Long-range Energy Alternatives Planning System - Application to Canada

NSERC/Cenovus/Alberta Innovates Associate Industrial Chair Program in Energy and Environmental Systems Engineering

www.energysystems.ualberta.ca

Webinar

October 1, 2019

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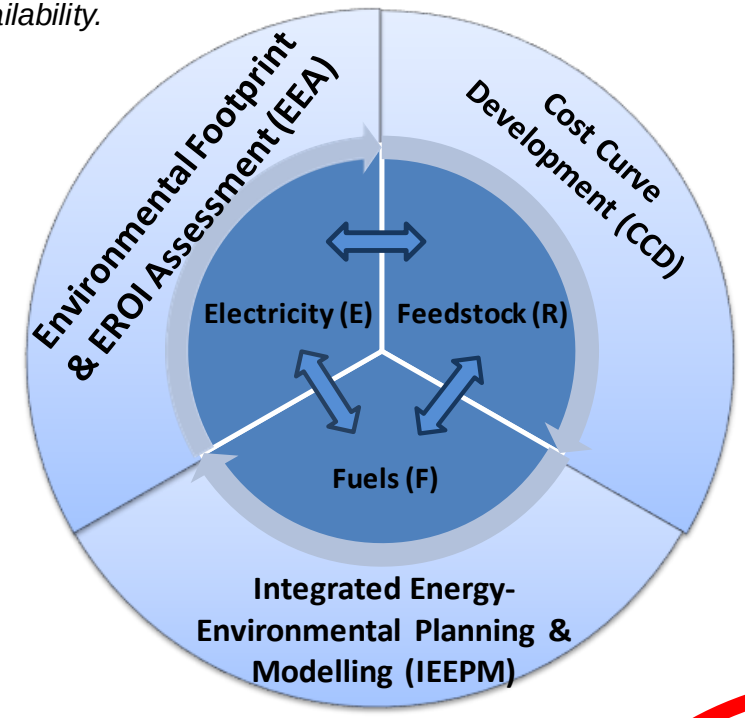
Industrial Research Chair Program

NSERC/Cenovus/Alberta Innovates Associate Industrial Chair Program in Energy and Environmental Systems Engineering

Objective: To identify pathways to low carbon energy production and use considering costs, environmental impacts, and resource availability.



Cost Curve Development (CCD)	Environmental Footprint & EROI Assessment (EEA)	Integrated Energy-Environmental Planning & Modelling (IEEPM)
Understand the costs of existing and new low carbon/decarboznied energy production and use through the development of techno-economic models	Understand the GHG, water, and land footprints and energy return on investment (EROI) of different energy production and use pathways	Understand the GHG abatement cost and mitigation potential for energy pathways for a jurisdiction along with feedstock availability

LEAP/WEAP GROUP

- Group members:
  - Matthew Davis, Research Engineer
  - Eskinder Gemechu, PDF
  - Saeidreza Radpour, PhD student
  - Anil Katta, MSc student (Recently graduated)
  - Ankit Gupta, MSc student
  - Ryan Janzen, MSc student
  - Christophe Owttrim, MSc student
  - Thomas Patrick, MSc student
  - Minza Haider, MSc student
  - Andre Siqueira, Undergraduate student intern

WEBINAR OUTLINE

- **Background and LEAP characteristics**
- **The LEAP-Canada model**
- **Scenario analysis**
- **Summary of research**
- **Questions – Please type your question in the chat box or just indicate that you have a question to ask**

BACKGROUND AND LEAP CHARACTERISTICS

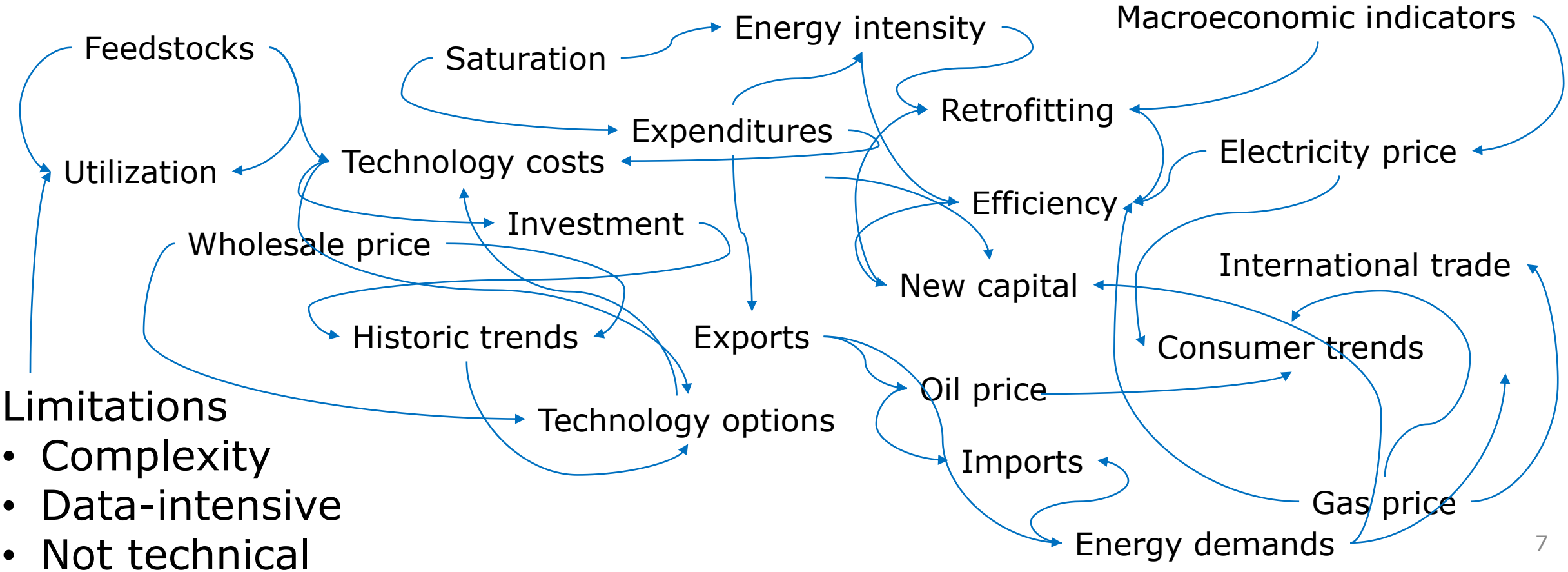
MODEL FRAMEWORK COMPARISONS

- **Optimization-based models**

Limitations
- Requires cost data
- Result quality relies on quality of cost data
- Non-transparent, complex

MODEL FRAMEWORK COMPARISONS

- **Simulation-based models**

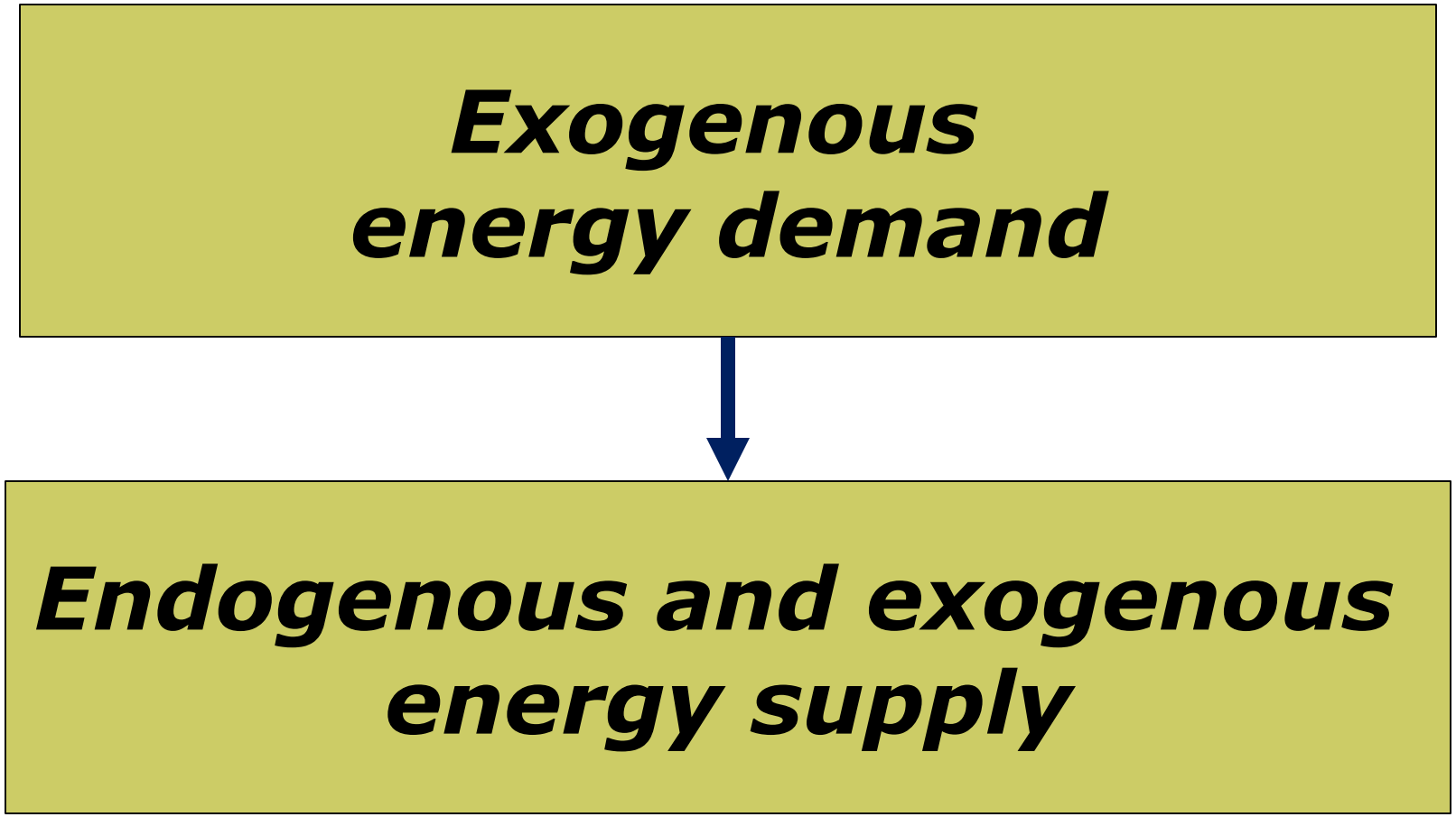


Limitations

- Complexity
- Data-intensive
- Not technical

MODEL FRAMEWORK COMPARISONS

- **Accounting-based model**



MODEL FRAMEWORK COMPARISONS

- **Hybrid model – LEAP – Accounting-based, optimization, simulation**

Exogenous energy demand

Endogenous, optimized and/or exogenous energy supply

LEAP BACKGROUND & CHARACTERISTICS

- **LEAP background**
  - Long-range Energy Alternatives Planning (LEAP)
  - Develop by the Stockholm Environment Institute
  - Tool for creating models of energy systems
  - Extensive world-wide use (190 counties, U.N., others)
- **Key characteristics of LEAP**
  - Systems-based energy accounting/hybrid framework
  - Bottom-up, technology focused
  - Technology and Environmental Database
  - Simple and flexible
  - Integration with WEAP for water use impacts

LEAP-CANADA MODEL

LEAP: Blank model

Area Edit View Analysis Tags General Tree Chart Help

New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Effects Units What's This?

Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes

Blank model
- Key Assumptions
- Demand
- Transformation
- Resources
  - Primary
  - Secondary
- Non Energy

Tags: Settings

Branch: Demand

Branch: All Branches | Variable: None | Scenario: Current Accounts

No variables defined at this tree branch. Click another branch to see variables.

Region: Alberta

Notes on Branch: Demand

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References:

SEI-B (2000)

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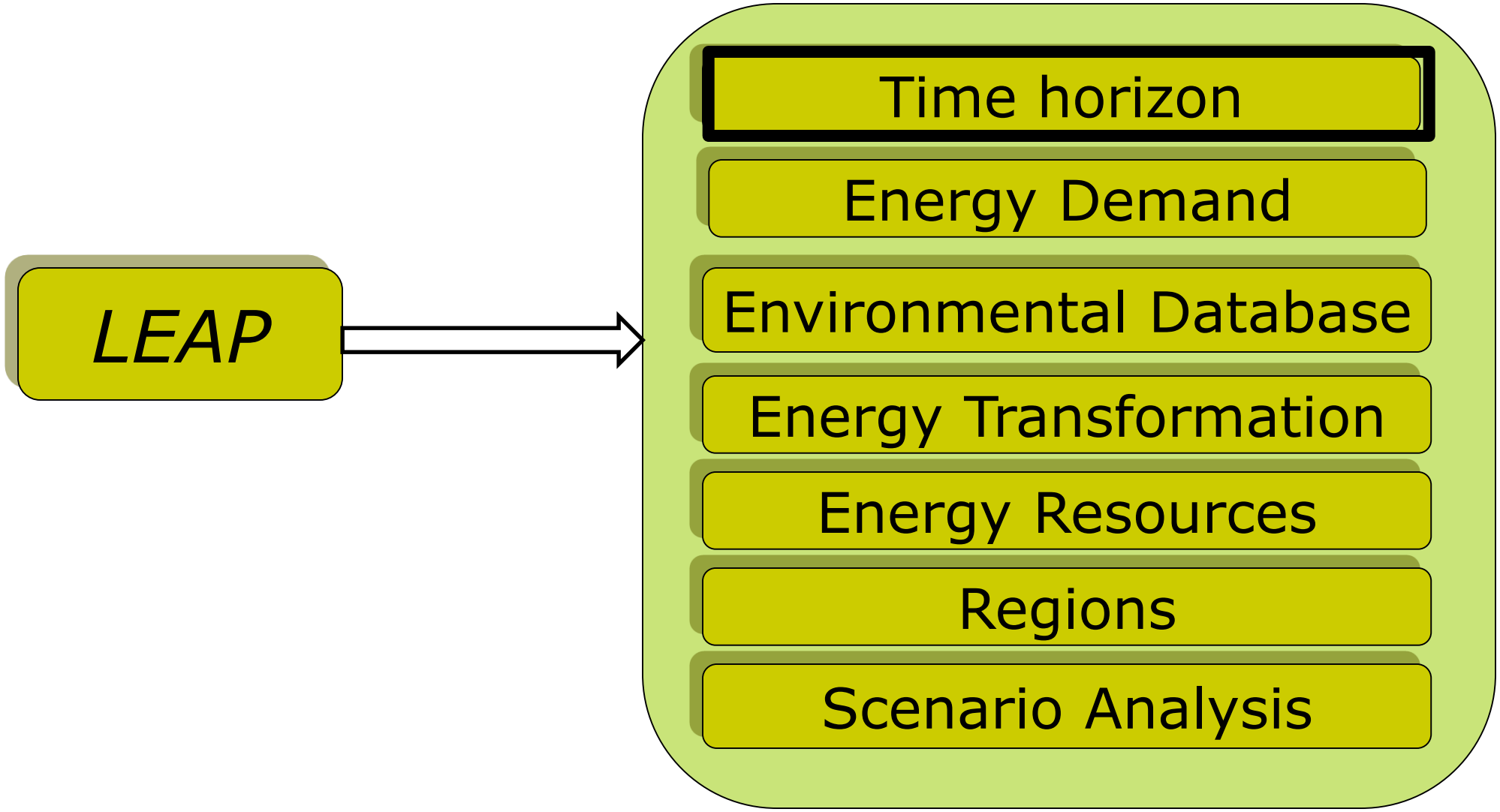
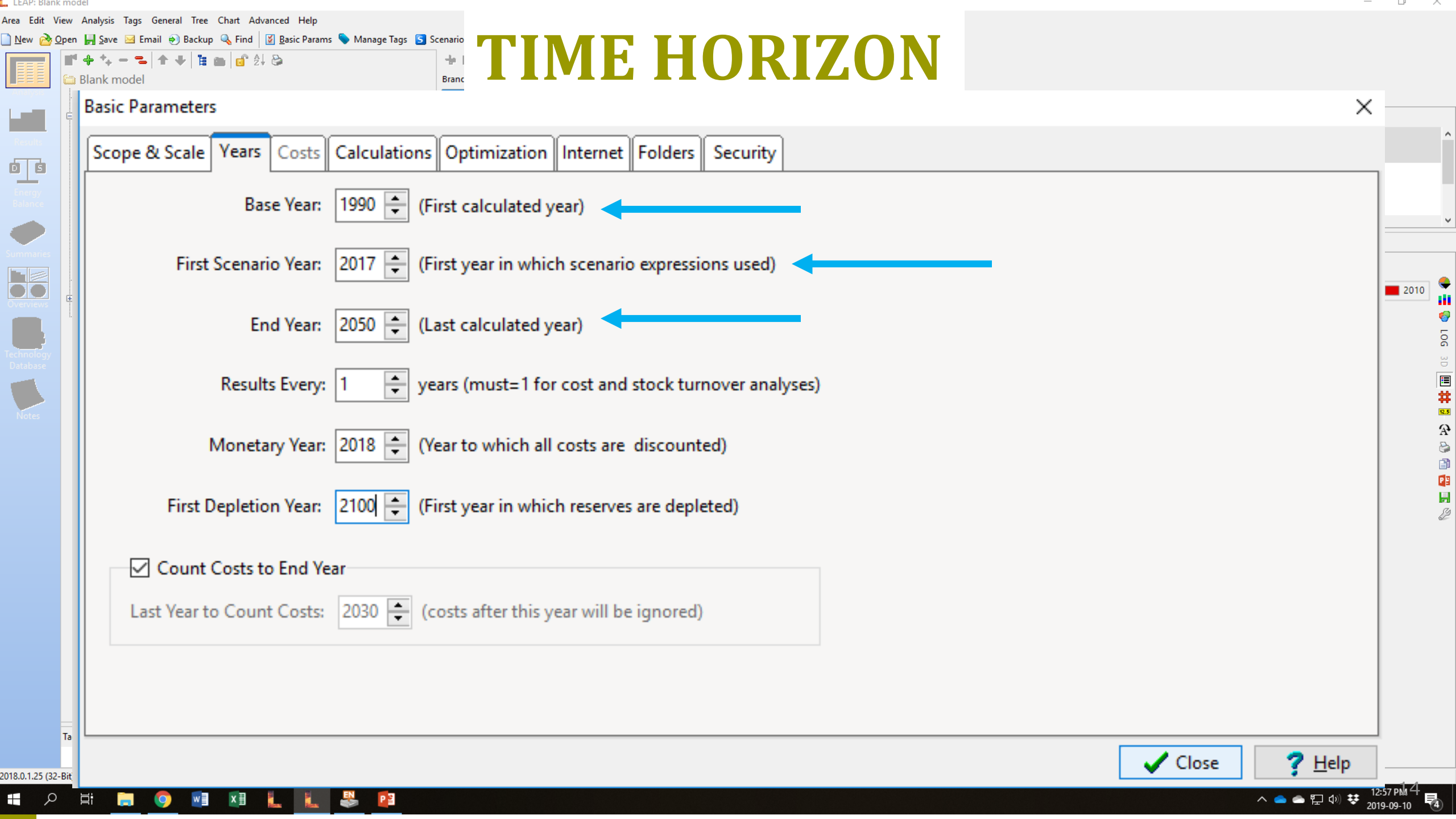
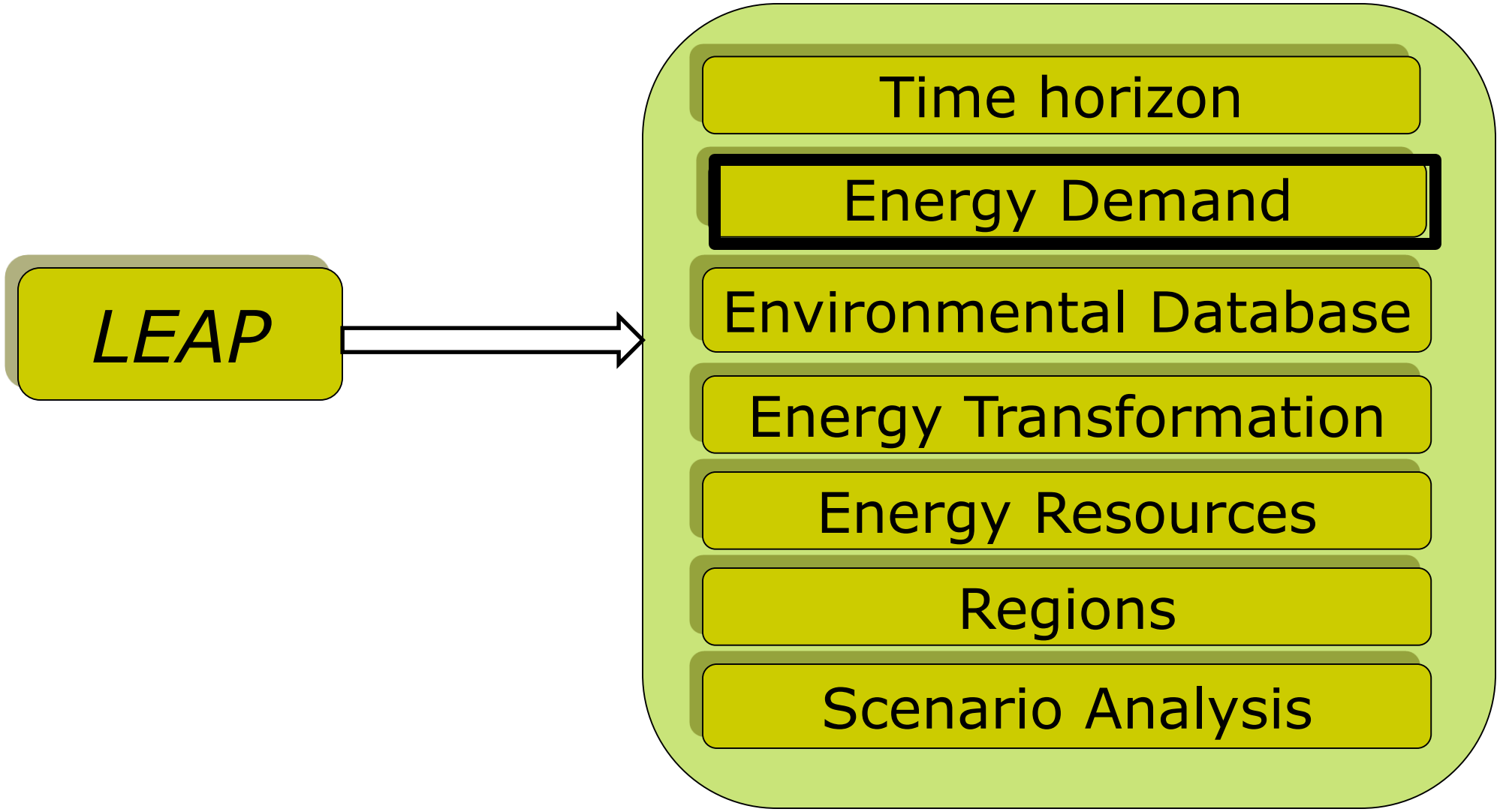
LEAP-CANADA MAIN ELEMENTS



