58	3.04	3.51	3.84	4.12	4.35	4.43	4.43	
c ...	1.03	2.57	3.38	3.88	3.93	4.09	4.26	4.35	4.42	4.33	4.18	3.99	2.95	2.58	2.08	1.6	1.16	0.76	0.5	0.32	0.21	
d ...	0.0	0.0	0.0	0.0	0.0	0.04	0.15	0.34	0.67	1.04	1.43	1.83	2.3	2.65	2.98	3.23	3.3	3.24	3.16	3.0	2.94	
e ...	0.45	0.45	0.14	0.11	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.08	

## Queries

Primary Energy

Primary Energy Consumption (Average Fossil Efficiency Conversion)

Primary Energy Consumption (Direct Equivalent)

Primary energy with CCS (Direct Equivalent)

Resource production

Regional primary energy costs

Electricity

Electricity generation by region (incl rooftop PV and CHP)

Electricity generation by region (central only)

Electricity generation by aggregate technology

Could not generate list.

Electricity generation by aggregate technology\_dispatch

Query

Update Single Queries

Create

Remove

Edit

2045	2050	2055
5.301	4.302	3.396
0.82	1.212	1.626
4.334	4.178	3.989
1.036	1.434	1.826
0.098	0.104	0.106
0.165	0.243	0.323
0.257	0.27	0.263
0.423	0.686	0.988
5.342	6.04	6.737
0.74	0.795	0.795
1.003	1.007	1.011
2.452	3.294	4.079
0.51	0.705	0.907
0.945	0.91	0.815

Display

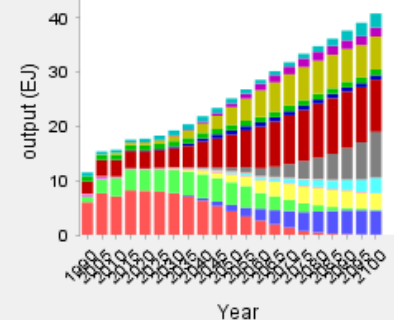
1

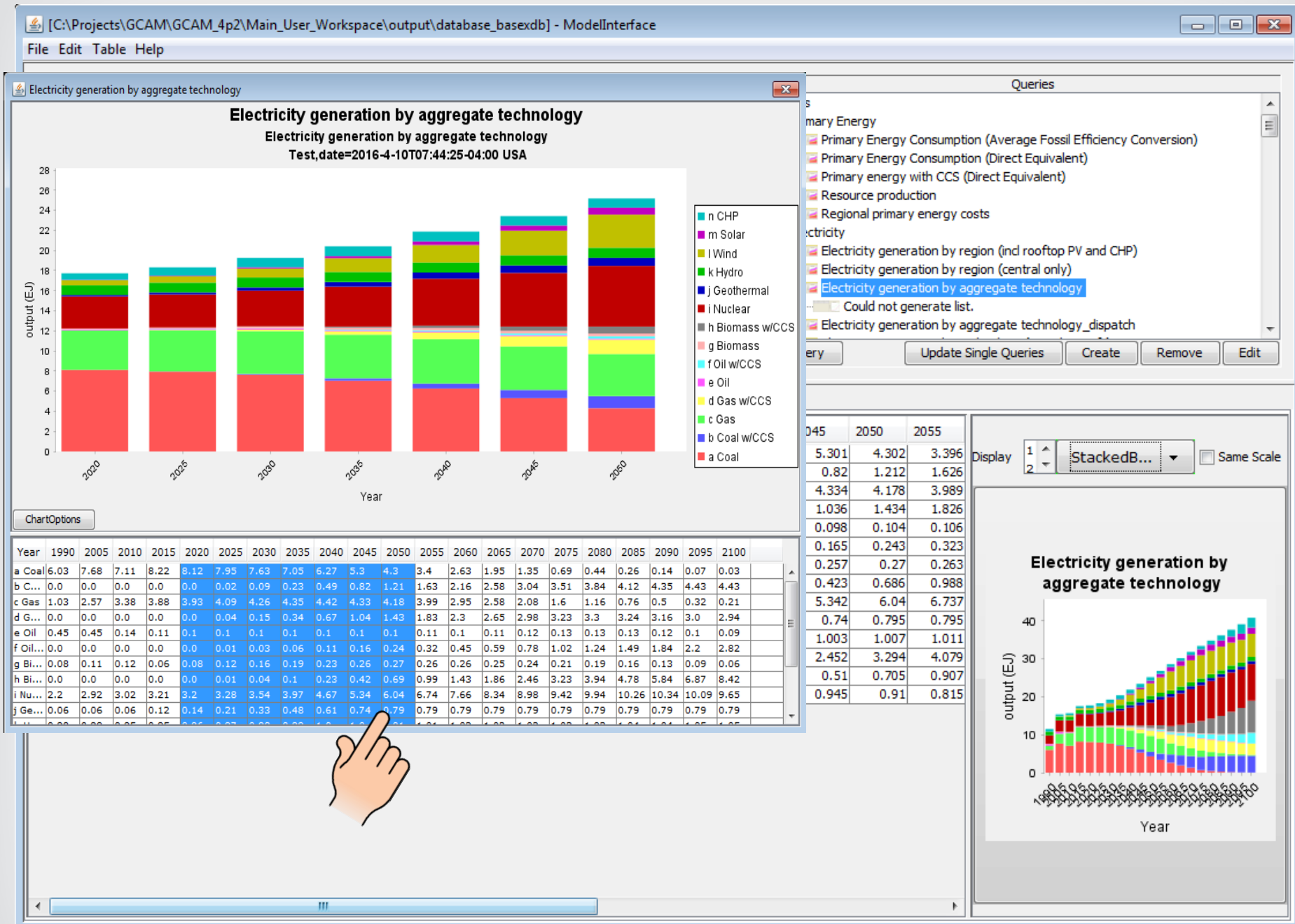
2

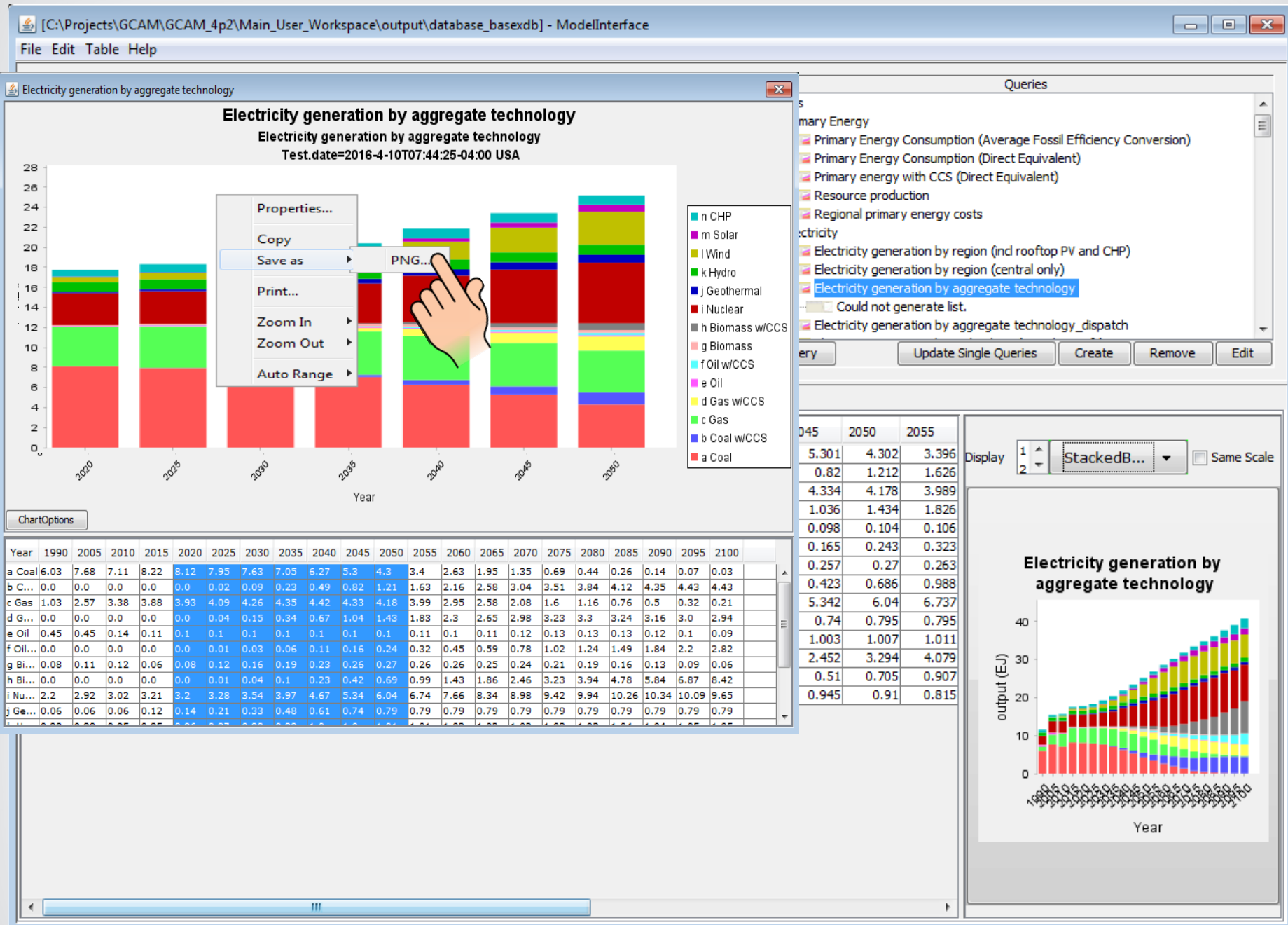
StackedB...