TIME HORIZON

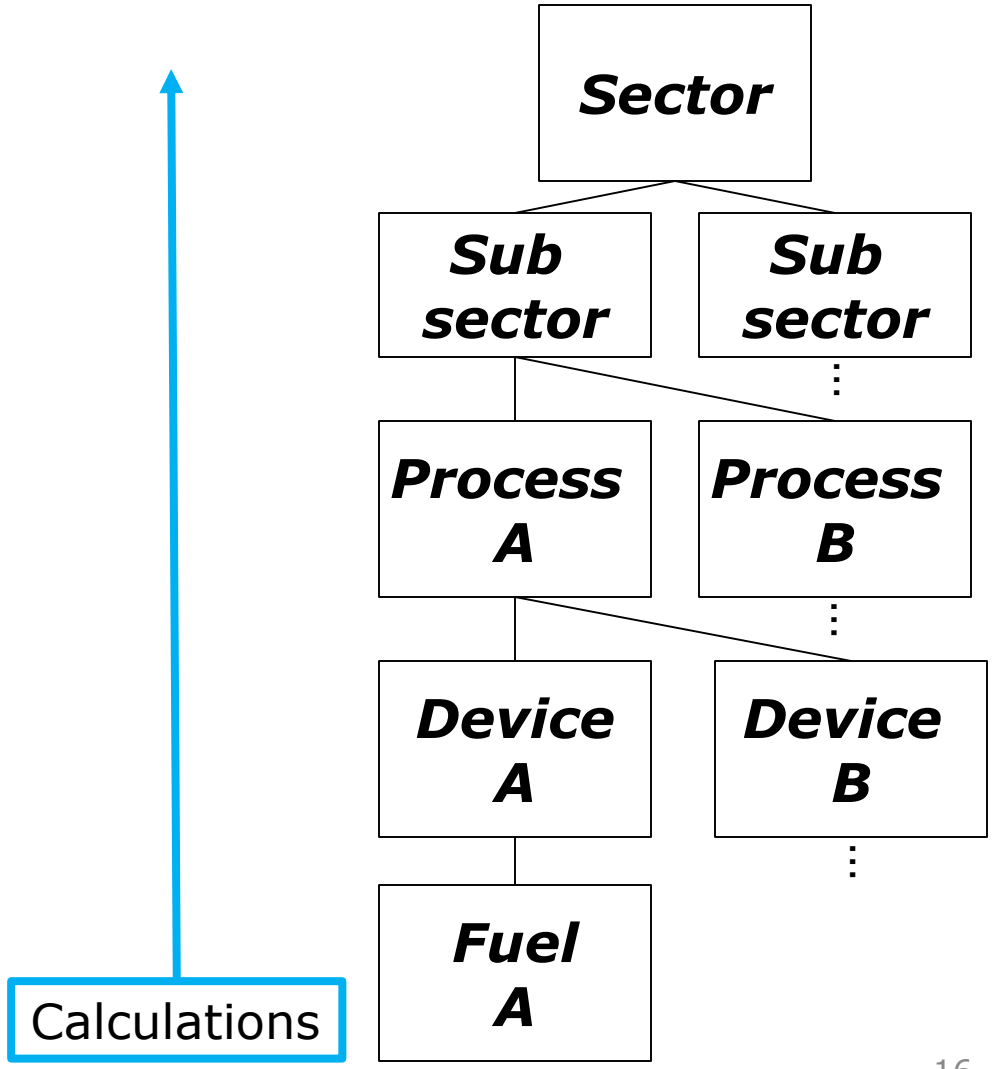


LEAP-CANADA MAIN ELEMENTS



Designing the demand tree

- Define sector
  - Define sub sectors
    - Define processes/categories
      - Define end users
        - Define fuels
- Design depends on available data



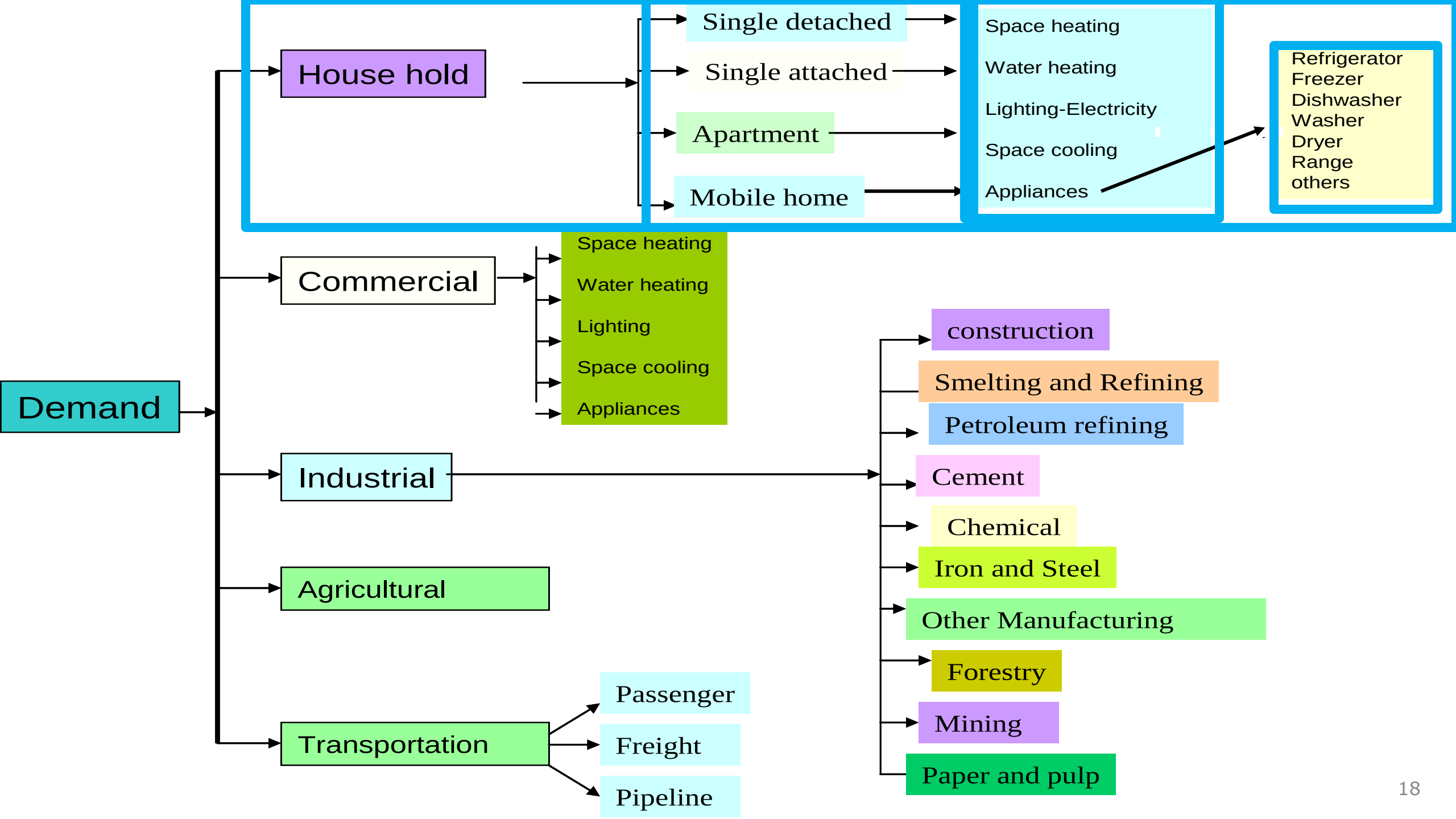
"BOTTOM-UP"

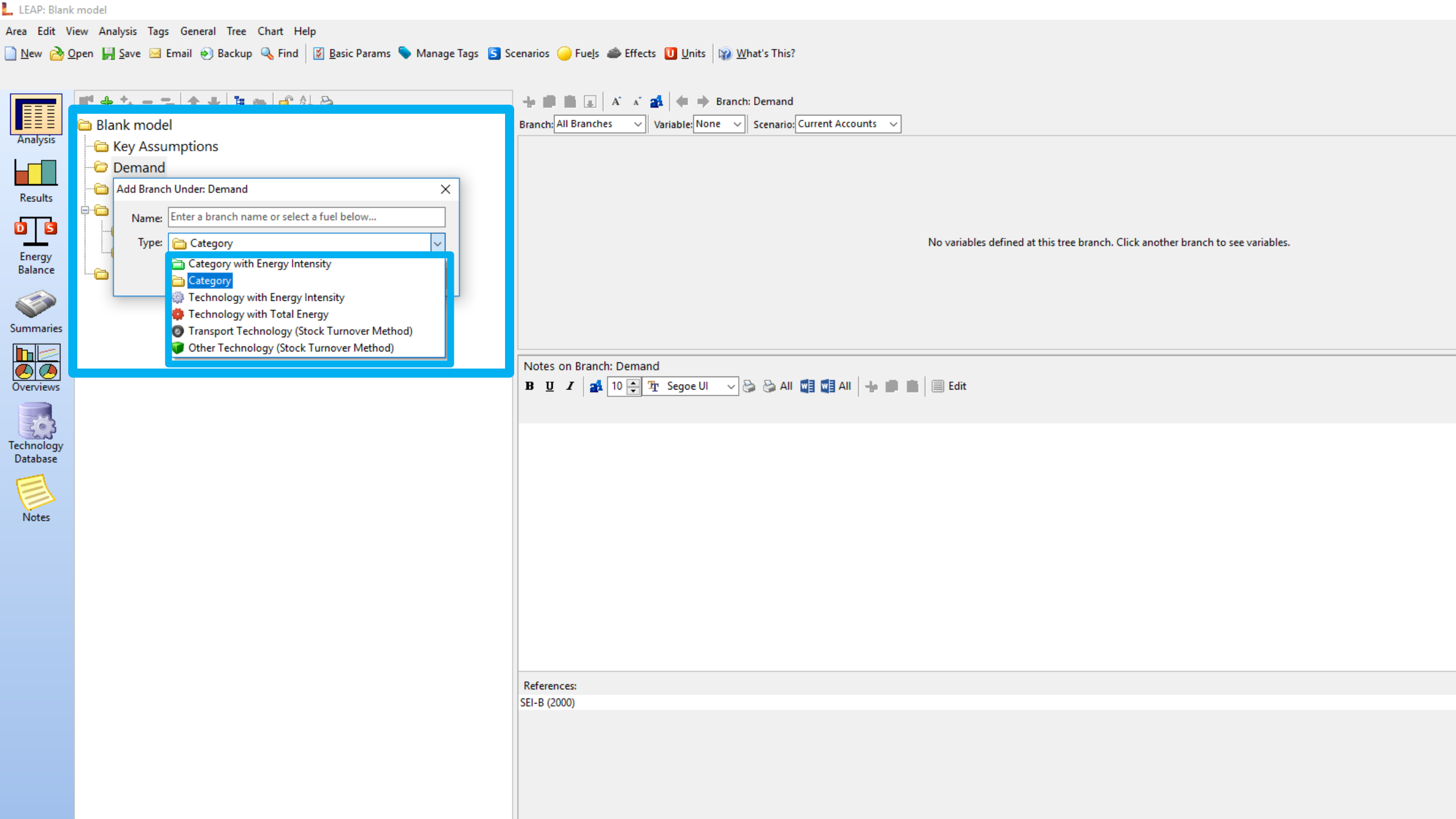
end use of energy;
at the device level;
technology or process specific:

$$Energy\ demand_{device} = energy\ intensity_{device} * activity_{device}$$

Calculated by the model

Data entered at this level


Demand
House hold
Single detached
Single attached
Apartment
Mobile home
Space heating
Water heating
Lighting-Electricity
Space cooling
Appliances
Refrigerator
Freezer
Dishwasher
Washer
Dryer
Range
others
Commercial
Space heating
Water heating
Lighting
Space cooling
Appliances
Industrial
construction
Smelting and Refining
Petroleum refining
Cement
Chemical
Iron and Steel
Other Manufacturing
Forestry
Mining
Paper and pulp
Agricultural
Transportation
Passenger
Freight
Pipeline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Area Edit View Analysis Tags General Tree Chart Help
New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Effects Units What's This?
Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes
Blank model
Key Assumptions
Demand
Add Branch Under: Demand
Name: Enter a branch name or select a fuel below...
Type: Category
Category with Energy Intensity
Category
Technology with Energy Intensity
Technology with Total Energy
Transport Technology (Stock Turnover Method)
Other Technology (Stock Turnover Method)
Branch: Demand
Branch: All Branches
Variable: None
Scenario: Current Accounts
No variables defined at this tree branch. Click another branch to see variables.
Notes on Branch: Demand
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References:
SEI-B (2000)

LEAP: 2019-08-23 LEAP-Canada model

Area Edit View Analysis Tags General Tree Chart Help

New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Regions Effects Units What's This?

Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes

Canada Model
- Key Assumptions
- Demand
  - Residential
  - Commercial and Institutional
  - Industrial
  - Transportation
  - Agriculture
  - Oil sands
- Transformation
- Resources
- Non Energy
- Indicators

Tags: Settings

Branch: Demand\...

Branch: All Branches | Variable: Activity Level | Region: Alberta | Scenario: Current Accounts

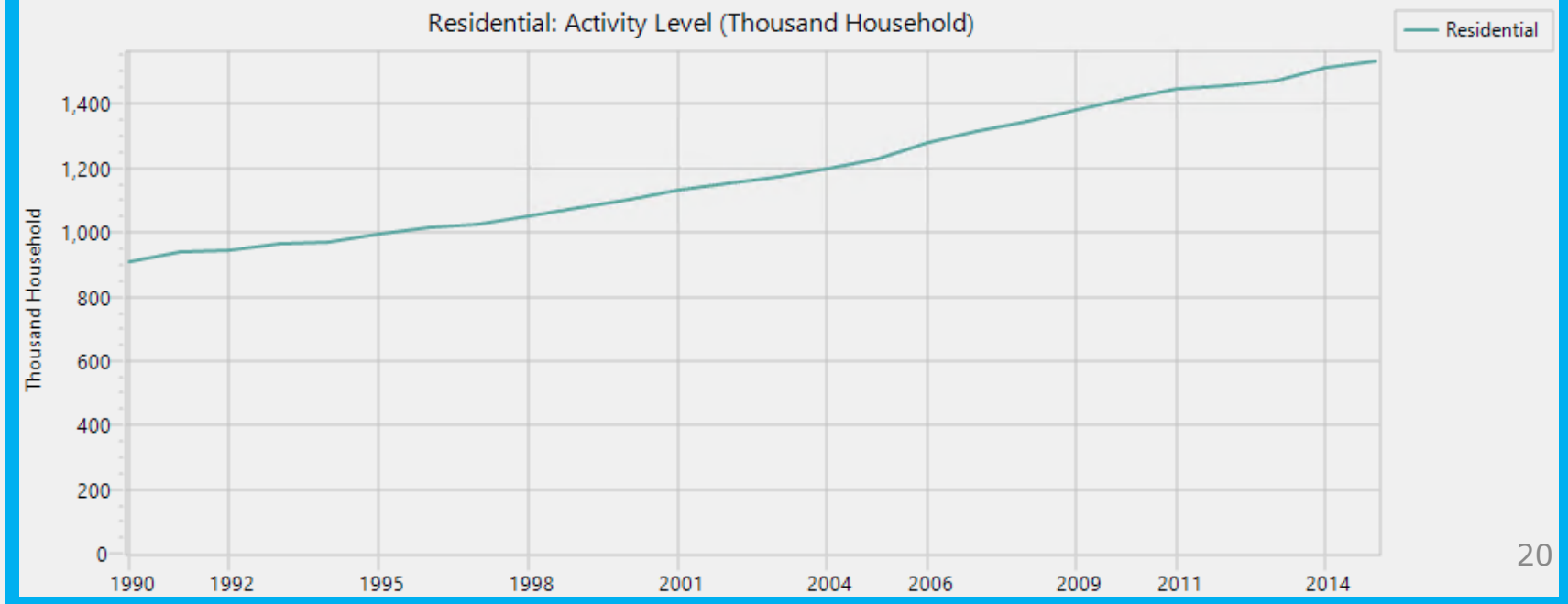
Activity Level

Activity Level: A measure of the social or economic activity for which energy is consumed. [Default="0"]

Branch	Expression	Scale	Units
Residential	Key\Activity and energy intensities\RES\Calculations\Activity Projection\Hc		Household
Commercial and Institu	Key\Activity and energy intensities\COM\Calculations\Activity Projection\C	Million	Square Meter
Industrial			No data
Transportation			No data
Agriculture	Key\Activity and energy intensities\AGR\Calculations\AGR GDP\AGR GDP	Million	Canadian Dollar
Oil sands			No data

Chart Table Builder Notes Elaboration Help

Show: Activity Level



LOG 3D

LEAP: 2019-08-23 LEAP-Canada model

Area Edit View Analysis Tags General Tree Chart Help

New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Regions Effects Units What's This?

Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes

Canada Model
- Key Assumptions
- Demand
  - Residential
    - Single Detached
      - Space Heating
      - Water Heating
      - Appliances
      - Lighting
      - Space Cooling
    - Single Attached
    - Apartment
    - Mobile Home
  - Commercial and Institutional
  - Industrial
  - Transportation
  - Agriculture
  - Oil sands
- Transformation
- Resources
- Non Energy
- Indicators

Tags: Settings

Branch: Demand\Residential\...

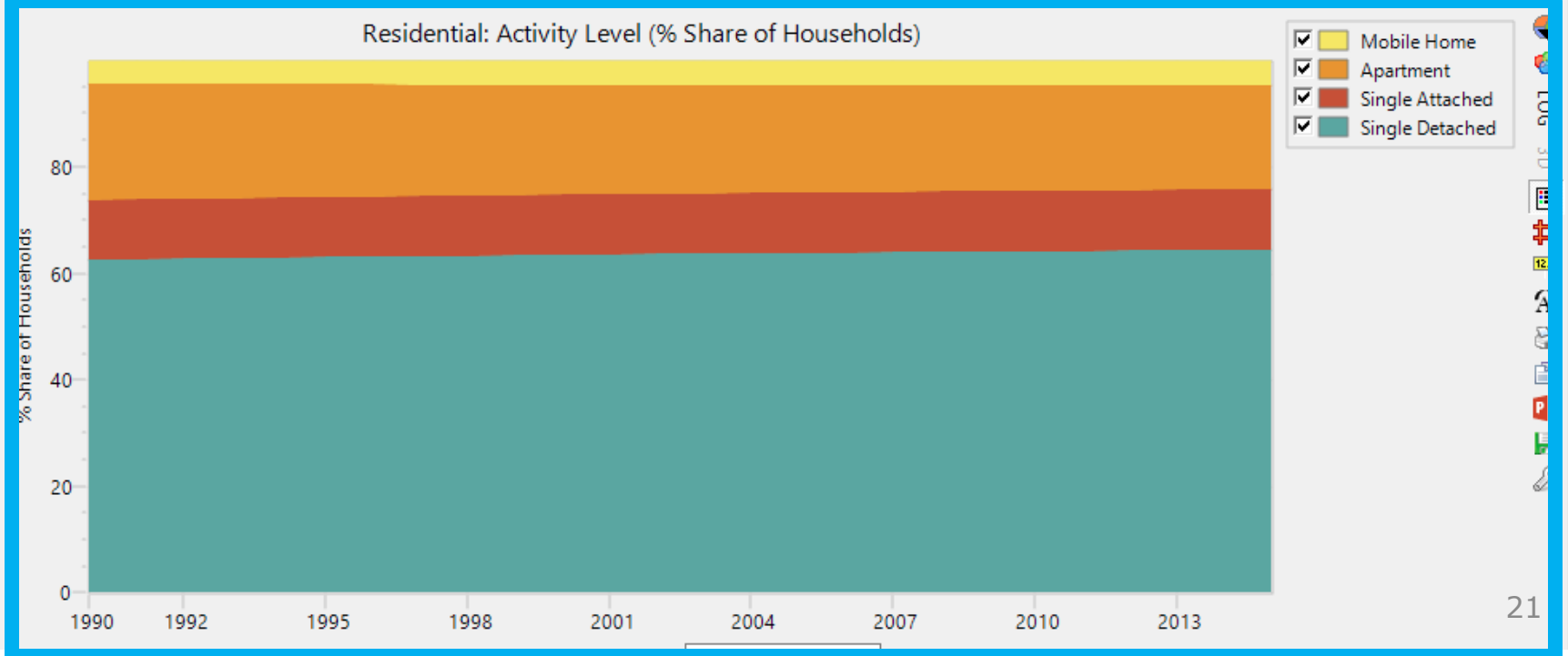
Branch: All Branches | Variable: Activity Level | Region: Alberta | Scenario: Current Accounts

Activity Level

Activity Level: A measure of the social or economic activity for which energy is consumed. [Default="0"]

Branch	Expression	Scale	Units	Per
Residential	Key\Activity and energy intensities\RES\Calculatio		Household	
Single Detached	Key\Activity and energy intensities\RES\Raw Data	Percent	Share	of Households
Single Attached	Key\Activity and energy intensities\RES\Raw Data	Percent	Share	of Households
Apartment	Key\Activity and energy intensities\RES\Raw Data	Percent	Share	of Households
Mobile Home	Key\Activity and energy intensities\RES\Raw Data	Percent	Share	of Households

Show: Activity Level



LEAP: 2019-08-23 LEAP-Canada model

Area Edit View Analysis Tags General Tree Chart Help

New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Regions Effects Units What's This?

Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes

Canada Model
- Key Assumptions
- Demand
  - Residential
    - Single Detached
      - Space Heating
        - Electric heating
        - Natural gas furnace
        - Heating Oil
        - Others
        - Wood
    - Appliances
    - Lighting
    - Space Cooling
    - Single Attached
    - Apartment
    - Mobile Home
  - Commercial and Institutional
  - Industrial
  - Transportation
  - Agriculture
  - Oil sands
- Transformation
- Resources
- Non Energy
- Indicators

Tags: Settings

Branch: Demand\Residential\Single Detached\Space Heating\...

Branch: All Branches | Variable: Activity Level | Region: Alberta | Scenario: Current Accounts

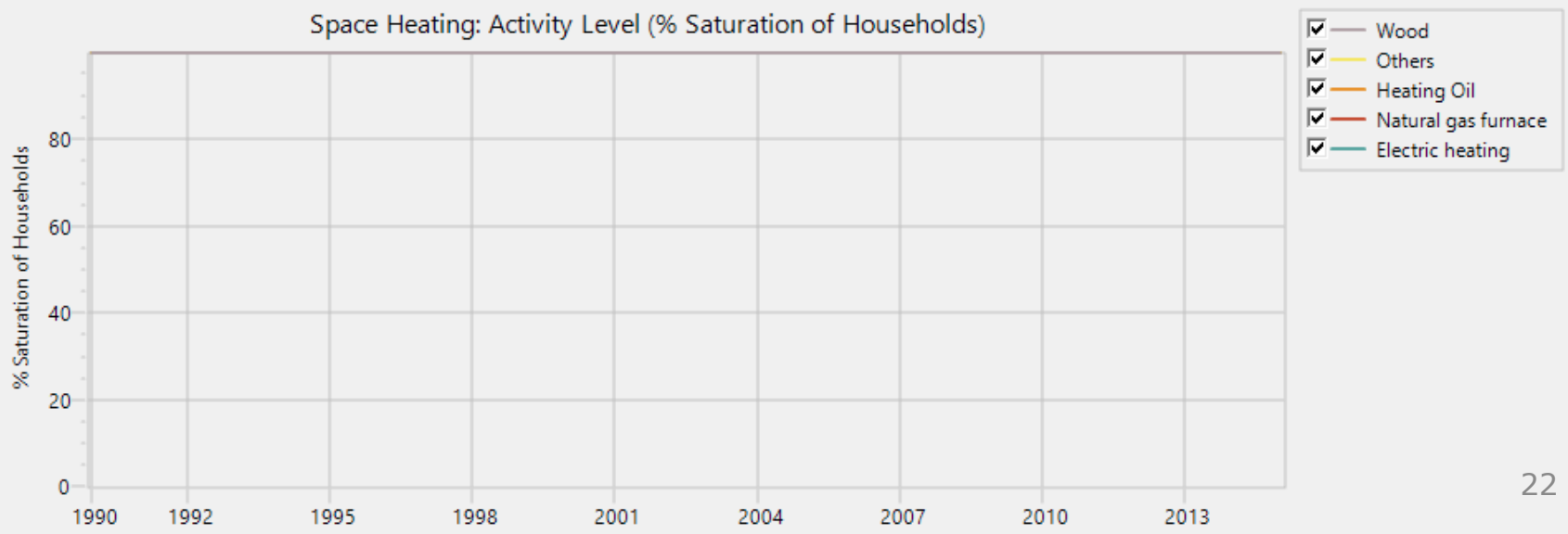
Activity Level | nal Energy Intensity

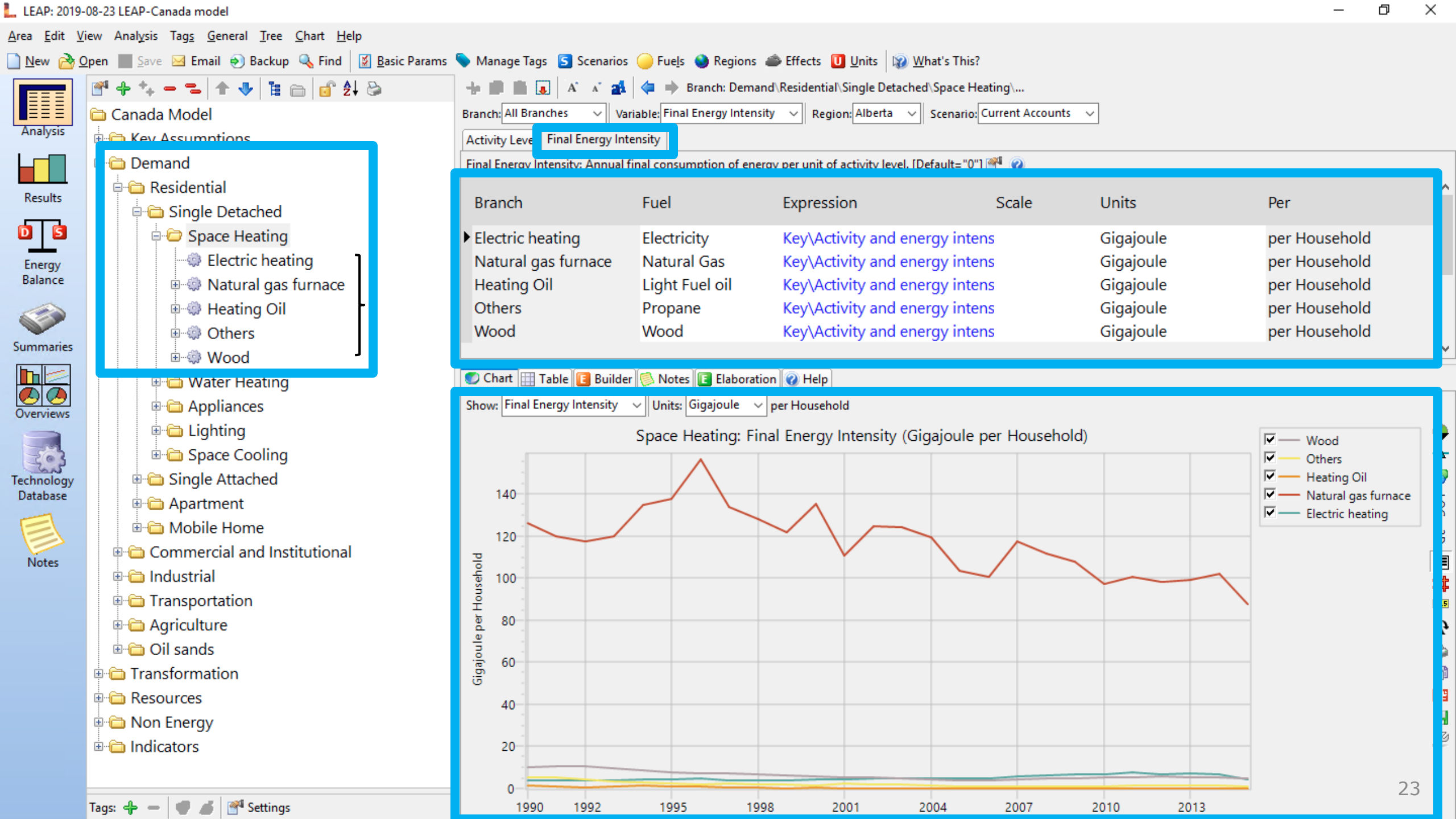
Activity Level: A measure of the social or economic activity for which energy is consumed. [Default="0"]

Branch	Expression	Scale	Units	Per
Residential	Key\Activity and energy intensities\RES\Calculatio		Household	
Single Detached	Key\Activity and energy intensities\RES\Raw Data	Percent	Share	of Households
Space Heating	100	Percent	Saturation	of Households
Electric heating	100	Percent	Saturation	of Households
Natural gas furnace	100	Percent	Saturation	of Households
Heating Oil	100	Percent	Saturation	of Households
Others	100	Percent	Saturation	of Households
Wood	100	Percent	Saturation	of Households

Chart | Table | Builder | Notes | Elaboration | Help

Show: Activity Level

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Area Edit View Analysis Tags General Tree Chart Help
New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Regions Effects Units What's This?
Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes
Canada Model
Key Assumptions
Demand
Residential
Single Detached
Space Heating
Electric heating
Natural gas furnace
Heating Oil
Others
Wood
Water Heating
Appliances
Lighting
Space Cooling
Single Attached
Apartment
Mobile Home
Commercial and Institutional
Industrial
Transportation
Agriculture
Oil sands
Transformation
Resources
Non Energy
Indicators
Tags: Settings
Branch: Demand\Residential\Single Detached\Space Heating\...
Branch: All Branches
Variable: Final Energy Intensity
Region: Alberta
Scenario: Current Accounts
Activity Leve
Final Energy Intensity
Final Energy Intensity: Annual final consumption of energy per unit of activity level. [Default="0"]
Branch Fuel Expression Scale Units Per
Electric heating Electricity Key\Activity and energy intens Gigajoule per Household
Natural gas furnace Natural Gas Key\Activity and energy intens Gigajoule per Household
Heating Oil Light Fuel oil Key\Activity and energy intens Gigajoule per Household
Others Propane Key\Activity and energy intens Gigajoule per Household
Wood Wood Key\Activity and energy intens Gigajoule per Household
Chart Table Builder Notes Elaboration Help
Show: Final Energy Intensity
Units: Gigajoule per Household
Space Heating: Final Energy Intensity (Gigajoule per Household)
Gigajoule per Household
0 20 40 60 80 100 120 140
1990 1992 1995 1998 2001 2004 2007 2010 2013
Wood
Others
Heating Oil
Natural gas furnace
Electric heating
23

LEAP: 2019-08-23 LEAP-Canada model

Area Edit View Analysis Tags General Tree Chart Help

New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Regions Effects Units What's This?

Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes

Canada Model
- Key Assumptions
- Demand
  - Residential
    - Single Detached
      - Space Heating
        - Electric heating
        - Natural gas furnace
        - Heating Oil
        - Others
        - Wood
      - Water Heating
      - Appliances
      - Lighting
      - Space Cooling
    - Single Attached
    - Apartment
    - Mobile Home
  - Commercial and Institutional
  - Industrial
  - Transportation
  - Agriculture
  - Oil sands
- Transformation
- Resources
- Non Energy
- Indicators

Tags: Settings

Branch: Demand\Residential\Single Detached\Space Heating\...

Branch: All Branches | Variable: Final Energy Intensity | Region: Alberta | Scenario: Current Accounts

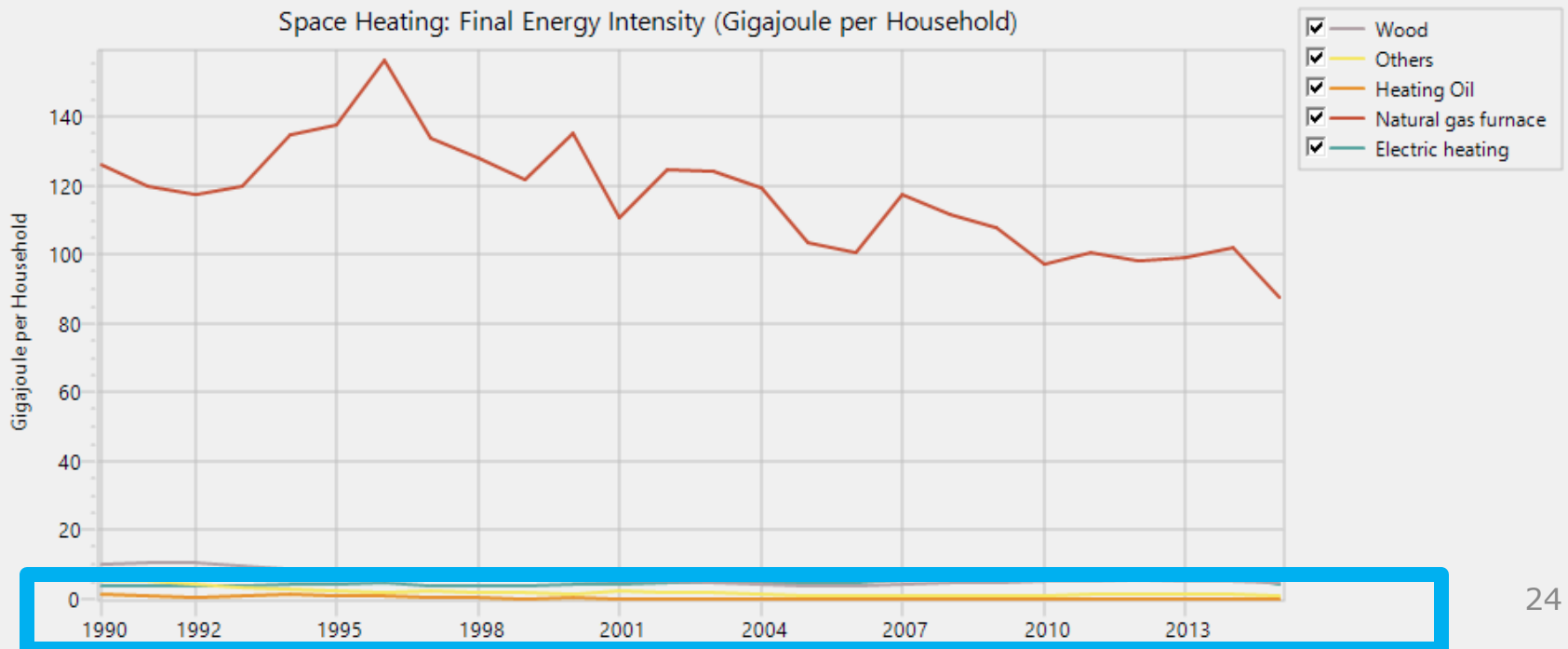
Activity Level | Final Energy Intensity

Final Energy Intensity: Annual final consumption of energy per unit of activity level. [Default="0"]

Branch	Fuel	Expression	Scale	Units	Per
Electric heating	Electricity	Key\Activity and energy intens		Gigajoule	per Household
Natural gas furnace	Natural Gas	Key\Activity and energy intens		Gigajoule	per Household
Heating Oil	Light Fuel oil	Key\Activity and energy intens		Gigajoule	per Household
Others	Propane	Key\Activity and energy intens		Gigajoule	per Household
Wood	Wood	Key\Activity and energy intens		Gigajoule	per Household

Chart | Table | Builder | Notes | Elaboration | Help

Show: Final Energy Intensity | Units: Gigajoule per Household



LEAP: 2019-08-23 LEAP-Canada model

Area Edit View Analysis Tags General Tree Chart Help

New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Regions Effects Units What's This?

Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes

- Canada Model
  - Key Assumptions
  - Demand
    - Residential
      - Single Detached
        - Space Heating
          - Electric heating
          - Natural gas furnace
          - Heating Oil
          - Others
          - Wood
        - Water Heating
        - Appliances
        - Lighting
        - Space Cooling
      - Single Attached
      - Apartment
      - Mobile Home
    - Commercial and Institutional
    - Industrial
    - Transportation
    - Agriculture
    - Oil sands
  - Transformation
  - Resources
  - Non Energy
  - Indicators

Tags: Settings

Branch: Demand\Residential\Single...

Branch: All Branches | Variable: Activity Level | Region: Alberta | Scenario: REF: Reference

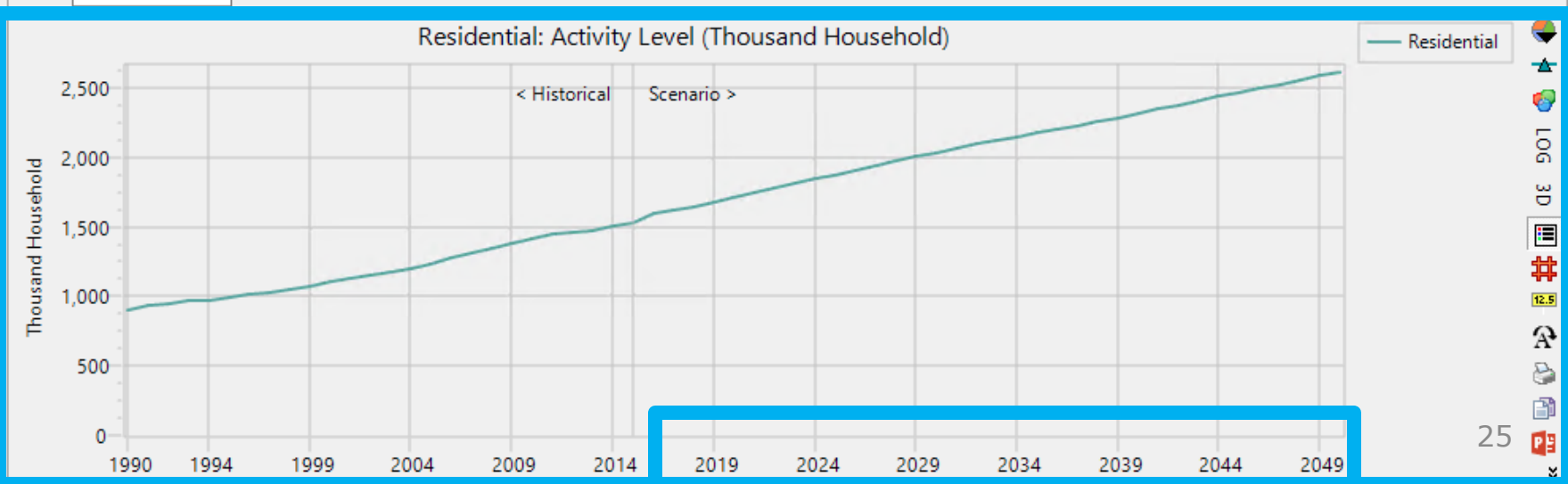
Activity Level | Final Energy Intensity

Activity Level: A measure of the social or economic activity for which energy is consumed. [Default="0"]

Branch	2015 Value	Expression	Scale	Units	Per
Residential	1,533,889.98	Key\Activity and energy intensi		Household	
Single Detached	64.52	Value(FirstScenarioYear-1)	Percent	Share	of Households
Space Heating	100.00	100	Percent	Saturation	of Households
Electric heating	100.00	100	Percent	Saturation	of Households
Natural gas furnace	100.00	100	Percent	Saturation	of Households
Heating Oil	100.00	100	Percent	Saturation	of Households
Others	100.00	100	Percent	Saturation	of Households
Wood	100.00	100	Percent	Saturation	of Households

Chart | Table | Builder | Notes | Elaboration | Help

Show: Activity Level



LOG 3D

LEAP: 2019-08-23 LEAP-Canada model

Area Edit View Analysis Tags General Tree Chart Help

New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Regions Effects Units What's This?

Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes

Canada Model
- Key Assumptions
- Demand
  - Residential
    - Single Detached
      - Space Heating
        - Electric heating
        - Natural gas furnace
        - Heating Oil
        - Others
        - Wood
      - Water Heating
      - Appliances
      - Lighting
      - Space Cooling
    - Single Attached
    - Apartment
    - Mobile Home
  - Commercial and Institutional
  - Industrial
  - Transportation
  - Agriculture
  - Oil sands
- Transformation
- Resources
- Non Energy
- Indicators

Tags: Settings

Branch: Demand\Residential\Single Detach

Branch: All Branches | Variable: Final Energy Intensity | Region: Alberta | Scenario: REF: Reference

Activity Leve | Final Energy Intensity

Final Energy Intensity: Annual final consumption of energy per unit of activity level. [Default="0"]

Branch	Fuel	2015 Value	Expression	Scale	Units	Per
Electric heating	Electricity	4.54	Key\Activity an		Gigajoule	per Household
Natural gas furnace	Natural Gas	87.80	Key\Activity an		Gigajoule	per Household
Heating Oil	Light Fuel oil	0.01	Key\Activity an		Gigajoule	per Household
Others	Propane	1.10	Key\Activity an		Gigajoule	per Household
Wood	Wood	4.84	Key\Activity an		Gigajoule	per Household

Chart Table Builder Notes Elaboration Help

Show: Final Energy Intensity | Units: Gigajoule per Household

Space Heating: Final Energy Intensity (Gigajoule per Household)

< Historical | Scenario >

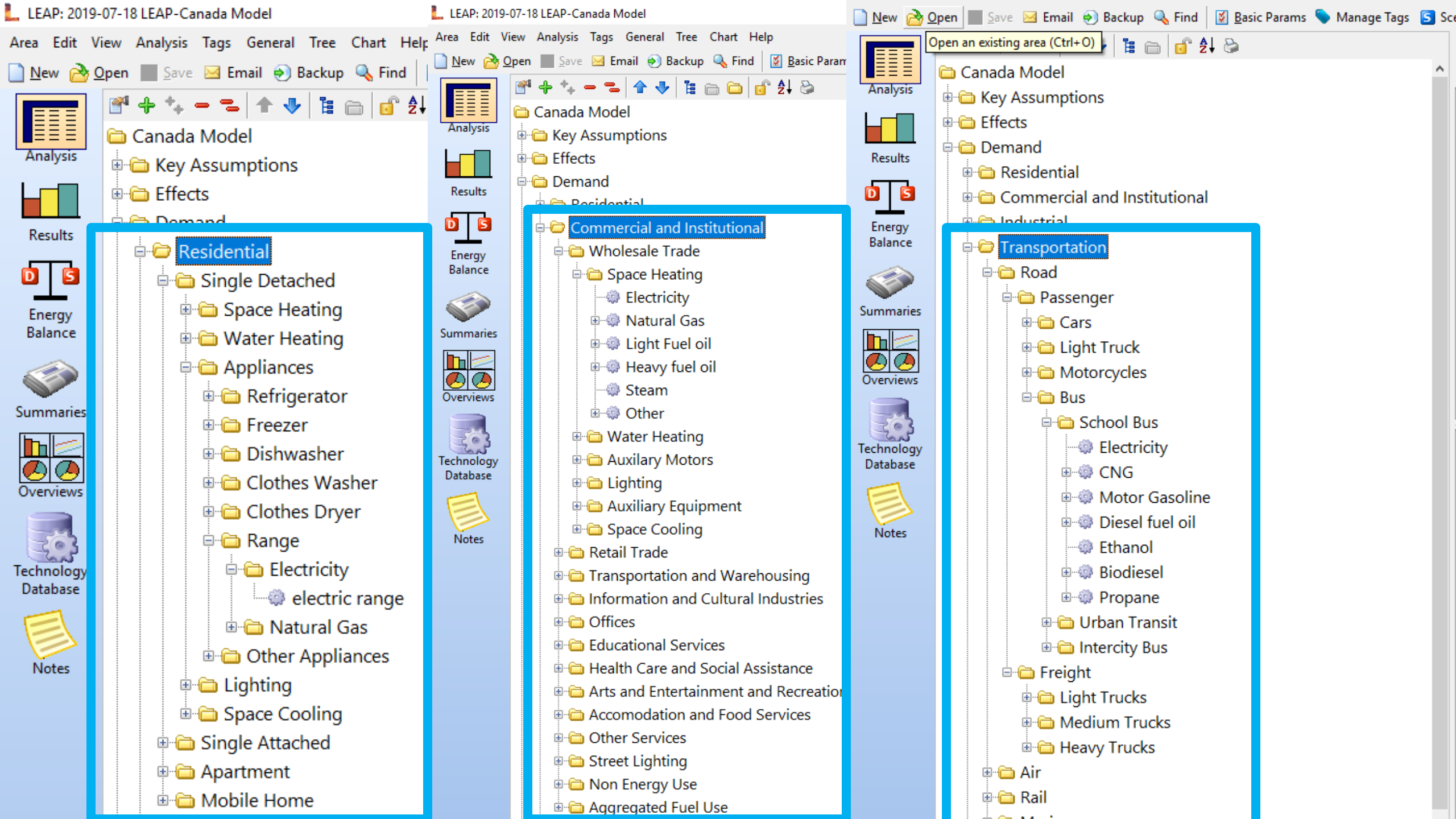
Gigajoule per Household

0 20 40 60 80 100 120 140

1990 1994 2000 2006 2012 2018 2024 2030 2036 2042 2048

Wood
Others
Heating Oil
Natural gas furnace
Electric heating

LOG 3D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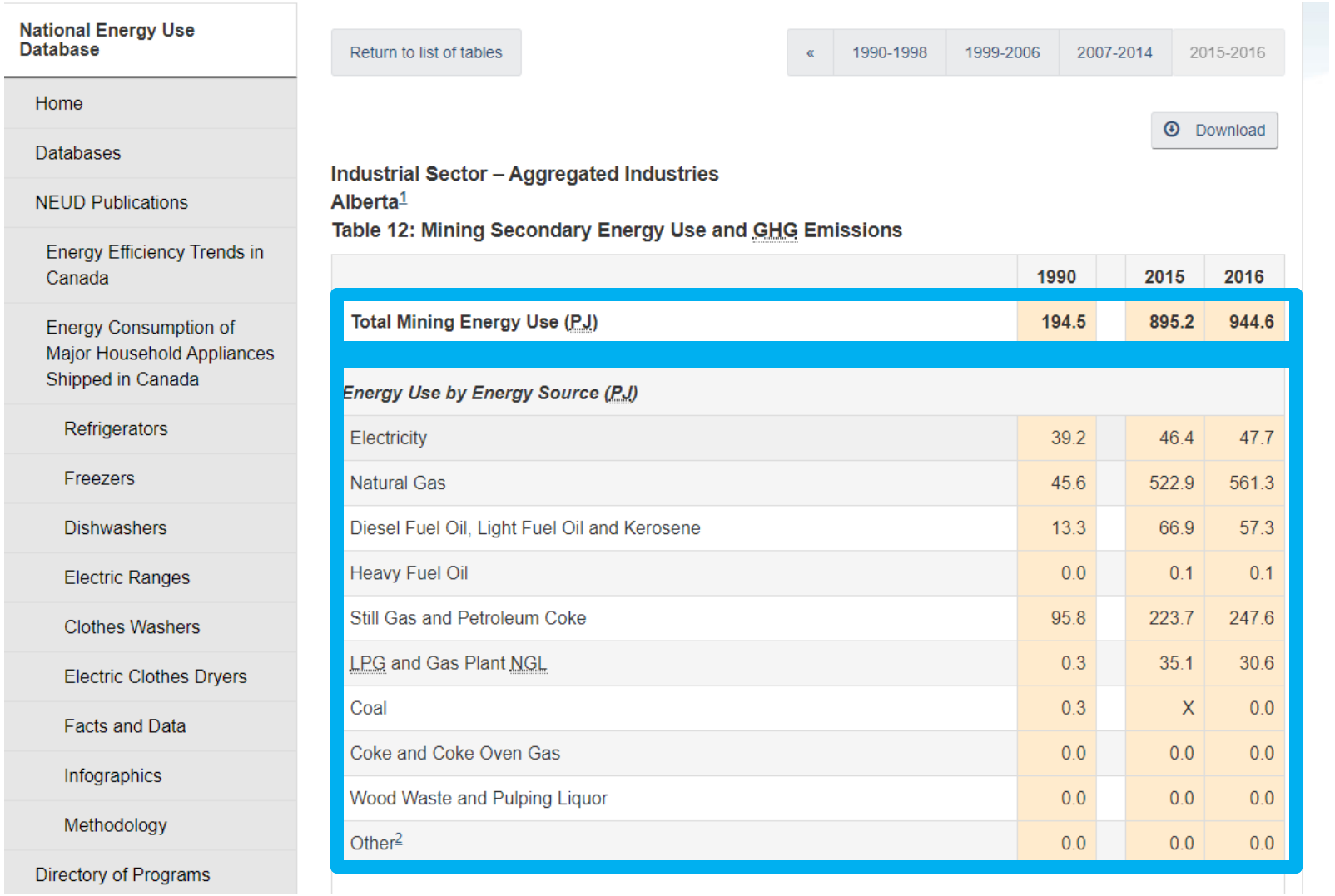
Area Edit View Analysis Tags General Tree Chart Help
New Open Save Email Backup Find Basic Params Manage Tags
Open an existing area (Ctrl+O)
Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes
Canada Model
Key Assumptions
Effects
Demand
Residential
Single Detached
Space Heating
Water Heating
Appliances
Refrigerator
Freezer
Dishwasher
Clothes Washer
Clothes Dryer
Range
Electricity
electric range
Natural Gas
Other Appliances
Lighting
Space Cooling
Single Attached
Apartment
Mobile Home
Commercial and Institutional
Wholesale Trade
Space Heating
Electricity
Natural Gas
Light Fuel oil
Heavy fuel oil
Steam
Other
Water Heating
Auxilary Motors
Lighting
Auxiliary Equipment
Space Cooling
Retail Trade
Transportation and Warehousing
Information and Cultural Industries
Offices
Educational Services
Health Care and Social Assistance
Arts and Entertainment and Recreation
Accomodation and Food Services
Other Services
Street Lighting
Non Energy Use
Aggregated Fuel Use
Industrial
Transportation
Road
Passenger
Cars
Light Truck
Motorcycles
Bus
School Bus
Electricity
CNG
Motor Gasoline
Diesel fuel oil
Ethanol
Biodiesel
Propane
Urban Transit
Intercity Bus
Freight
Light Trucks
Medium Trucks
Heavy Trucks
Air
Rail

PUBLICALLY AVAILABLE DATA



National Energy Use Database

- Home
- Databases
- NEUD Publications
- Energy Efficiency Trends in Canada
- Energy Consumption of Major Household Appliances Shipped in Canada
- Refrigerators
- Freezers
- Dishwashers
- Electric Ranges
- Clothes Washers
- Electric Clothes Dryers
- Facts and Data
- Infographics
- Methodology
- Directory of Programs

Return to list of tables

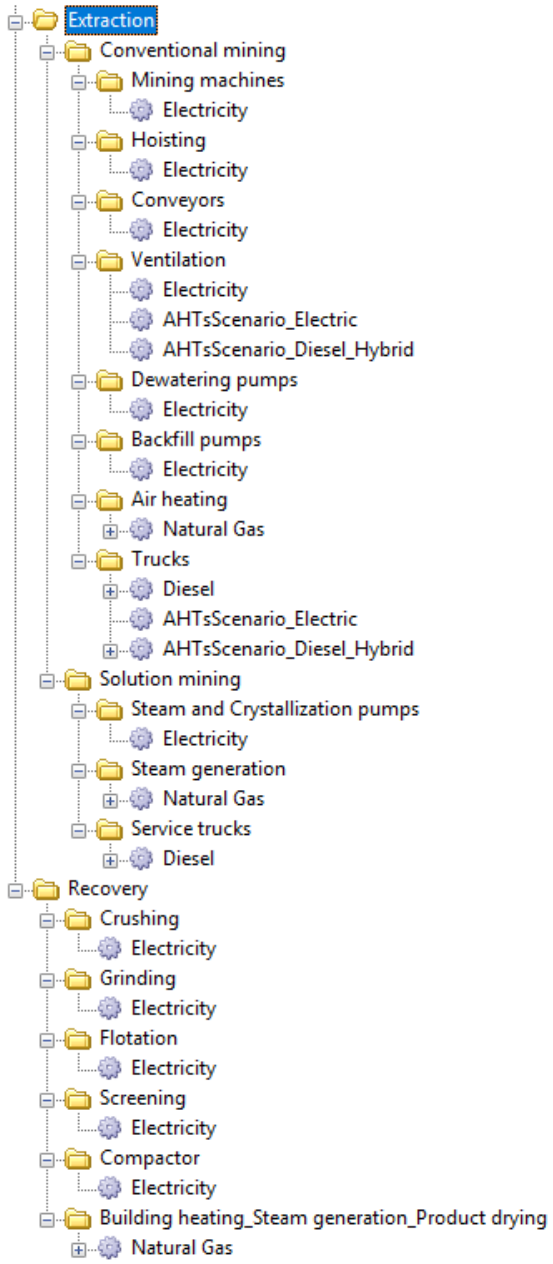
« 1990-1998 1999-2006 2007-2014 2015-2016

Download

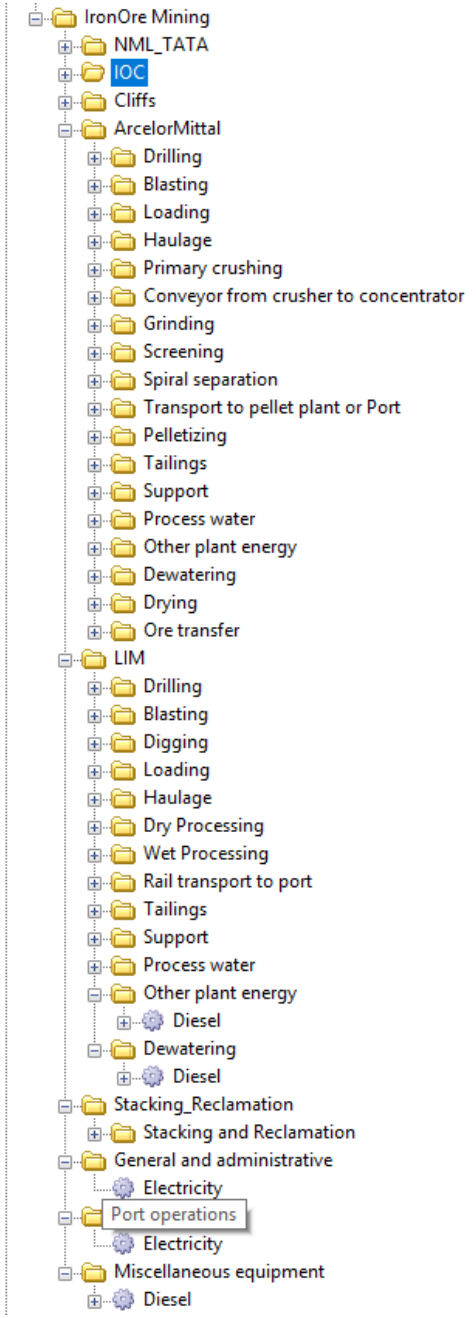
Industrial Sector – Aggregated Industries
Alberta[1]
Table 12: Mining Secondary Energy Use and GHG Emissions