Same Scale

## Electricity generation by aggregate technology







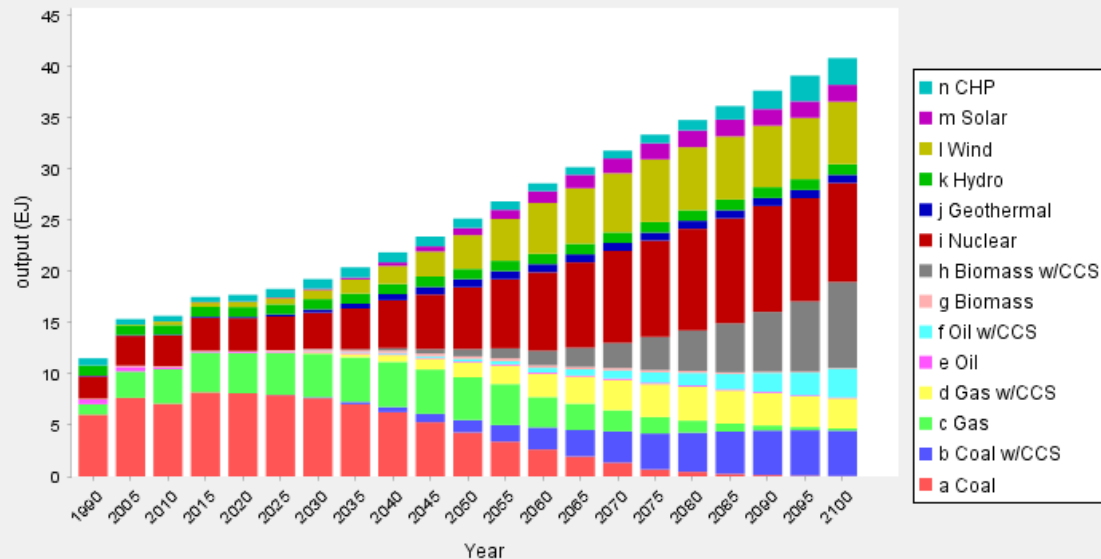
And save the graphic as a png file



## Electricity generation by aggregate technology

## Electricity generation by aggregate technology

Test,date=2016-4-10T07:44:25-04:00 USA



ChartOptions

Y...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...	2...		
a ...	7.11	8.22	8.12	7.95	7.63	7.05	6.27	5.3	4.3	3.4	2.63	1.95	1.35	0.69	0.44	0.26	0.14	0.07	0.03		
b ...	0.0	0.0	0.0	0.02	0.09	0.23	0.49	0.82	1.21	1.63	2.16	2.58	3.04	3.51	3.84	4.12	4.35	4.43	4.43		
c ...	1.03	2.57	3.38	3.88	3.93	4.09	4.26	4.35	4.42	4.33	4.18	3.99	2.95	2.58	2.08	1.6	1.16	0.76	0.5	0.32	0.21
d ...	0.0	0.0	0.0	0.0	0.04	0.15	0.34	0.67	1.04	1.43	1.83	2.3	2.65	2.98	3.23	3.3	3.24	3.16	3.0	2.94	
e Oil	0.45	0.45	0.44	0.41	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	

## Queries

## Primary Energy

- Primary Energy Consumption (Average Fossil Efficiency Conversion)
- Primary Energy Consumption (Direct Equivalent)
- Primary energy with CCS (Direct Equivalent)
- Resource production
- Regional primary energy costs

## Electricity

- Electricity generation by region (incl rooftop PV and CHP)
- Electricity generation by region (central only)
- Electricity generation by aggregate technology
- Could not generate list.
- Electricity generation by aggregate technology\_dispatch

Query

Update Single Queries

Create

Remove

Edit

2045	2050	2055
5.301	4.302	3.396
0.82	1.212	1.626
4.334	4.178	3.989
1.036	1.434	1.826
0.098	0.104	0.106
0.165	0.243	0.323
0.257	0.27	0.263
0.423	0.686	0.988
5.342	6.04	6.737
0.74	0.795	0.795
1.003	1.007	1.011
2.452	3.294	4.079
0.51	0.705	0.907
0.945	0.91	0.815