	1990	2015	2016
Total Mining Energy Use (PJ)	**194.5**	**895.2**	**944.6**
Energy Use by Energy Source (PJ)			
Electricity	39.2	46.4	47.7
Natural Gas	45.6	522.9	561.3
Diesel Fuel Oil, Light Fuel Oil and Kerosene	13.3	66.9	57.3
Heavy Fuel Oil	0.0	0.1	0.1
Still Gas and Petroleum Coke	95.8	223.7	247.6
LPG and Gas Plant NGL	0.3	35.1	30.6
Coal	0.3	X	0.0
Coke and Coke Oven Gas	0.0	0.0	0.0
Wood Waste and Pulping Liquor	0.0	0.0	0.0
Other[2]	0.0	0.0	0.0

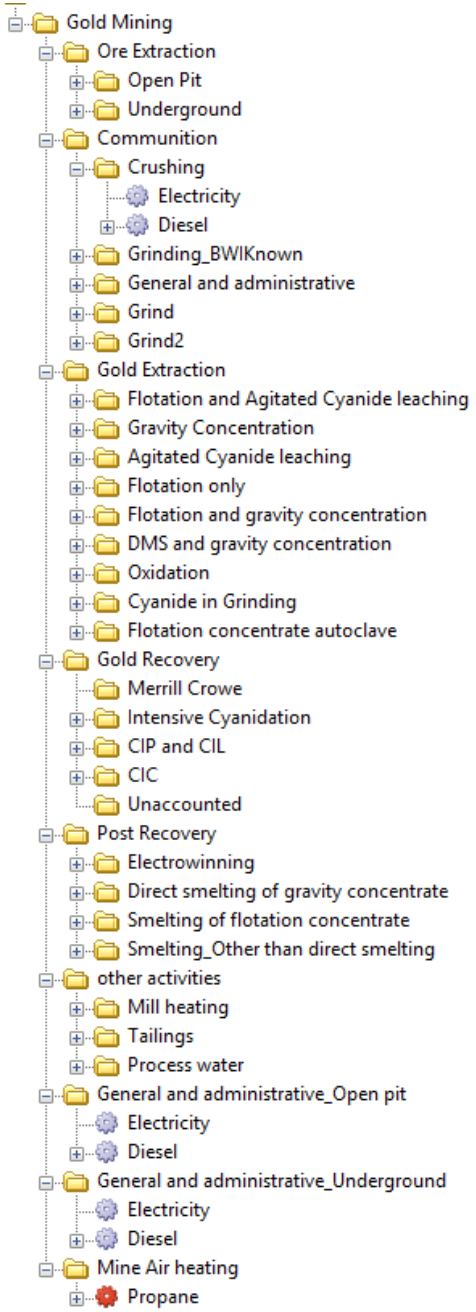
POTASH MINING



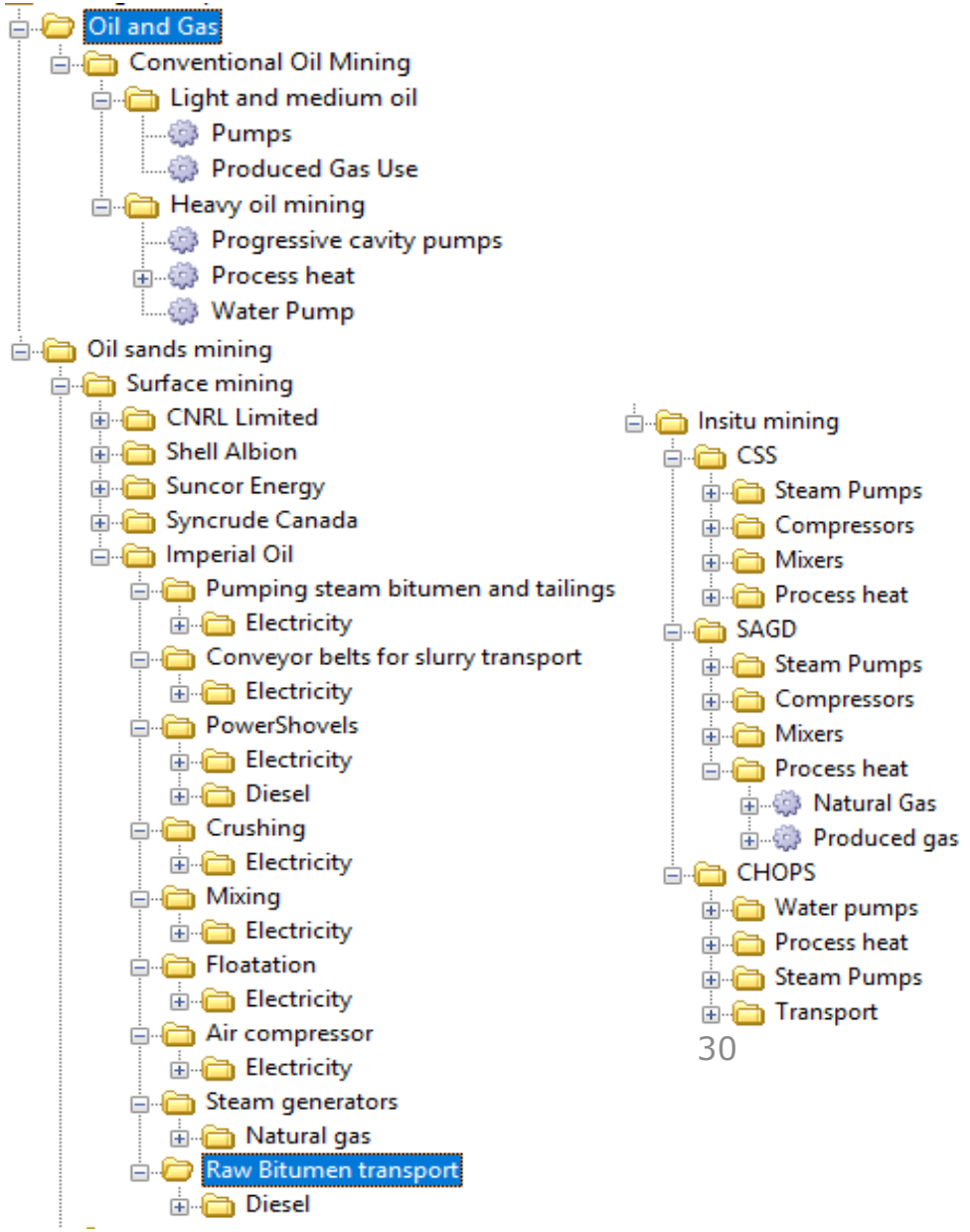
IRON MINING



GOLD MINING



UPSTREAM OIL AND GAS



PET. REFINING

- Petrolume refining
  - Oilsands refining
    - Seperation
      - CDU
        - Electricity
        - Still gas
        - CDU Heat Integration Still Gas
        - CDU Combustion air preheating Still Gas
        - pump intensity improvement
      - VDU
        - Electricity
        - Still gas
        - VDU Heat Integration Still Gas
    - converstion
      - Alkylation
        - Electricity
        - Alkylation Unit steam saving
      - Cracking
        - Coking
        - Catalytic cracking
      - Reforming
        - Catalytic reforming
        - Isomeration
    - Treatment
      - Hydro treating
    - Utilities
      - Hydrogen manufacturing
        - Electricity
        - Natural Gas
      - Steam generation
  - Conventional refining
    - Seperation
      - Desalter
      - CDU
      - VDU
    - converstion
      - Alkylation
      - Cracking
      - Reforming
    - Treatment
      - Hydro treating
    - Utilities
      - Hydrogen manufacturing
      - Steam generation
        - Natural Gas
        - Still gas

PULP AND PAPER

- Disaggregated Pulp and Paper
  - Kraft Pulp Mills
    - Chip Conveying
      - Electricity
      - Electricity with fibrous fillers
    - Washing and Screening
    - Oxygen Delignification
    - Bleaching
      - Electricity
      - Natural Gas
      - Electricity with fibrous fillers
      - Natural Gas with fibrous filler
    - Digestor
    - Pulp Machine
    - Black Liquor Evaporators
    - PowerPlant
      - Electricity
      - Natural Gas
      - Electricity with fibrous fillers
      - Natural Gas with fibrous filler
    - Kiln and Recausticizing
    - Hot Water Supply
    - Waste water treatment
      - Electricity
      - Electricity with fibrous fillers
    - Miscellaneous
    - Wood Waste and Pulping Liquor Use
  - BCTMP Mill
    - Chip Conveying
      - Electricity
    - Refiners
    - Bleaching
    - Pulp Dryer
      - Electricity
      - Natural Gas
      - Natural Gas with efficient heat recovery system
    - Effluent Treatment
      - Electricity
  - Newspaper
    - Chip Conveying
    - Refiners
    - Heat Recovery
    - Effluent Treatment
    - Auxillaries
    - Stock_Preparation
    - Forming Pressing Operation

CEMENT

- Dry Processing
  - Kiln Feed Preparation
    - Raw Material Crushing and Treatment
      - Electricity
      - Electricity Efficient Transport Systems
      - Electricity Raw Material Blending
      - Electricity RMPC for vertical mills
      - Electricity Advanced Roll Meal Grinding
      - Electricity High Effi. Classifiers Separators
      - Electricity Separate Raw Material Grinding
  - Clinker Production
    - Electricity
      - Electricity
      - Electricity EM and PC Systems
      - Electricity Adjustable Speed Drive Kiln Fan
      - Electricity Low Temperature Heat Recoveryy for Pow
      - Electricity Drop Cyclones for Suspension Preheate
      - Electricity Efficient Kiln Drives
    - Coal
    - Pet Coke
    - Natural Gas
      - Natural Gas
      - Natural Gas Improved Refractories
      - NG EM and PC Systems
      - NG Adjustable Speed Drive for Kiln Fan
      - NG Installation Preheater Precalciner
      - NG Long Dry to Preheater Calciner
      - NG Dry Process Upgrade to Multi Stage Preheater
      - NG Increasing Number of Preheater Stages
      - NG Conversion to Reciprocrating Cooler
      - NG Kiln Combustion System Improvements
      - NG Indirect Firing
      - NG Low Temp Recovery for Pow Generation
      - NG Seal Replacement
      - NG Efficient Kiln Drives
      - NG Suspension Preheater
    - Waste Fuel
  - Finishing Grinding and Distribution
    - Electricity
    - Vertical Roller Mill for Finish Grinding
    - Electricity High PRessure Roller Press
    - Electricity Horizontal Roller Mill
    - Electricity High Eff. Classifiers
    - Electricity Improved grinding media

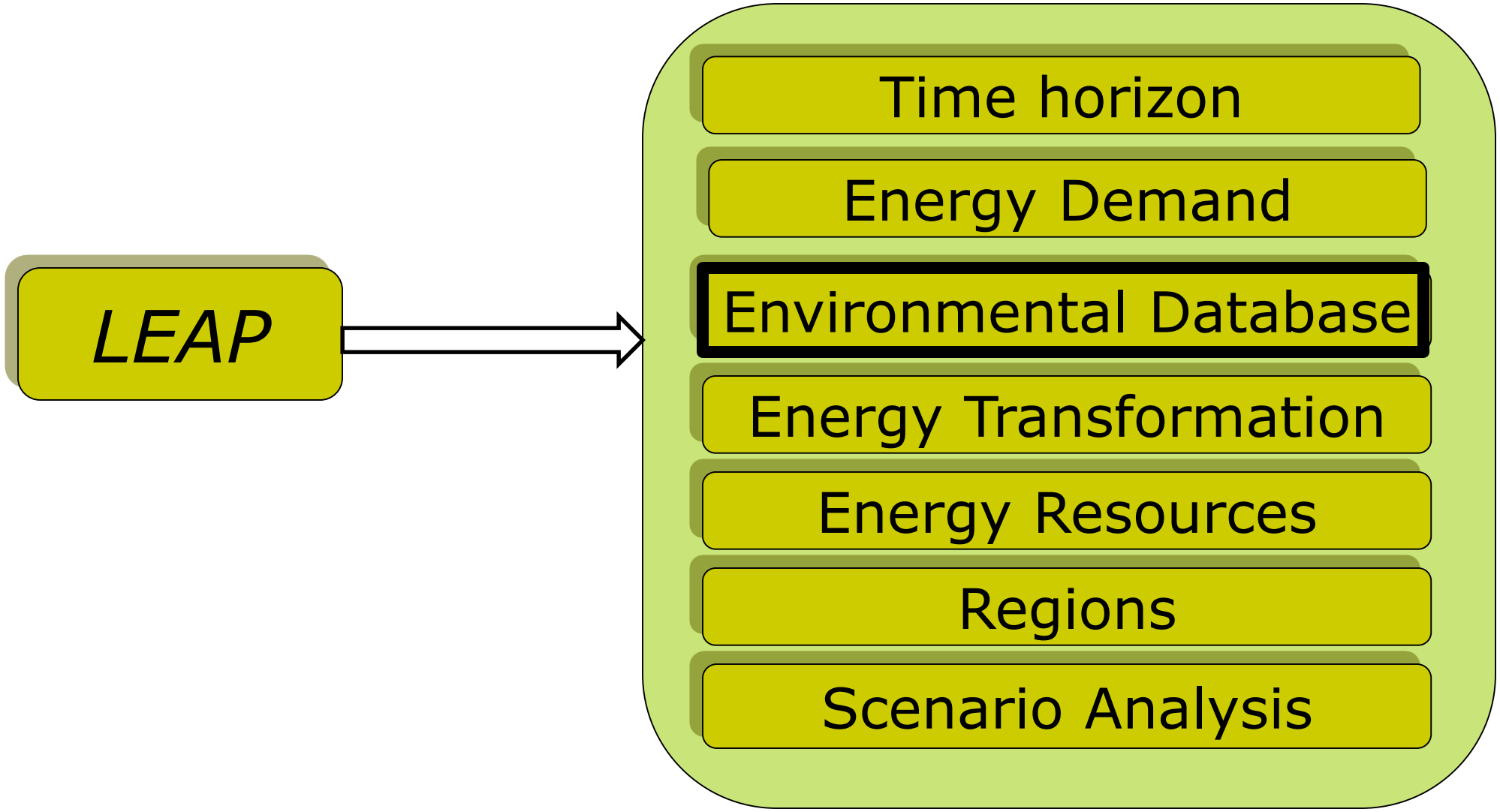
CHEMICAL

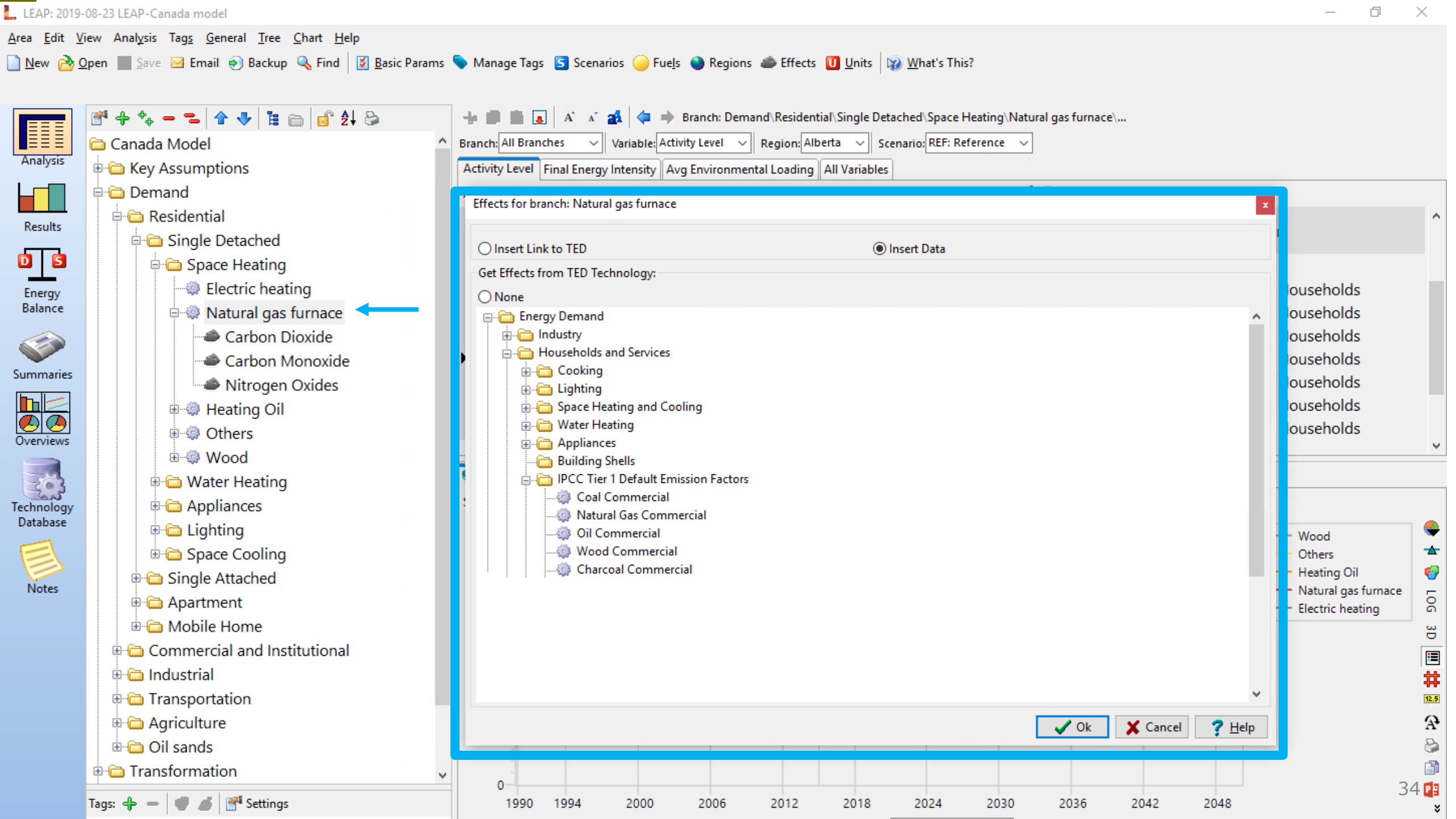
- chemical sector
  - Ammonia
    - Reforming
      - Natural Gas
      - Steam
      - NG prereformer
      - NG heat recovery
      - CHP
    - Waste Heat Boiler
      - Steam
    - Shift and CO2 removal
    - Methanator
    - Synthesis loop
      - Electricity
      - Steam
      - NG catalist
      - NG recovery
      - Elec autocotrol
      - NG autocontrol
      - Elec large scale
      - NG largscale
      - NG synthesis molecular
    - Aux. Boiler
      - Natural Gas
      - Steam
    - Turbine Compressor
      - steam
    - Miscellaneous
      - Electricity
      - Loss
    - Flare
      - Natural Gas
  - Ethylene
    - Cracker
      - Steam
      - Heating and Loss
      - NG process integration
      - NG high pressure combustion
      - NG process managment
      - NG heat of reaction
    - Compression
      - Electricity
    - Seperation
      - Chiller
        - Electricity
      - Steam