Display

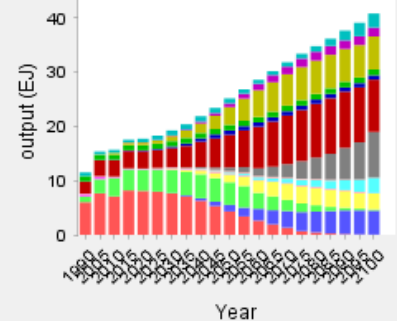
1

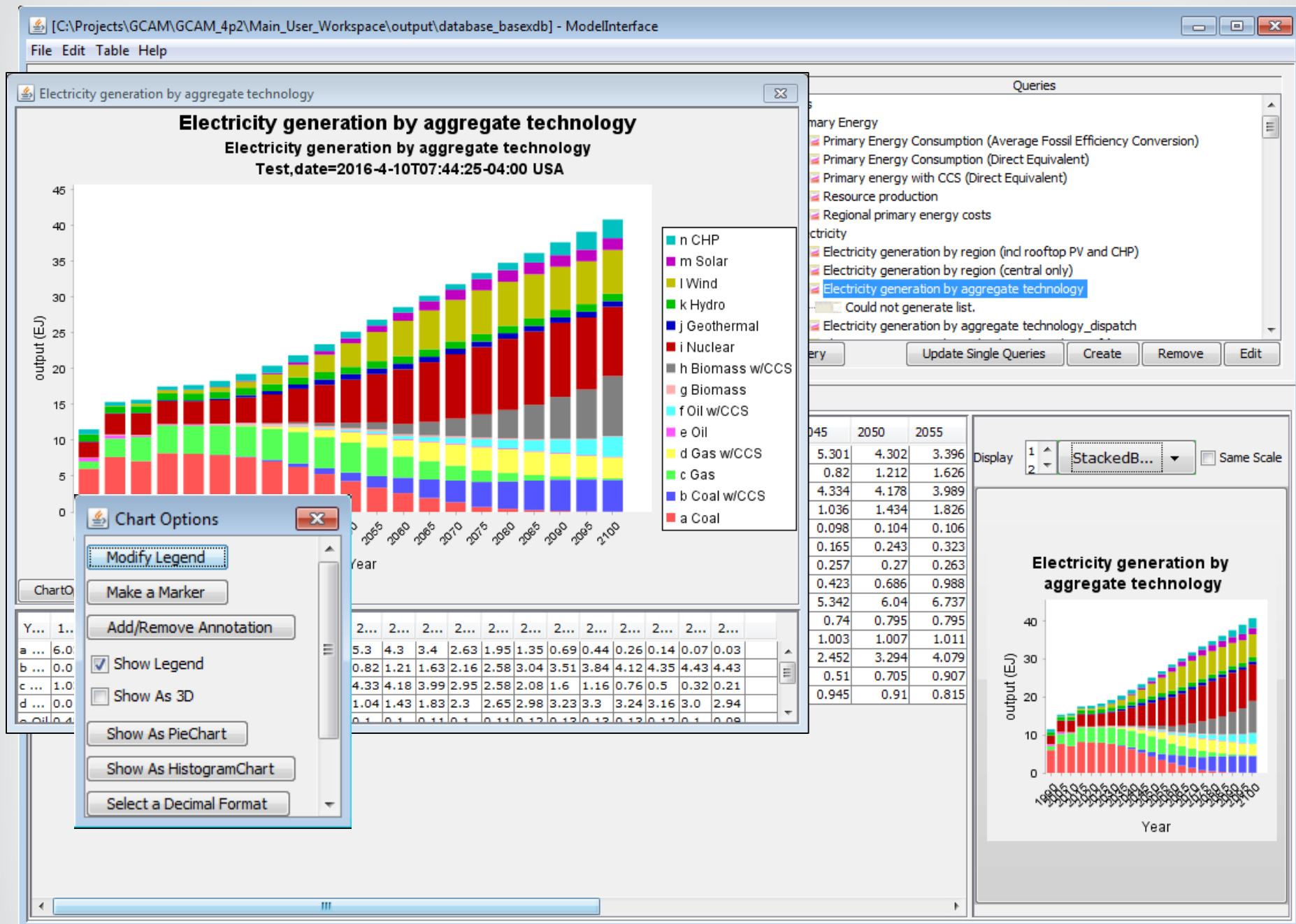
2

StackedB...

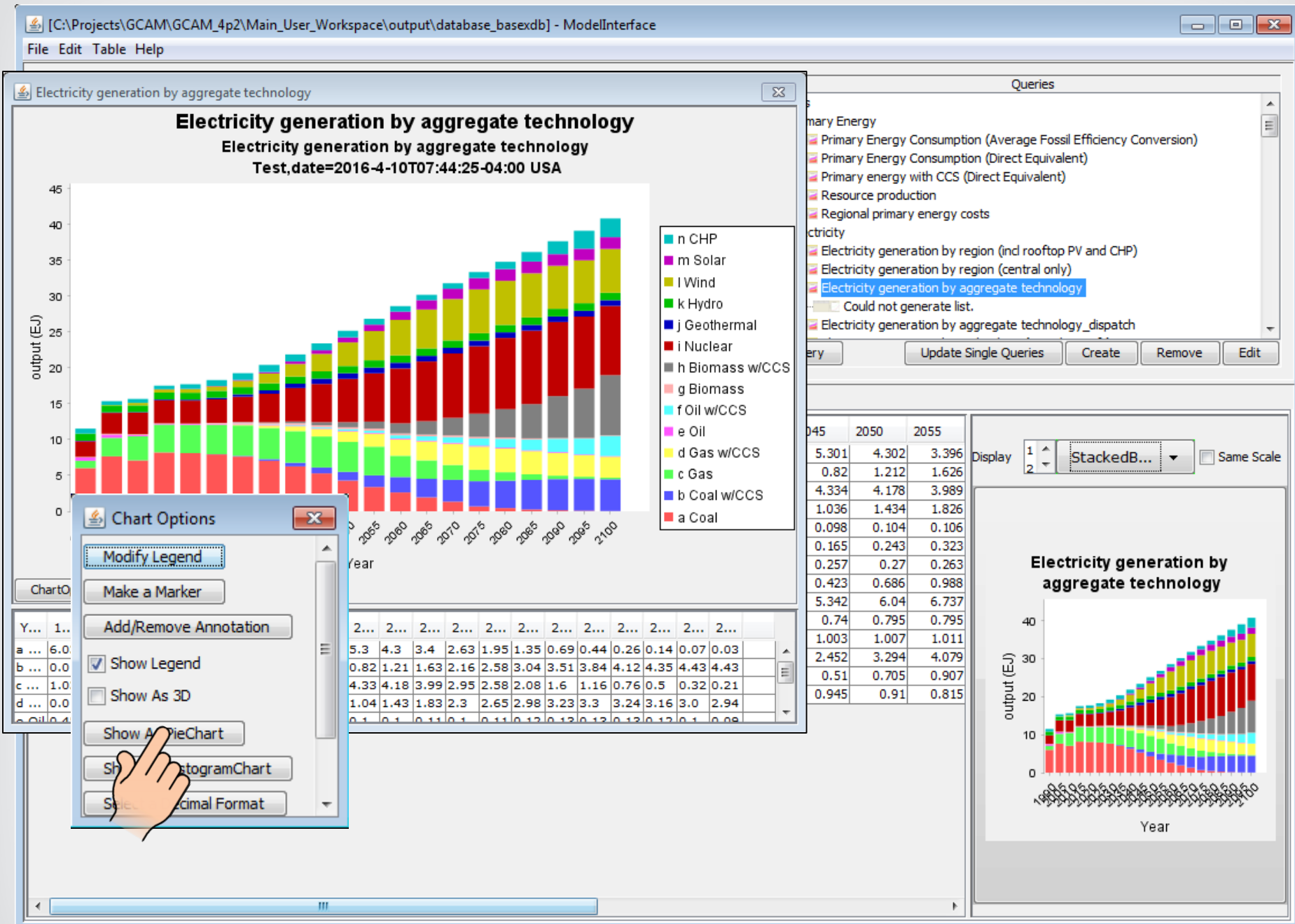
Same Scale

## Electricity generation by aggregate technology



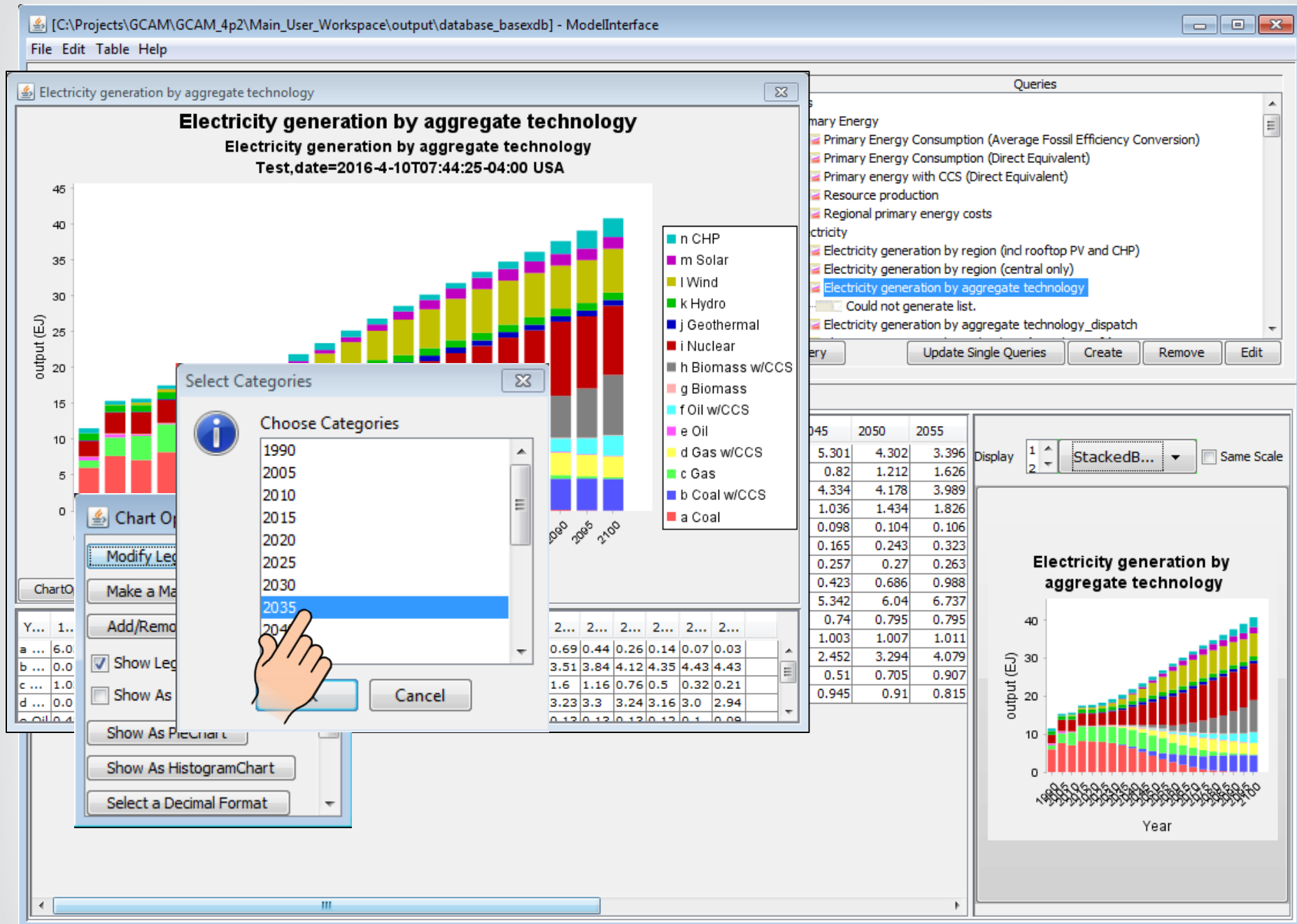


Plots support additional functions



Plots support additional functions





Plots support additional functions

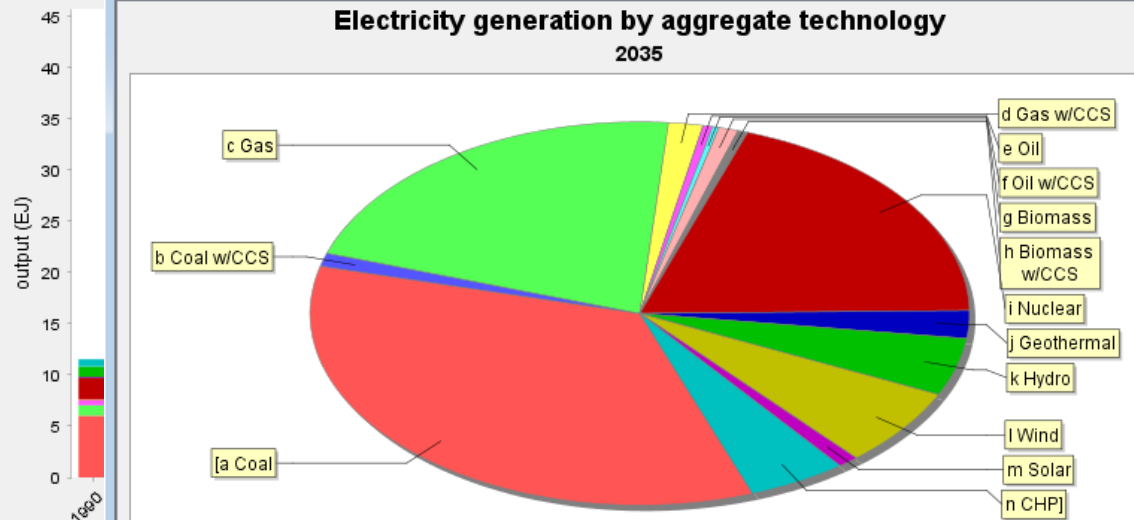


## Electricity generation by aggregate technology

## Electricity generation by aggregate technology

## Electricity generation by aggregate technology

2035



ChartOptions

● [a Coal] ● [b Coal w/CCS] ● [c Gas] ● [d Gas w/CCS] ● [e Oil] ● [f Oil w/CCS] ● [g Biomass] ● [h Biomass w/CCS] ● [i Nuclear] ● [j Geothermal] ● [k Hydro] ● [l Wind] ● [m Solar] ● [n CHP]

ChartOptions

Y...	1...	2...	3...	4...	5...	6...	7...	8...	9...	10...	11...	12...	13...	14...	15...	16...	17...	18...	19...	20...
a ...	6.037																			
b ...	0.0	0.0																		
c ...	1.032																			
d ...	0.0	0.0																		
e ...	0.45	0.45	0.14	0.11	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.09	
f ...	0.0	0.0	0.0	0.0	0.0	0.01	0.03	0.06	0.11	0.16	0.24	0.32	0.45	0.59	0.78	1.02	1.24	1.49	1.84	2.2

## Queries

Primary Energy

Primary Energy Consumption (Average Fossil Efficiency Conversion)

Primary Energy Consumption (Direct Equivalent)

Primary energy with CCS (Direct Equivalent)

Source production

Regional primary energy costs

Electricity generation by region (incl rooftop PV and CHP)

Electricity generation by region (central only)

Electricity generation by aggregate technology

Could not generate list.

Electricity generation by aggregate technology\_dispatch

Update Single Queries

Create

Remove

Edit

	2050	2055
1	4.302	3.396
2	1.212	1.626
4	4.178	3.989
5	1.434	1.826
3	0.104	0.106
5	0.243	0.323
7	0.27	0.263
3	0.686	0.988
2	6.04	6.737
4	0.795	0.795
3	1.007	1.011
2	3.294	4.079
1	0.705	0.907
5	0.91	0.815

Display

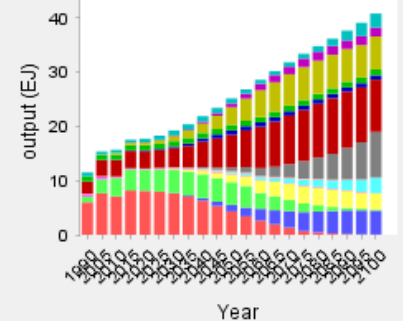
1

2

StackedB...

Same Scale

## Electricity generation by aggregate technology





Scenario	Regions
Ref4p2 2016-8-2T14:04:25-05:00	USA
30pctCO2RdxUSA 2016-8-2T15:01:32-05:00	Africa_Eastern
40pctCO2RdxUSA 2016-8-2T15:46:21-05:00	Africa_Northern
50pctCO2RdxUSA 2016-8-2T16:16:28-05:00	Africa_Southern
60pctCO2RdxUSA 2016-8-2T16:51:10-05:00	Africa_Western
70pctCO2RdxUSA 2016-8-2T17:12:26-05:00	Australia_NZ
80pctCO2RdxUSA 2016-8-2T17:39:01-05:00	Brazil
Test 2016-4-10T07:44:25-04:00	Canada
	Central America and Caribbean
	Central Asia
	China
	EU-12
	EU-15
	Europe_Eastern
	Europe_Non_EU

Queries
queries
Primary Energy
Primary Energy Consumption (Average Fossil Efficiency Conversion)
Primary Energy Consumption (Direct Equivalent)
Primary energy with CCS (Direct Equivalent)
Resource production
Regional primary energy costs
Electricity
Electricity generation by region (ind rooftop PV and CHP)
Electricity generation by region (central only)
Electricity generation by aggregate technology
Could not generate list.
Electricity generation by aggregate technology_dispatch

Run Query Update Single Queries Create Remove Edit

[C:\Projects\GCAM\GCAM\_4p2\Main\_User\_Workspace\output\database\_basexdb] - ModelInterface