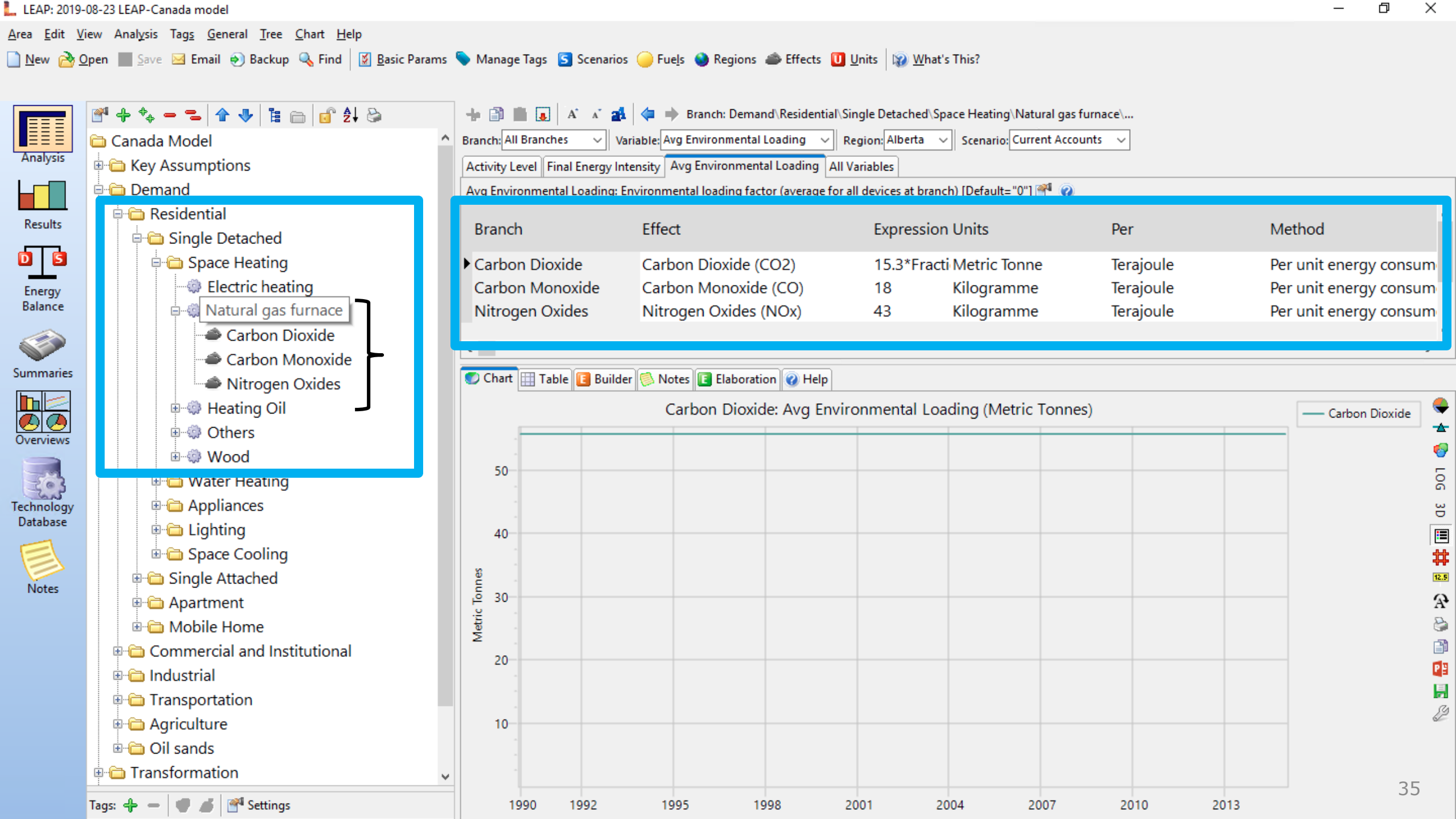
IRON AND STEEL

- Iron and Steel
  - Integrated Plant
    - Sintering
      - Coke
      - Coke oven gas
      - Electricity
      - Heat recovery
      - Reductin of air leakage
      - Improved process control
      - Use of waste fuels in sinter plant
    - Cocking
    - Blast Furnace
    - Basic Oxygen Furnace
    - Casting
      - Continous Casting
        - Electricity
      - Ignot Casting
        - Electricity
        - Natural Gas
    - forming and finishing
      - Ladle Metallurgy
      - Slab Mill
      - Hot Rolling
      - Pickling
      - Hot Dip
      - Tempring and Finishing hot rolling
  - Electric Arc Furnace
    - EAF
    - Casting
      - Continous Casting
        - Electricity
    - forming and finishing
      - Ladle Metallurgy
      - Hot Rolling
      - Pickling
      - Hot Dip
        - Electricity
        - Natural Gas
      - Tempring and Finishing hot rolling
        - Electricity
        - Natural Gas

LEAP-CANADA MAIN ELEMENTS




LEAP: 2019-08-23 LEAP-Canada model
Area Edit View Analysis Tags General Tree Chart Help
New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Regions Effects Units What's This?
Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes
Canada Model
Key Assumptions
Demand
Residential
Single Detached
Space Heating
Electric heating
Natural gas furnace
Carbon Dioxide
Carbon Monoxide
Nitrogen Oxides
Heating Oil
Others
Wood
Water Heating
Appliances
Lighting
Space Cooling
Single Attached
Apartment
Mobile Home
Commercial and Institutional
Industrial
Transportation
Agriculture
Oil sands
Transformation
Tags: Settings
Branch: Demand\Residential\Single Detached\Space Heating\Natural gas furnace\...
Branch: All Branches
Variable: Activity Level
Region: Alberta
Scenario: REF: Reference
Activity Level
Final Energy Intensity
Avg Environmental Loading
All Variables
Effects for branch: Natural gas furnace
Insert Link to TED
Insert Data
Get Effects from TED Technology:
None
Energy Demand
Industry
Households and Services
Cooking
Lighting
Space Heating and Cooling
Water Heating
Appliances
Building Shells
IPCC Tier 1 Default Emission Factors
Coal Commercial
Natural Gas Commercial
Oil Commercial
Wood Commercial
Charcoal Commercial
Ok
Cancel
Help
Wood
Others
Heating Oil
Natural gas furnace
Electric heating
0
1990 1994 2000 2006 2012 2018 2024 2030 2036 2042 2048
34


LEAP: 2019-08-23 LEAP-Canada model
Area Edit View Analysis Tags General Tree Chart Help
New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Regions Effects Units What's This?
Analysis
Results
Energy Balance
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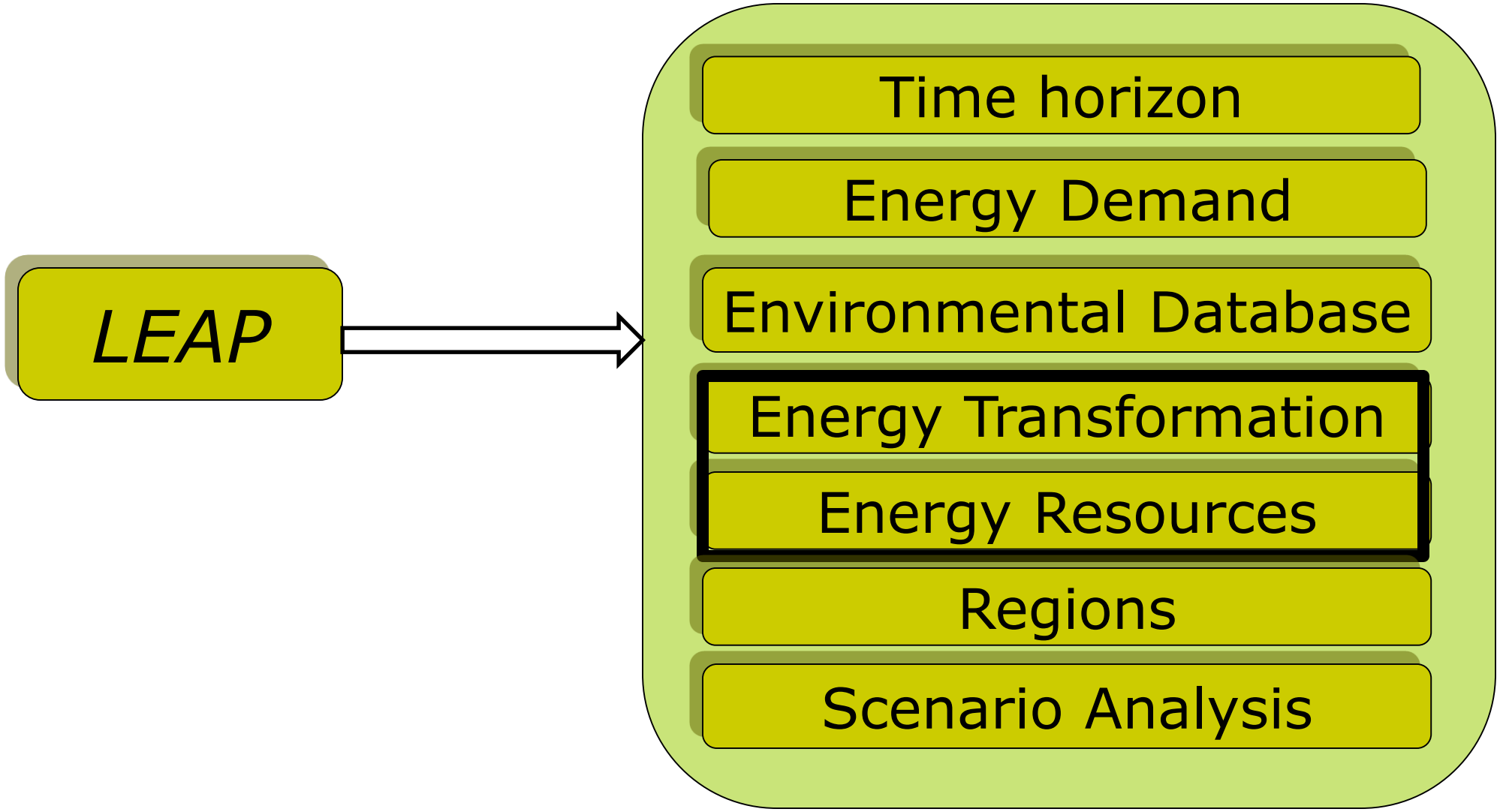
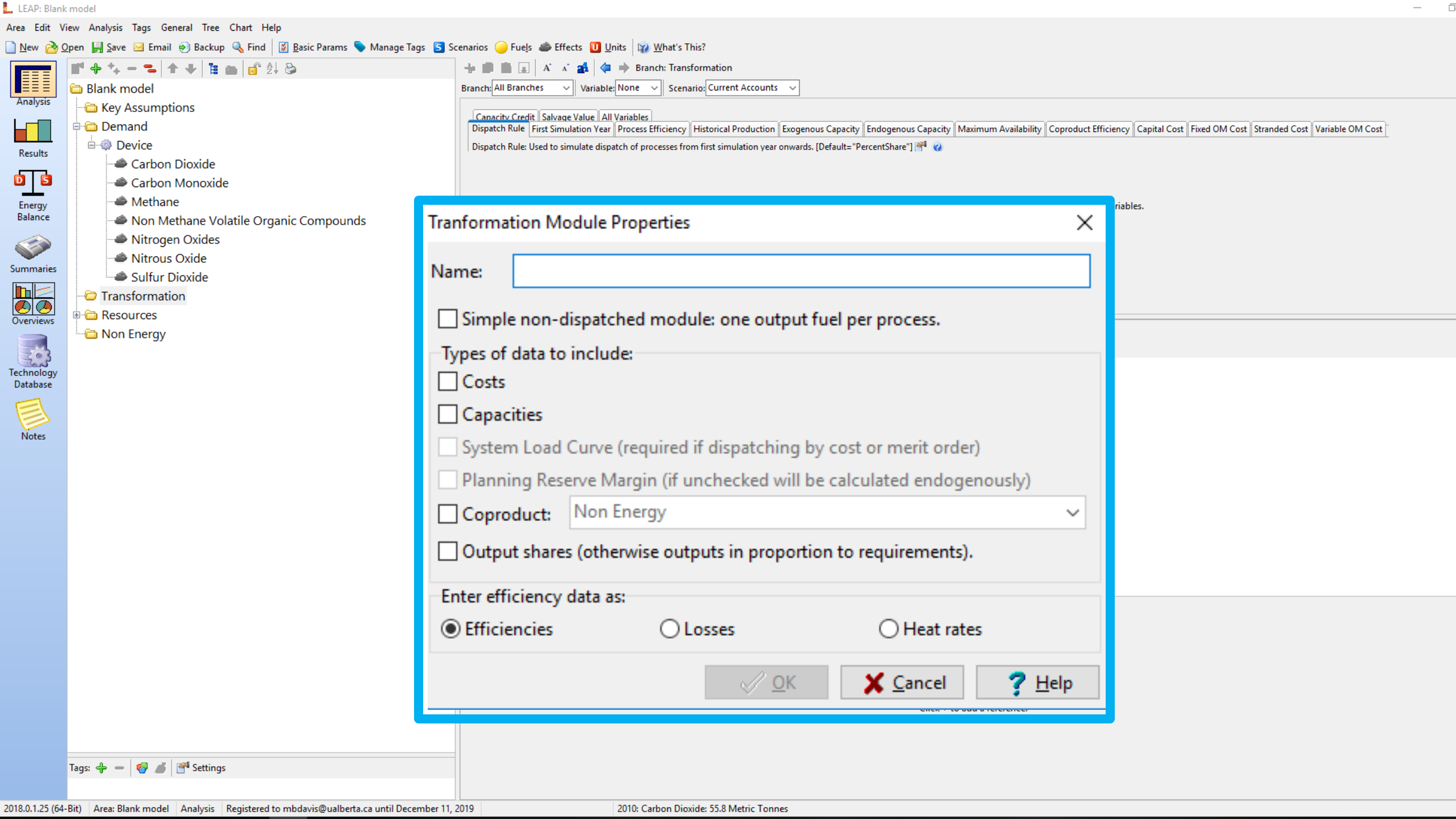
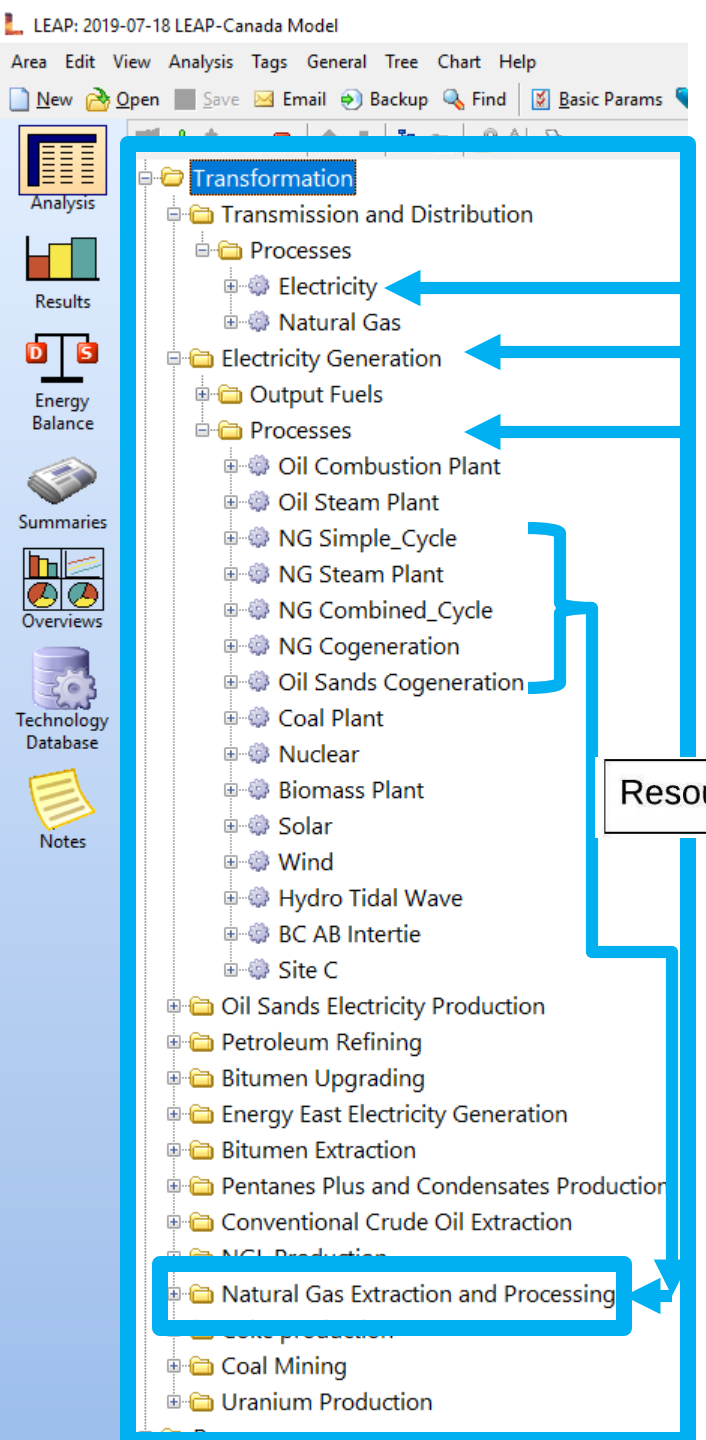
Canada Model
Key Assumptions
Demand
Residential
Single Detached
Space Heating
Electric heating
Natural gas furnace
Carbon Dioxide
Carbon Monoxide
Nitrogen Oxides
Heating Oil
Others
Wood
Water Heating
Appliances
Lighting
Space Cooling
Single Attached
Apartment
Mobile Home
Commercial and Institutional
Industrial
Transportation
Agriculture
Oil sands
Transformation
Tags: Settings
Branch: Demand\Residential\Single Detached\Space Heating\Natural gas furnace\...
Branch: All Branches
Variable: Avg Environmental Loading
Region: Alberta
Scenario: Current Accounts
Activity Level
Final Energy Intensity
Avg Environmental Loading
All Variables
Avg Environmental Loading: Environmental loading factor (average for all devices at branch) [Default="0"]
Branch
Effect
Expression
Units
Per
Method
Carbon Dioxide
Carbon Dioxide (CO2)
15.3*Fracti
Metric Tonne
Terajoule
Per unit energy consum
Carbon Monoxide
Carbon Monoxide (CO)
18
Kilogramme
Terajoule
Per unit energy consum
Nitrogen Oxides
Nitrogen Oxides (NOx)
43
Kilogramme
Terajoule
Per unit energy consum
Chart
Table
Builder
Notes
Elaboration
Help
Carbon Dioxide: Avg Environmental Loading (Metric Tonnes)
Carbon Dioxide
Metric Tonnes
50
40
30
20
10
1990
1992
1995
1998
2001
2004
2007
2010
2013