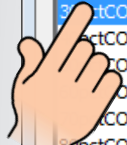
File Edit Table Help

Scenario	Regions
Ref4p2 2016-8-2T14:04:25-05:00	USA
3pctCO2RdxUSA 2016-8-2T15:01:32-05:00	Africa_Eastern
ActCO2RdxUSA 2016-8-2T15:46:21-05:00	Africa_Northern
CO2RdxUSA 2016-8-2T16:16:28-05:00	Africa_Southern
CO2RdxUSA 2016-8-2T16:51:10-05:00	Africa_Western
CO2RdxUSA 2016-8-2T17:12:26-05:00	Australia_NZ
60pctCO2RdxUSA 2016-8-2T17:39:01-05:00	Brazil
Test 2016-4-10T07:44:25-04:00	Canada
	Central America and Caribbean
	Central Asia
	China
	EU-12
	EU-15
	Europe_Eastern
	Europe_Non_EU

Queries

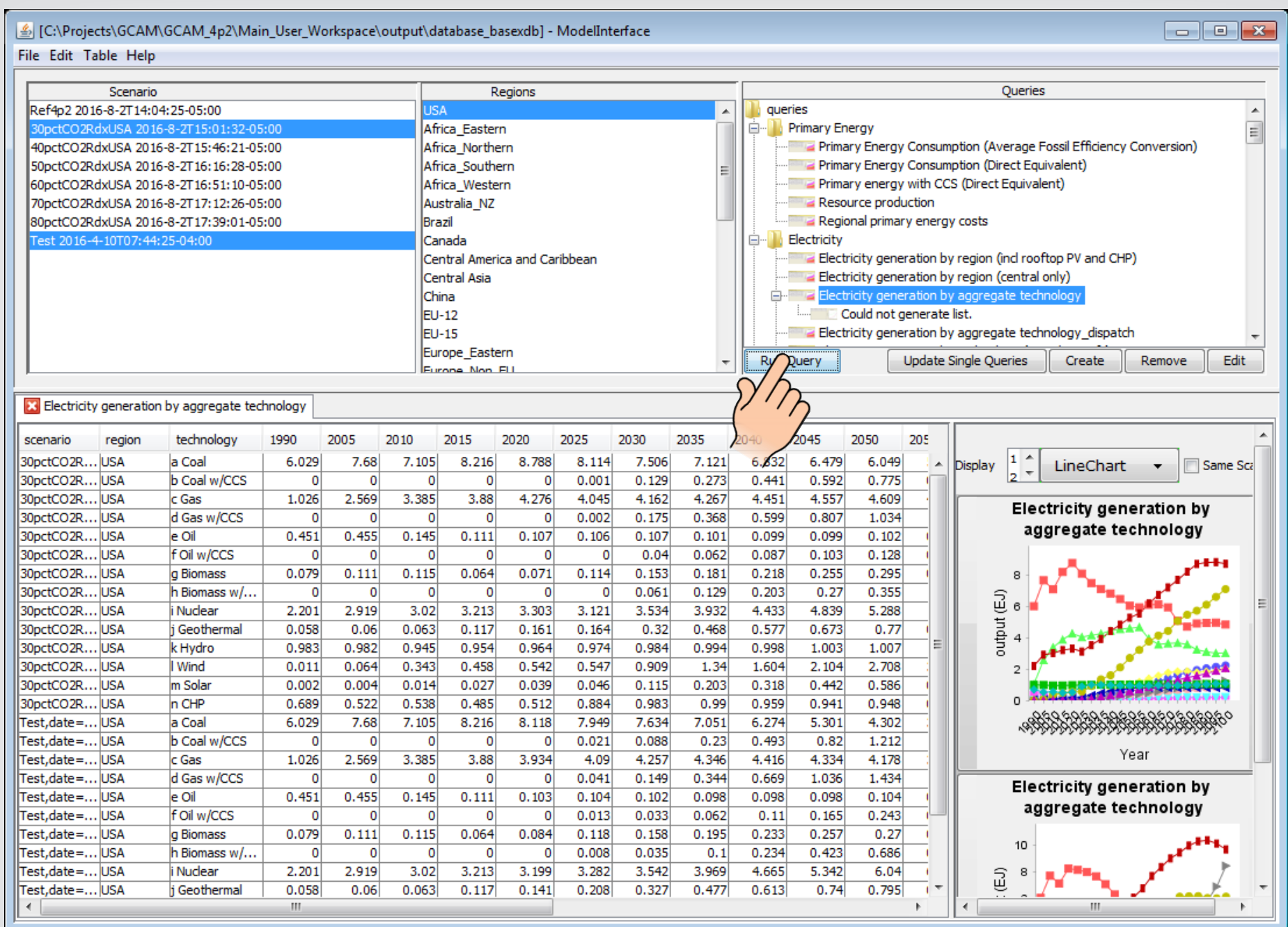
- queries
  - Primary Energy
    - Primary Energy Consumption (Average Fossil Efficiency Conversion)
    - Primary Energy Consumption (Direct Equivalent)
    - Primary energy with CCS (Direct Equivalent)
    - Resource production
    - Regional primary energy costs
  - Electricity
    - Electricity generation by region (ind rooftop PV and CHP)
    - Electricity generation by region (central only)
    - Electricity generation by aggregate technology
    - Could not generate list.
    - Electricity generation by aggregate technology\_dispatch

Run Query Update Single Queries Create Remove Edit

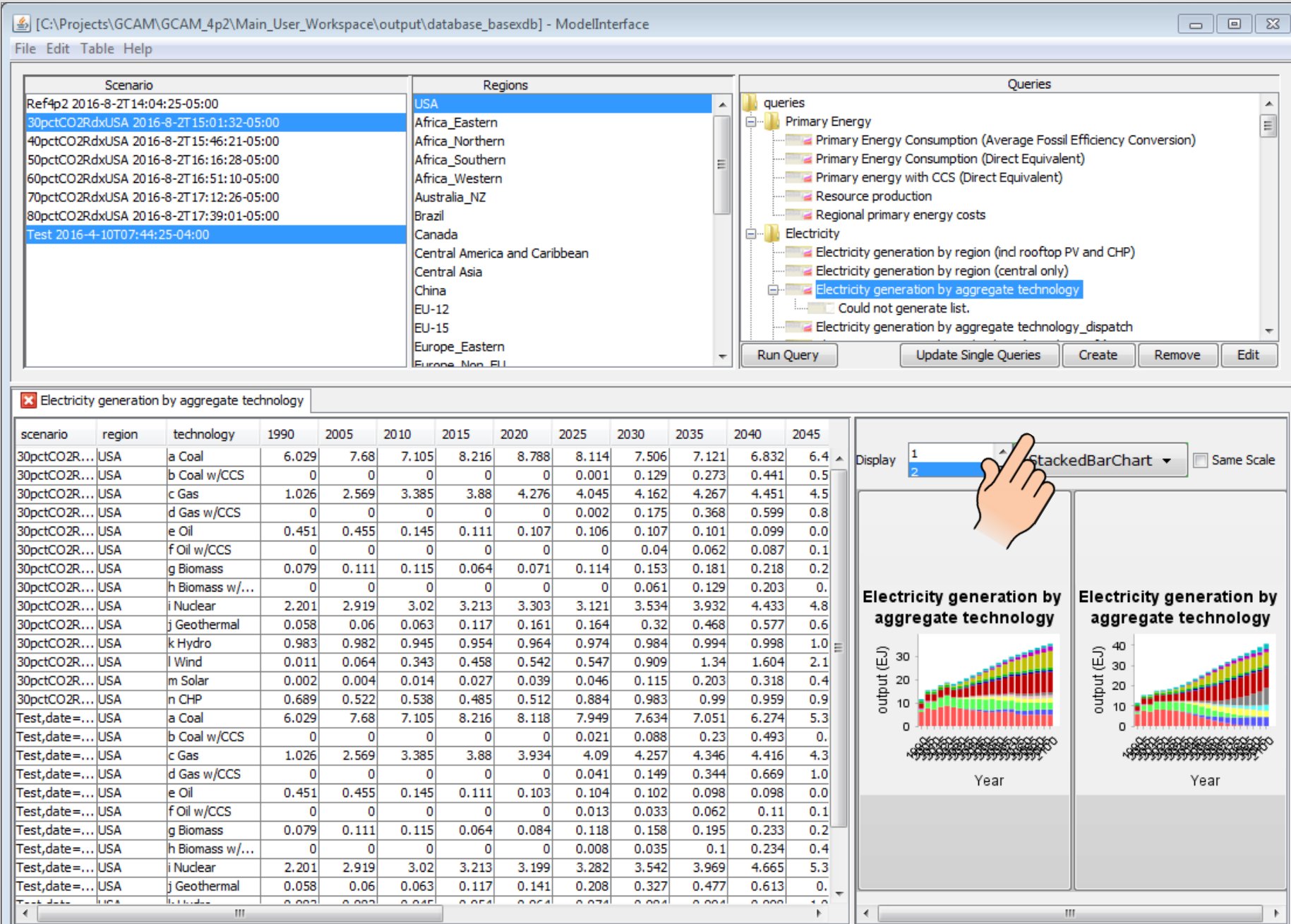


We can also view and compare multiple scenarios



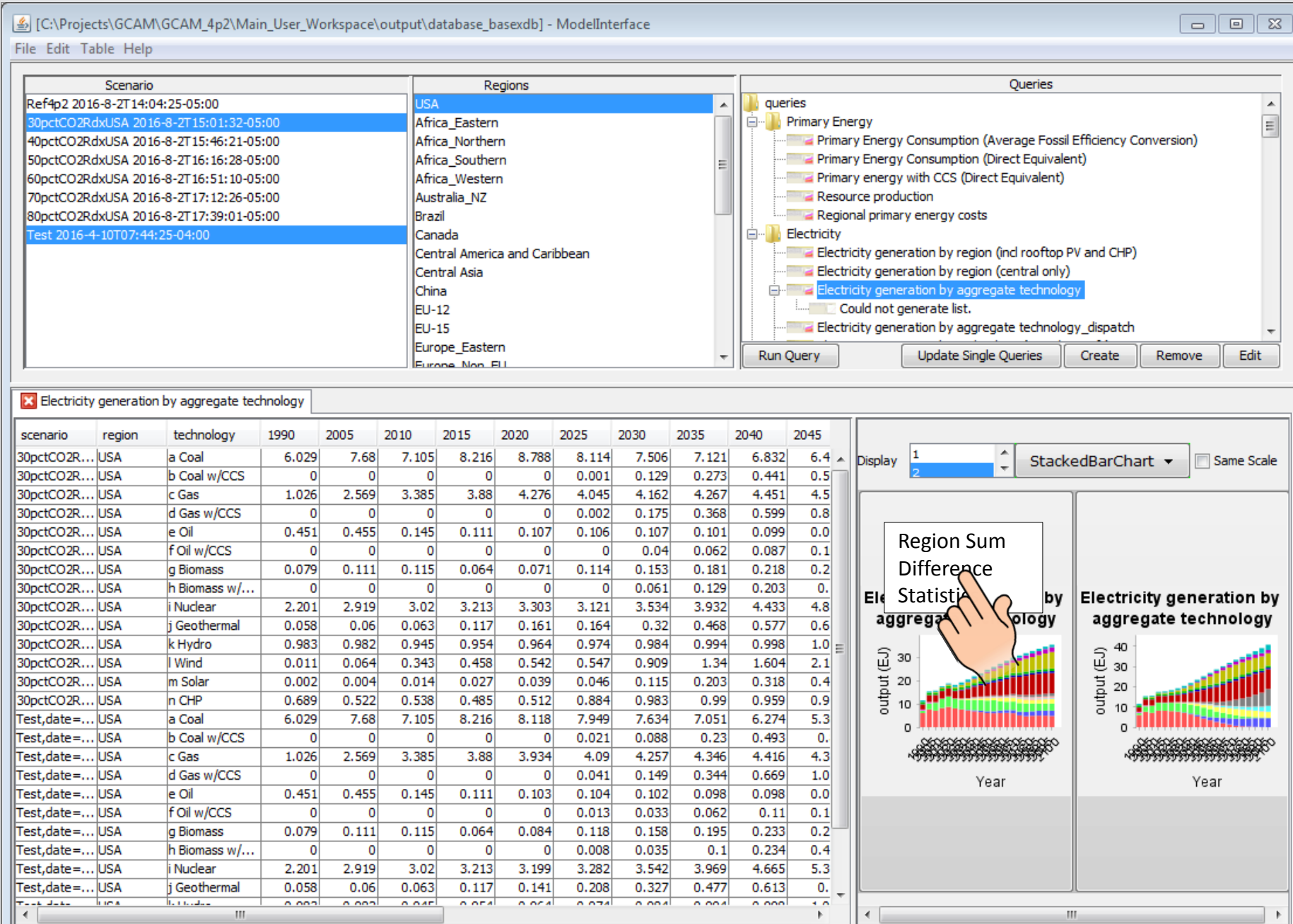


When multiple scenarios and/or regions are selected, graphics for each are created

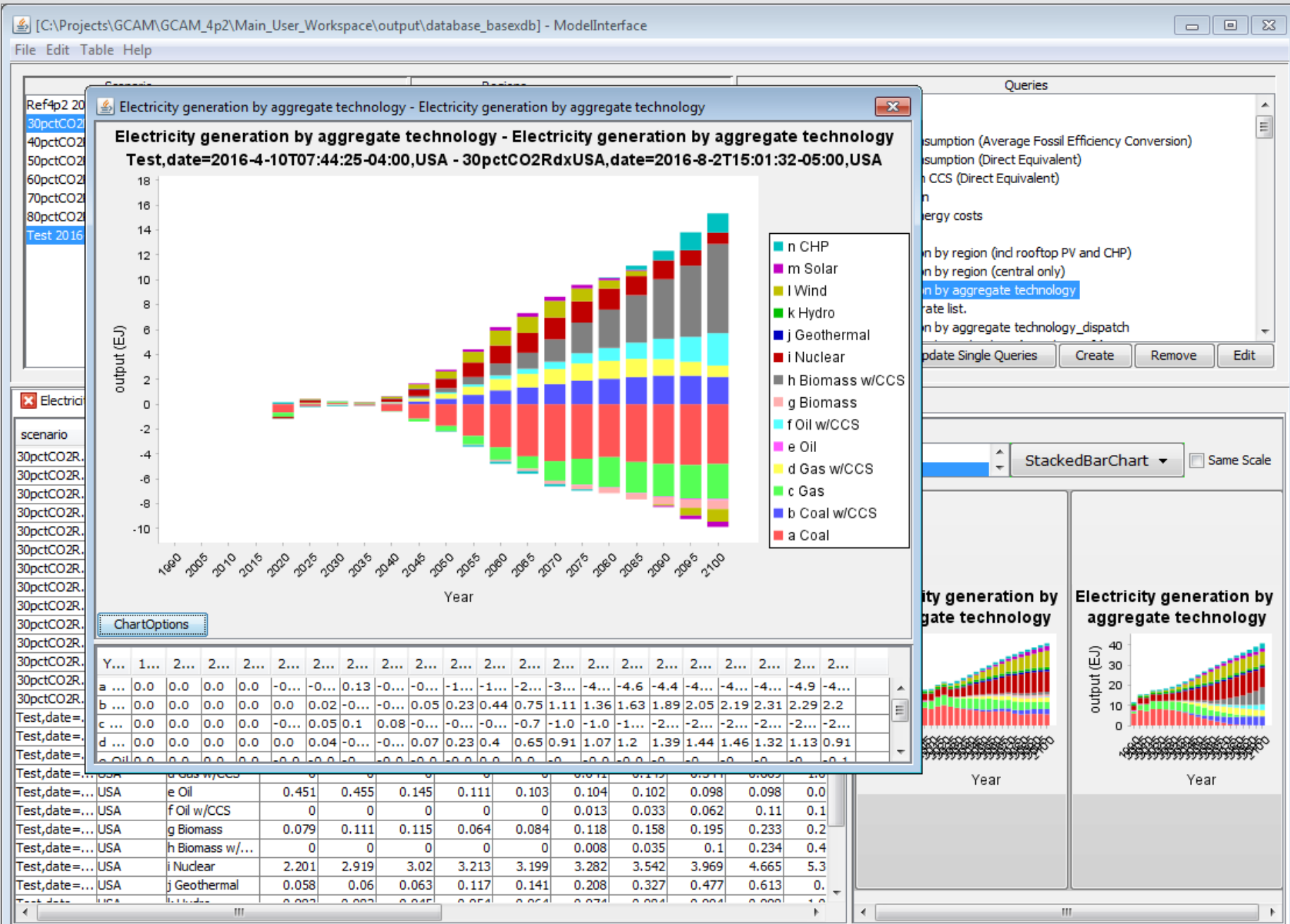


We can change the display type to facilitate comparison





And automatically show differences



Here is the resulting difference plot for electricity production between two scenarios