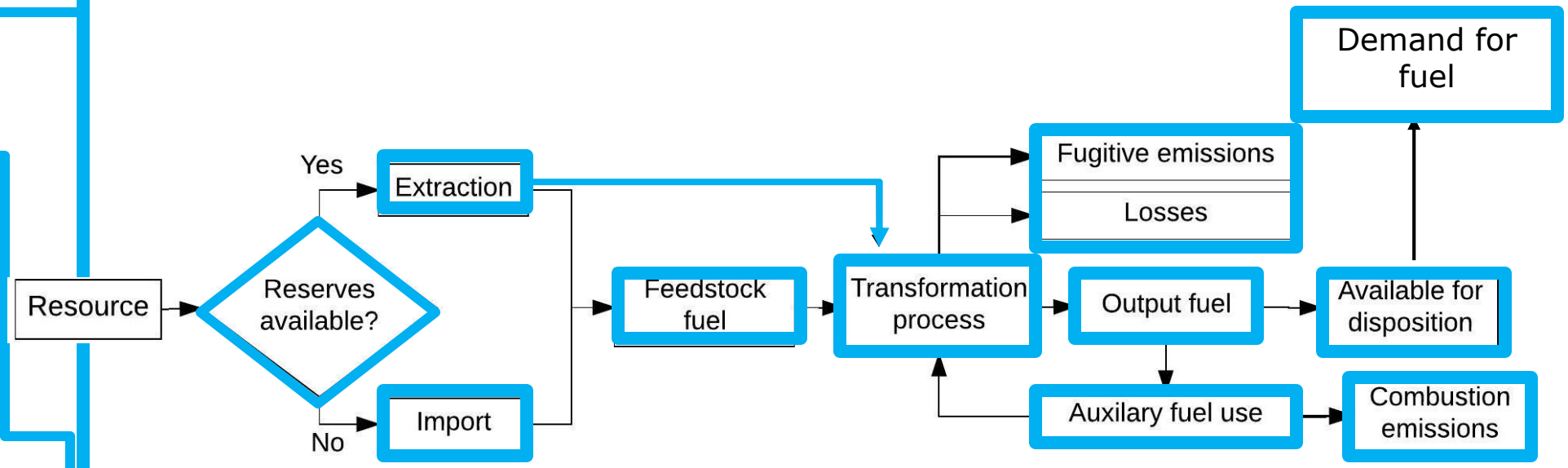
LEAP-CANADA MAIN ELEMENTS



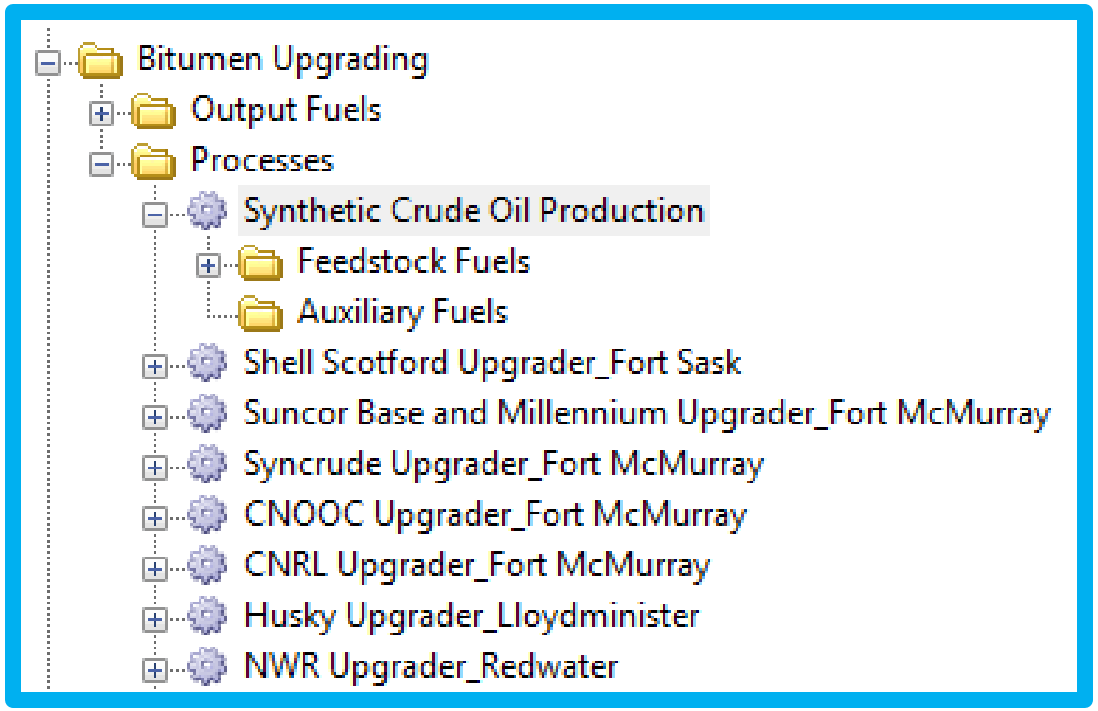

LEAP: Blank model
Area Edit View Analysis Tags General Tree Chart Help
New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Effects Units What's This?
Analysis
Results
Energy Balance
Summaries
Overviews
Technology Database
Notes
Blank model
Key Assumptions
Demand
Device
Carbon Dioxide
Carbon Monoxide
Methane
Non Methane Volatile Organic Compounds
Nitrogen Oxides
Nitrous Oxide
Sulfur Dioxide
Transformation
Resources
Non Energy
Branch: Transformation
Branch: All Branches
Variable: None
Scenario: Current Accounts
Capacity Credit
Salvage Value
All Variables
Dispatch Rule
First Simulation Year
Process Efficiency
Historical Production
Exogenous Capacity
Endogenous Capacity
Maximum Availability
Coproduct Efficiency
Capital Cost
Fixed OM Cost
Stranded Cost
Variable OM Cost
Dispatch Rule: Used to simulate dispatch of processes from first simulation year onwards. [Default="PercentShare"]
Tranformation Module Properties
Name:
Simple non-dispatched module: one output fuel per process.
Types of data to include:
Costs
Capacities
System Load Curve (required if dispatching by cost or merit order)
Planning Reserve Margin (if unchecked will be calculated endogenously)
Coproduct:
Non Energy
Output shares (otherwise outputs in proportion to requirements).
Enter efficiency data as:
Efficiencies
Losses
Heat rates
OK
Cancel
Help
Tags:
Settings
2018.0.1.25 (64-Bit)
Area: Blank model
Analysis
Registered to mbdavis@ualberta.ca until December 11, 2019
2010: Carbon Dioxide: 55.8 Metric Tonnes

TRANSFORMATION TREES



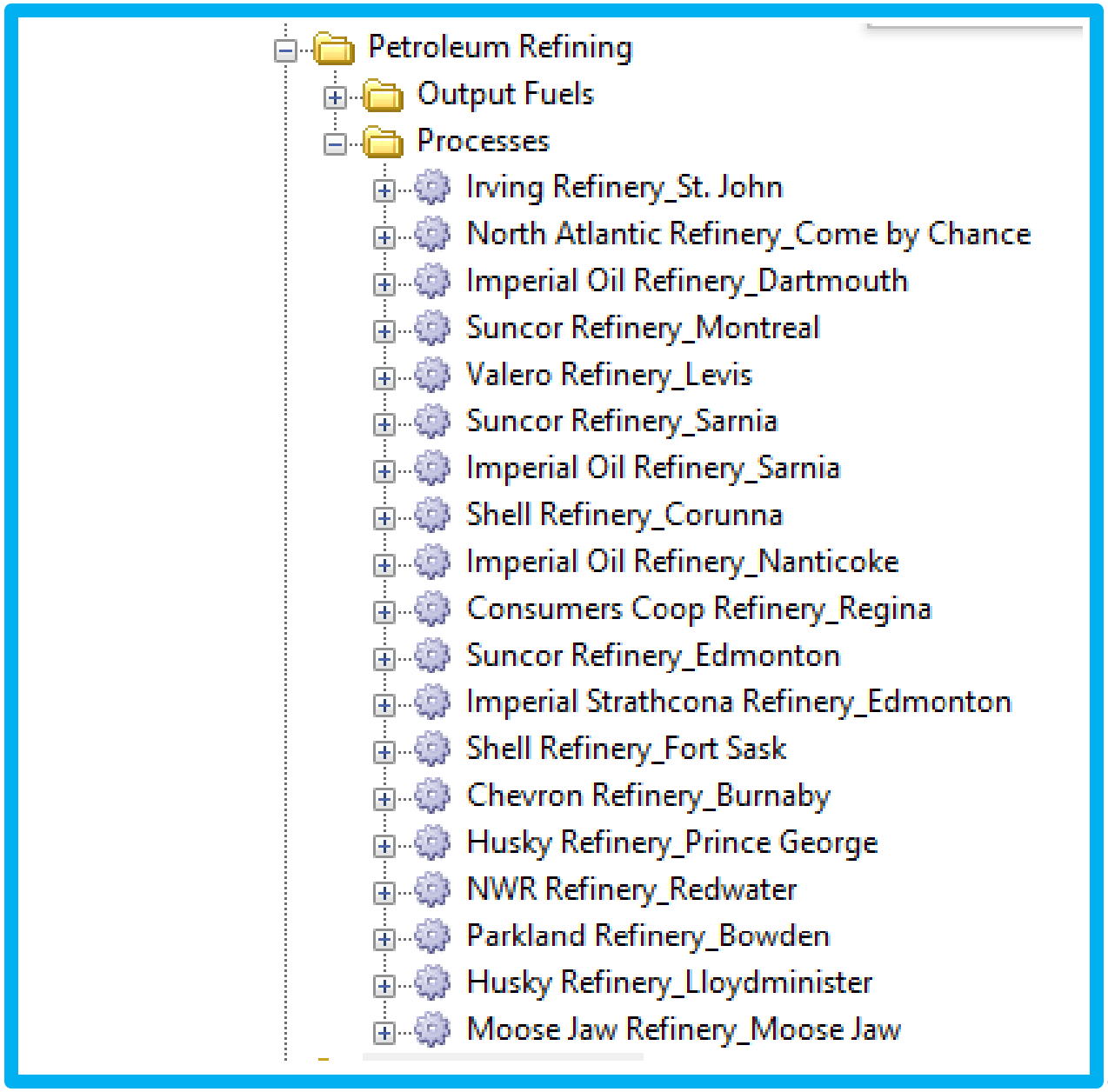


TRANSFORMATION PLANTS – OIL UPGRADING/REFINING



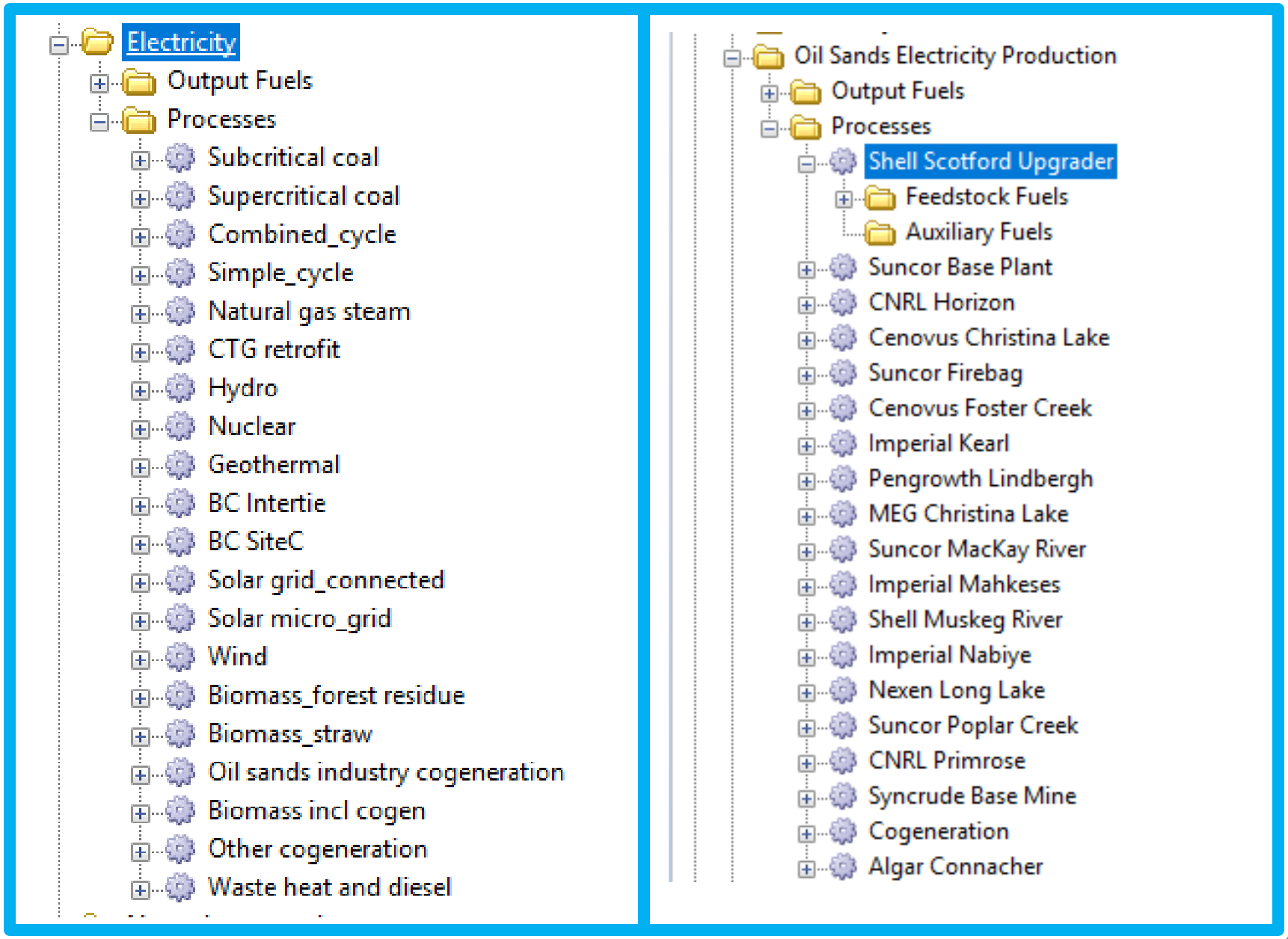
Data

- Historical production
- Capacity
- Availability
- Refinery utilization
- Lifetime
- Process efficiency
- Feedstock fuels
- Output fuels
- Auxiliary fuels



TRANSFORMATION PLANTS - ELECTRICITY

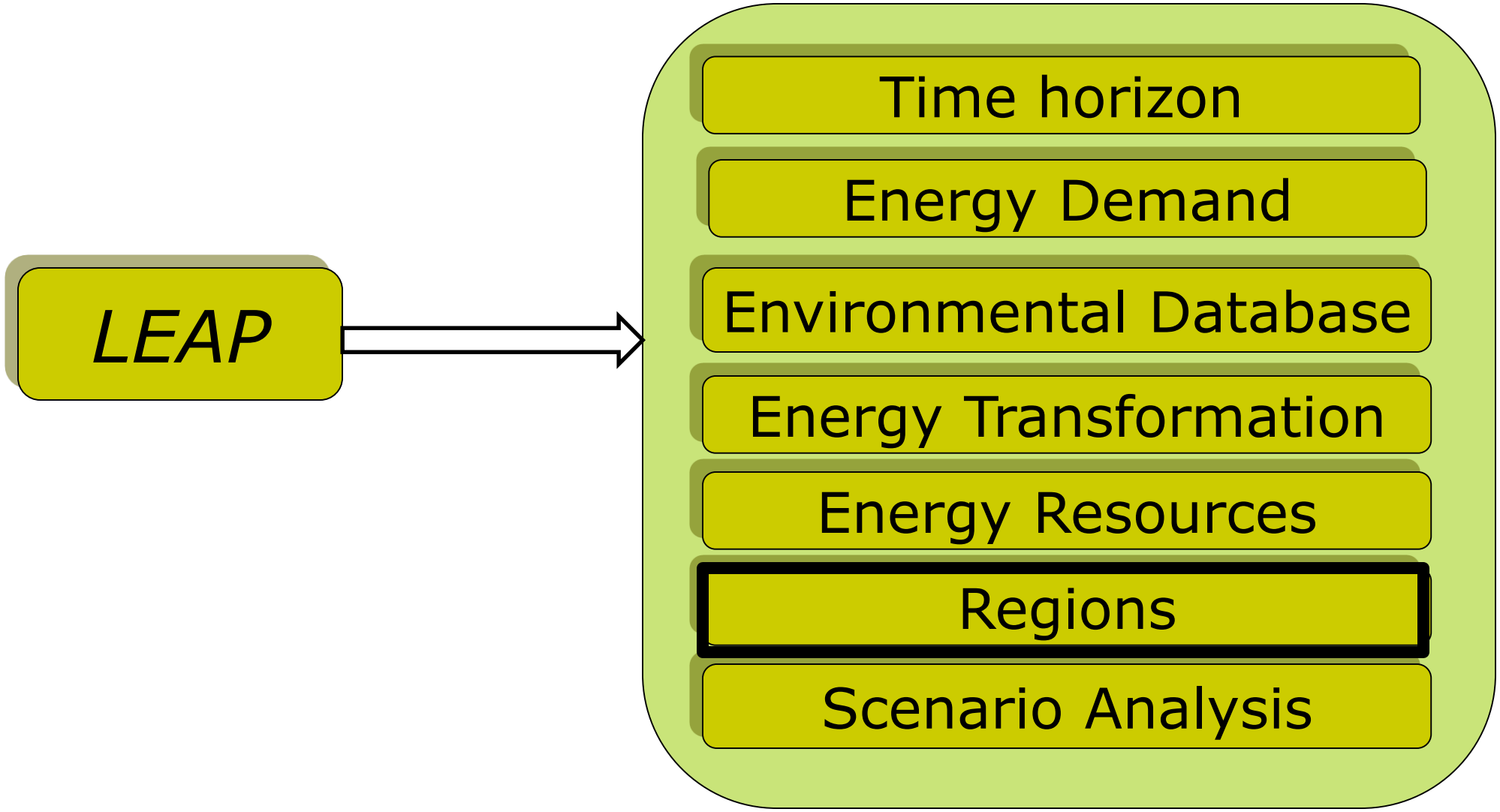
Data
- Historical generation
- Capacity
- Availability
- Capacity credit
- Lifetime
- Efficiency
- Dispatch rule
- Feedstock fuels
- Auxiliary fuels
- Electricity trade