[C:\Projects\GCAM\GCAM\_4p2\Main\_User\_Workspace\output\database\_basexdb] - ModelInterface

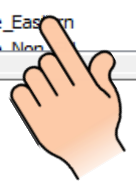
File Edit Table Help

Scenario	Regions
Ref4p2 2016-8-2T14:04:25-05:00	USA
30pctCO2RdxUSA 2016-8-2T15:01:32-05:00	Africa_Eastern
40pctCO2RdxUSA 2016-8-2T15:46:21-05:00	Africa_Northern
50pctCO2RdxUSA 2016-8-2T16:16:28-05:00	Africa_Southern
60pctCO2RdxUSA 2016-8-2T16:51:10-05:00	Africa_Western
70pctCO2RdxUSA 2016-8-2T17:12:26-05:00	Australia_NZ
80pctCO2RdxUSA 2016-8-2T17:39:01-05:00	Brazil
Test 2016-4-10T07:44:25-04:00	Canada
	Central America and Caribbean
	Central Asia
	China
	EU-12
	EU-15
	Europe_Eastern
	Europe_Northern

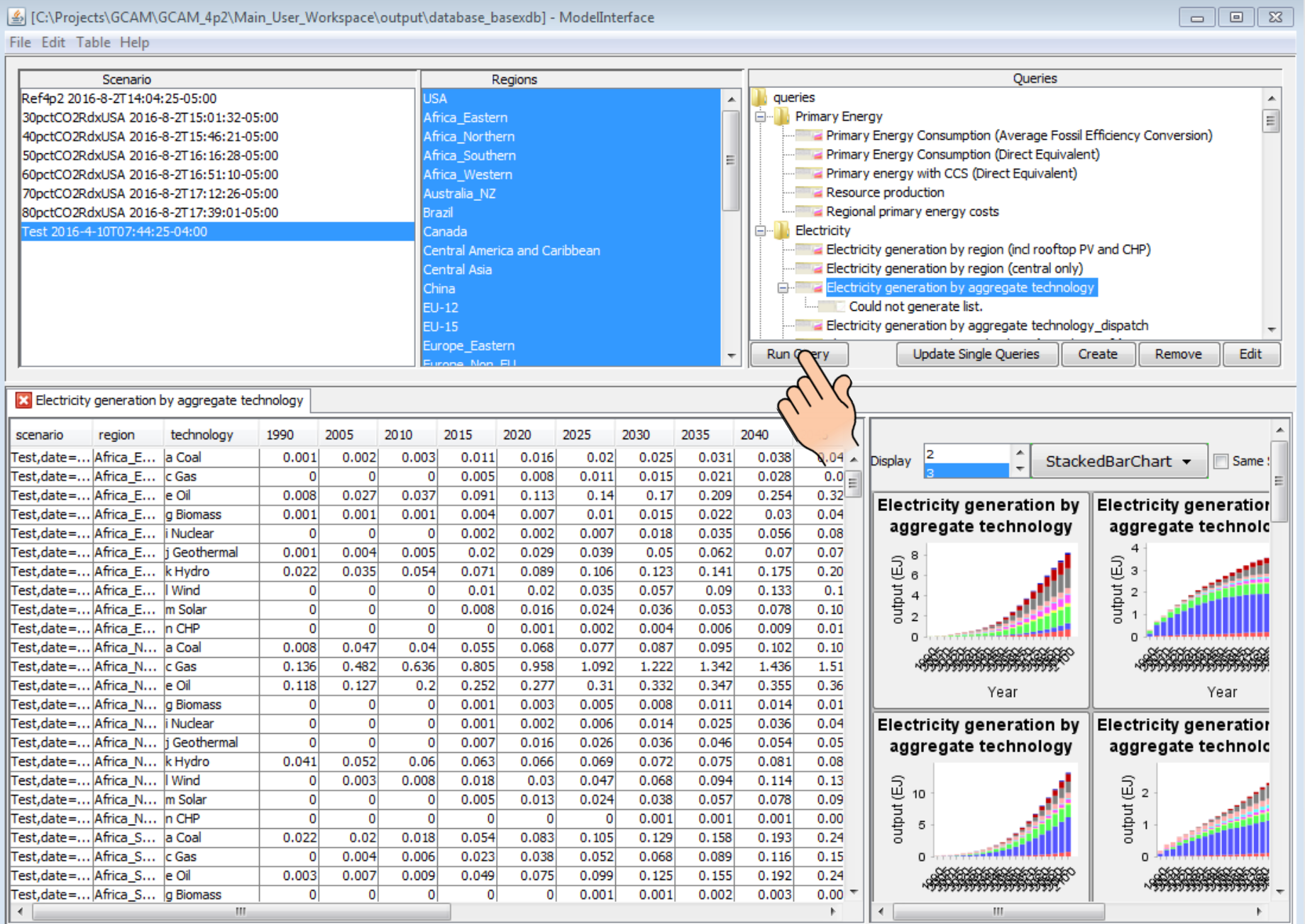
Queries

- queries
  - Primary Energy
    - Primary Energy Consumption (Average Fossil Efficiency Conversion)
    - Primary Energy Consumption (Direct Equivalent)
    - Primary energy with CCS (Direct Equivalent)
    - Resource production
    - Regional primary energy costs
  - Electricity
    - Electricity generation by region (ind rooftop PV and CHP)
    - Electricity generation by region (central only)
    - Electricity generation by aggregate technology
    - Could not generate list.
    - Electricity generation by aggregate technology\_dispatch

Run Query Update Single Queries Create Remove Edit

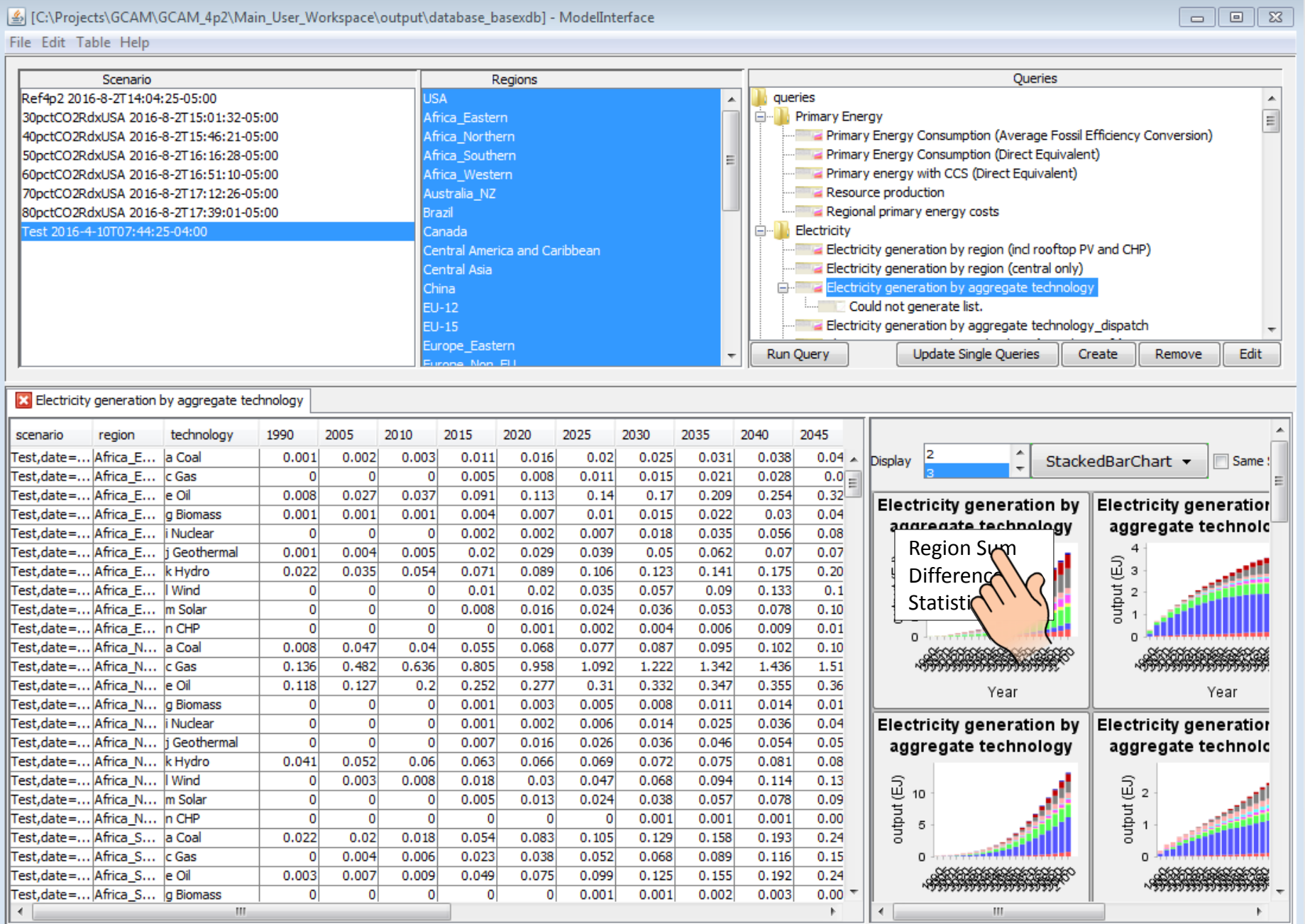


Another options is to view multiple regions simultaneously



When you select multiple regions, each gets its own figure.





You can create aggregate regions by summing over the model regions...



## Lessons:

- GCAM-USA is a complex modeling system and its use has required building expertise in R, C++, xml, MS Visual Studio
- However, it appears the paradigm of integrating GCAM-USA into the GLIMPSE framework is very workable and has value to our partners

## Next steps:

- Continue harmonizing emission factors
  - rail and marine shipping, industrial, other pollutants
- Improving policy levers
  - Renewable electricity standards applicable to both new and old generation
  - End-use efficiency standards
- Internal Beta test of Scenario Builder and Enhanced Model Interface in late 2016
- External Beta test of Scenario Builder and Enhanced Model Interface in 2017?



# Questions?

Contact information:

Dan Loughlin, U.S. EPA, ORD – [loughlin.dan@epa.gov](mailto:loughlin.dan@epa.gov)

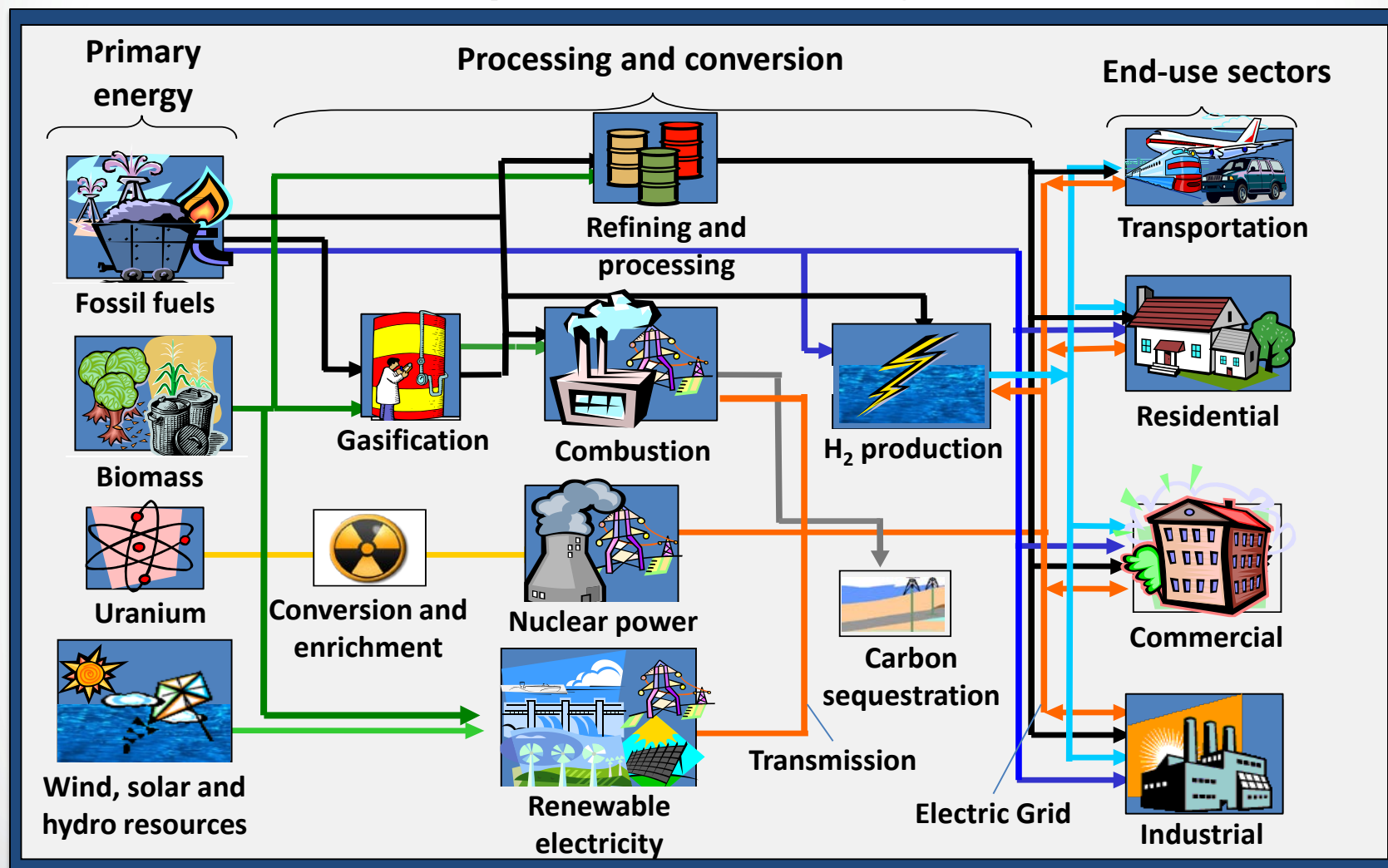
Chris Nolte, U.S. EPA, ORD – [nolte.chris@epa.gov](mailto:nolte.chris@epa.gov)



# Background

## The energy system

### Components of the energy system





## Energy system contributions to environmental concerns:

- **Air quality<sup>1</sup>**

- Photochemical smog: 92% of nitrogen oxide (NO<sub>x</sub>) emissions\*
- Acid rain: 90% of sulfur dioxide (SO<sub>2</sub>) emissions\*

\*Percentage of U.S. anthropogenic emissions from the energy system in 2014

<sup>1</sup> EPA trends report

- **Climate change<sup>2</sup>**

- Greenhouse gas emissions: 95% of carbon dioxide (CO<sub>2</sub>) emissions\*
- Major source of short-lived climate pollutants (e.g., black carbon, methane)

<sup>2</sup> EPA 2016 GHG Inventory

<sup>3</sup> Maupin et al., 2014 (USGS)

- **Water**

- Demands: electricity production accounts for 45% of U.S. water withdrawals<sup>3</sup>
- Pollution:
  - wastewater from fuel extraction and processing, seepage from waste
  - eutrophication from N deposition, acidification from S and N deposition
  - heat pollution from cooling water discharge

- **Waste production**

- Mine tailings, combustion residues, agricultural wastes