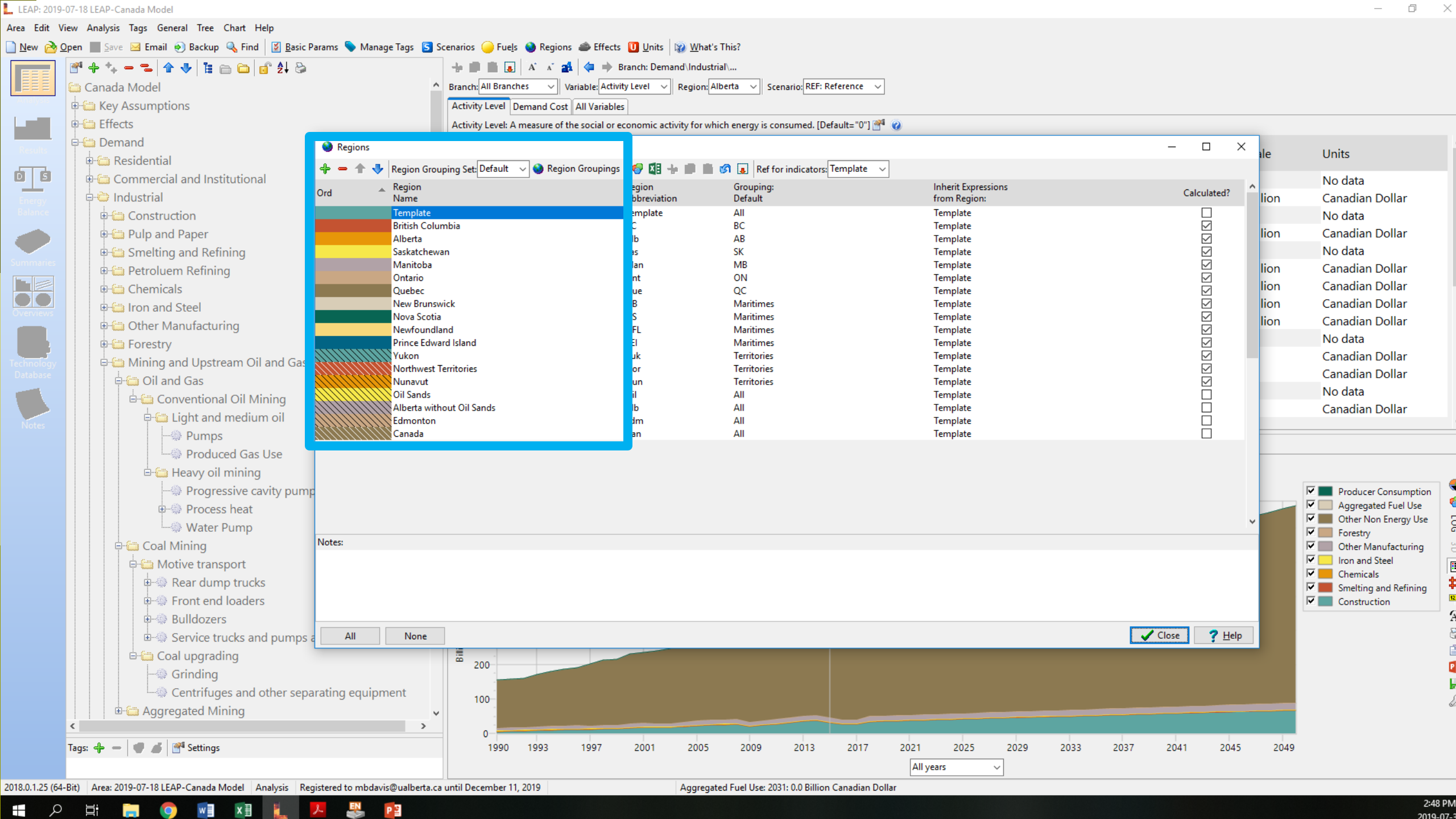


DATA SOURCES FOR LEAP-CANADA

Source	Description/Use
Natural Resources Canada Office of Energy Efficiency Comprehensive Energy Use Database	End-use energy demand Sectoral activity Model validation
Canadian socio-economic information management (CANSIM) Tables	End-use energy demand (pipeline and non-energy use) Energy transformation data Model validation
National Energy Board Energy Futures Reports	GDP, population, assumptions for future energy intensity changes, sectoral activity future changes, energy supply and resource production projections, model validation
Technology and Environment Database	The TED holds information on technical characteristics, costs, and environmental impacts (GHG emission factors) over a range of technologies
National Inventory Report	Non-energy emissions, fugitive emission factors, model validation
Various peer reviewed literature, industry reports, others	End-use energy demand Sectoral activity Energy transformation data

LEAP-CANADA MAIN ELEMENTS



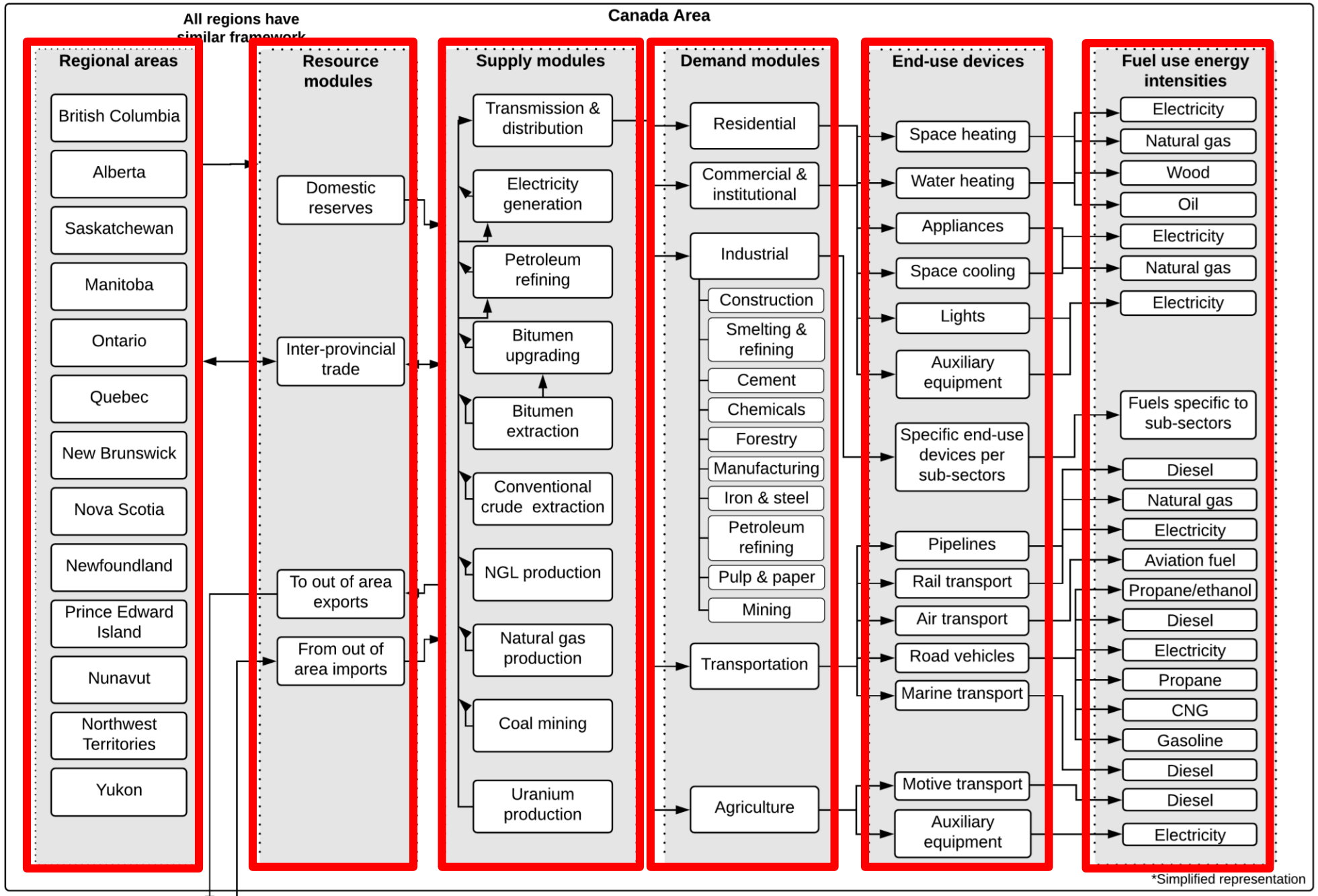

LEAP: 2019-07-18 LEAP-Canada Model
Area Edit View Analysis Tags General Tree Chart Help
New Open Save Email Backup Find Basic Params Manage Tags Scenarios Fuels Regions Effects Units What's This?
Canada Model
Key Assumptions
Effects
Demand
Residential
Commercial and Institutional
Industrial
Construction
Pulp and Paper
Smelting and Refining
Petroluem Refining
Chemicals
Iron and Steel
Other Manufacturing
Forestry
Mining and Upstream Oil and Gas
Oil and Gas
Conventional Oil Mining
Light and medium oil
Pumps
Produced Gas Use
Heavy oil mining
Progressive cavity pump
Process heat
Water Pump
Coal Mining
Motive transport
Rear dump trucks
Front end loaders
Bulldozers
Service trucks and pumps
Coal upgrading
Grinding
Centrifuges and other separating equipment
Aggregated Mining
Branch: Demand\Industrial\...
Branch: All Branches
Variable: Activity Level
Region: Alberta
Scenario: REF: Reference
Activity Level
Demand Cost
All Variables
Activity Level: A measure of the social or economic activity for which energy is consumed. [Default="0"]
Regions
Region Grouping Set: Default
Region Groupings
Ord
Region Name
Template
British Columbia
Alberta
Saskatchewan
Manitoba
Ontario
Quebec
New Brunswick
Nova Scotia
Newfoundland
Prince Edward Island
Yukon
Northwest Territories
Nunavut
Oil Sands
Alberta without Oil Sands
Edmonton
Canada
Ref for indicators: Template
Grouping: Default
Inherit Expressions from Region:
Calculated?
All
None
Close
Help
Notes:
Units
No data
Canadian Dollar
Producer Consumption
Aggregated Fuel Use
Other Non Energy Use
Forestry
Other Manufacturing
Iron and Steel
Chemicals
Smelting and Refining
Construction
200
100
0
1990 1993 1997 2001 2005 2009 2013 2017 2021 2025 2029 2033 2037 2041 2045 2049
All years
Tags:
Settings
2018.0.1.25 (64-Bit)
Area: 2019-07-18 LEAP-Canada Model
Analysis
Registered to mbdavis@ualberta.ca until December 11, 2019
Aggregated Fuel Use: 2031: 0.0 Billion Canadian Dollar

LEAP-CANADA REGIONS

- **Independent system models linked through energy trade**

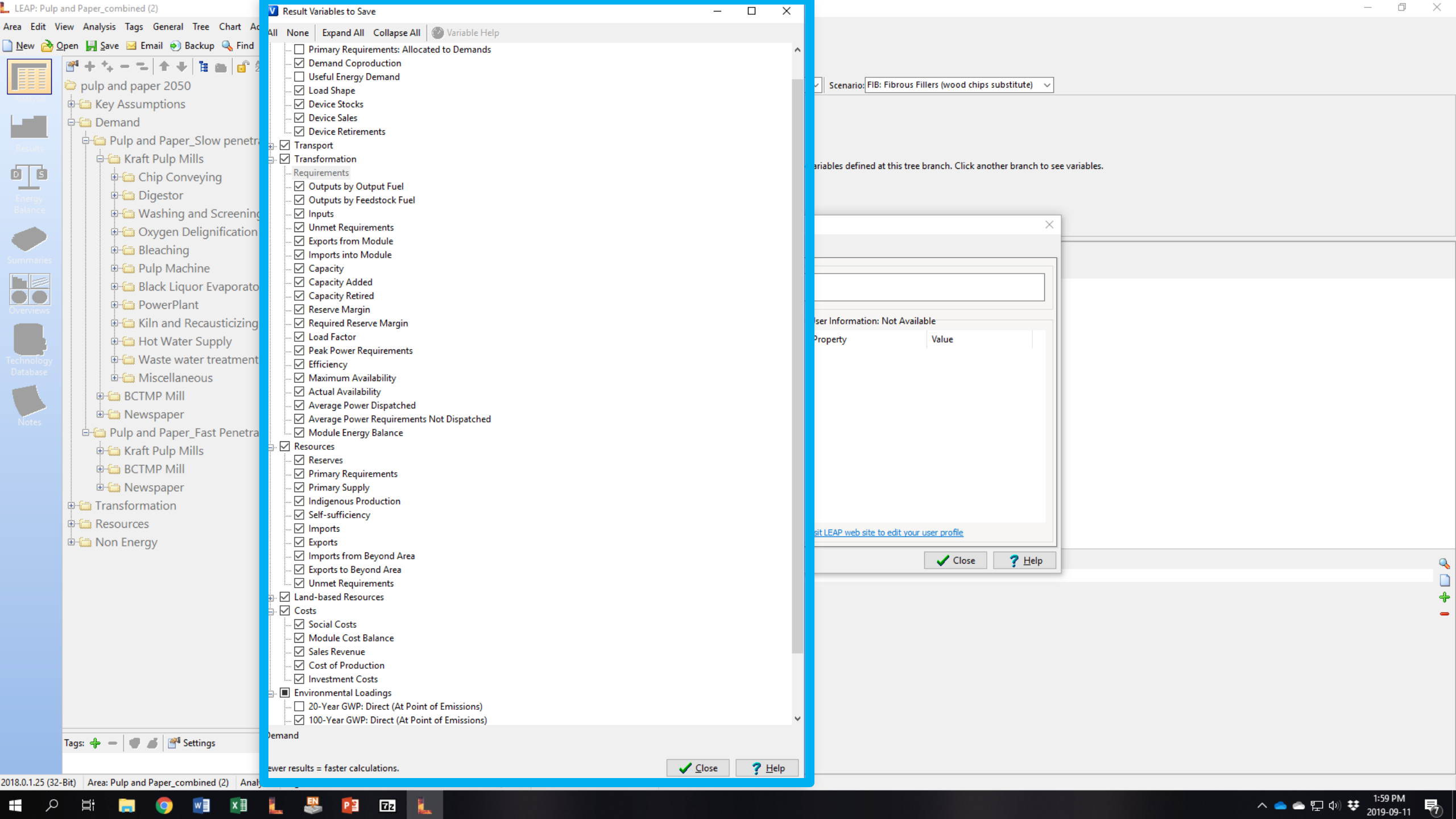
- LEAP-BC
- LEAP-Alberta
- LEAP-Saskatchewan
- LEAP-Manitoba
- LEAP-Ontario
- LEAP-Quebec
- LEAP-New Brunswick
- LEAP-Nova Scotia
- LEAP-Prince Edward Island
- LEAP-Newfoundland
- LEAP-Territories
- LEAP-Canada

LEAP-Canada Model*

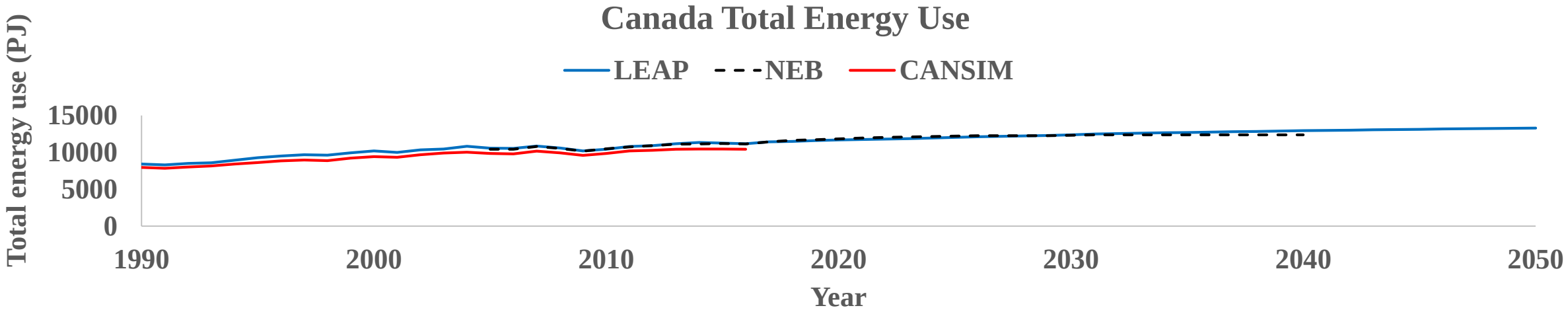


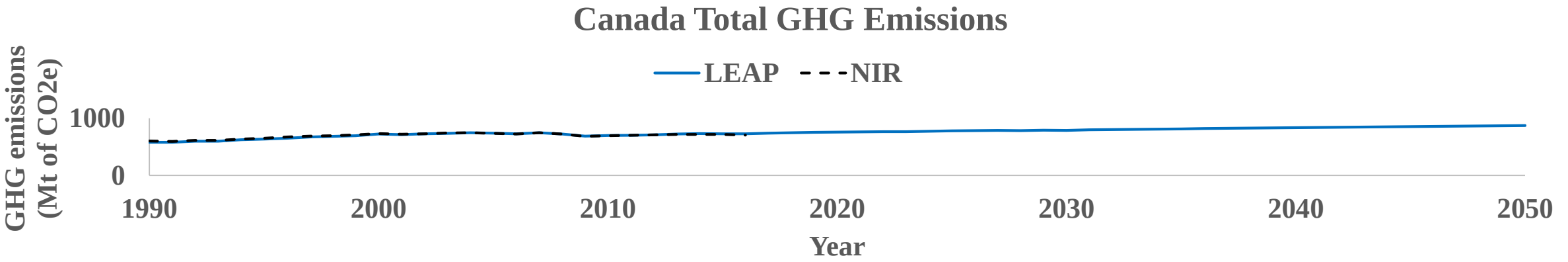
Input data

- Statistics Canada (CANSIM)
- Natural Resources Canada (OEE)
- National Energy Board (EFR)
- National Inventory Report (NIR)
- CAPP
- Published studies
- Government reports
- Company reports
- Data developed where gaps exist


LEAP: Pulp and Paper_combined (2)
Area Edit View Analysis Tags General Tree Chart
New Open Save Email Backup Find
pulp and paper 2050
Key Assumptions
Demand
Pulp and Paper_Slow penetra
Kraft Pulp Mills
Chip Conveying
Digestor
Washing and Screening
Oxygen Delignification
Bleaching
Pulp Machine
Black Liquor Evaporato
PowerPlant
Kiln and Recausticizing
Hot Water Supply
Waste water treatment
Miscellaneous
BCTMP Mill
Newspaper
Pulp and Paper_Fast Penetra
Kraft Pulp Mills
BCTMP Mill
Newspaper
Transformation
Resources
Non Energy
Tags: Settings
Result Variables to Save
All None Expand All Collapse All Variable Help
Primary Requirements: Allocated to Demands
Demand Coproduction
Useful Energy Demand
Load Shape
Device Stocks
Device Sales
Device Retirements
Transport
Transformation
Requirements
Outputs by Output Fuel
Outputs by Feedstock Fuel
Inputs
Unmet Requirements
Exports from Module
Imports into Module
Capacity
Capacity Added
Capacity Retired
Reserve Margin
Required Reserve Margin
Load Factor
Peak Power Requirements
Efficiency
Maximum Availability
Actual Availability
Average Power Dispatched
Average Power Requirements Not Dispatched
Module Energy Balance
Resources
Reserves
Primary Requirements
Primary Supply
Indigenous Production
Self-sufficiency
Imports
Exports
Imports from Beyond Area
Exports to Beyond Area
Unmet Requirements
Land-based Resources
Costs
Social Costs
Module Cost Balance
Sales Revenue
Cost of Production
Investment Costs
Environmental Loadings
20-Year GWP: Direct (At Point of Emissions)
100-Year GWP: Direct (At Point of Emissions)
Demand
ewer results = faster calculations.
Close
Help
Scenario: FIB: Fibrous Fillers (wood chips substitute)
ariables defined at this tree branch. Click another branch to see variables.
ser Information: Not Available
Property
Value
sit LEAP web site to edit your user profile
Close
Help
2018.0.1.25 (32-Bit)
Area: Pulp and Paper_combined (2)
1:59 PM
2019-09-11

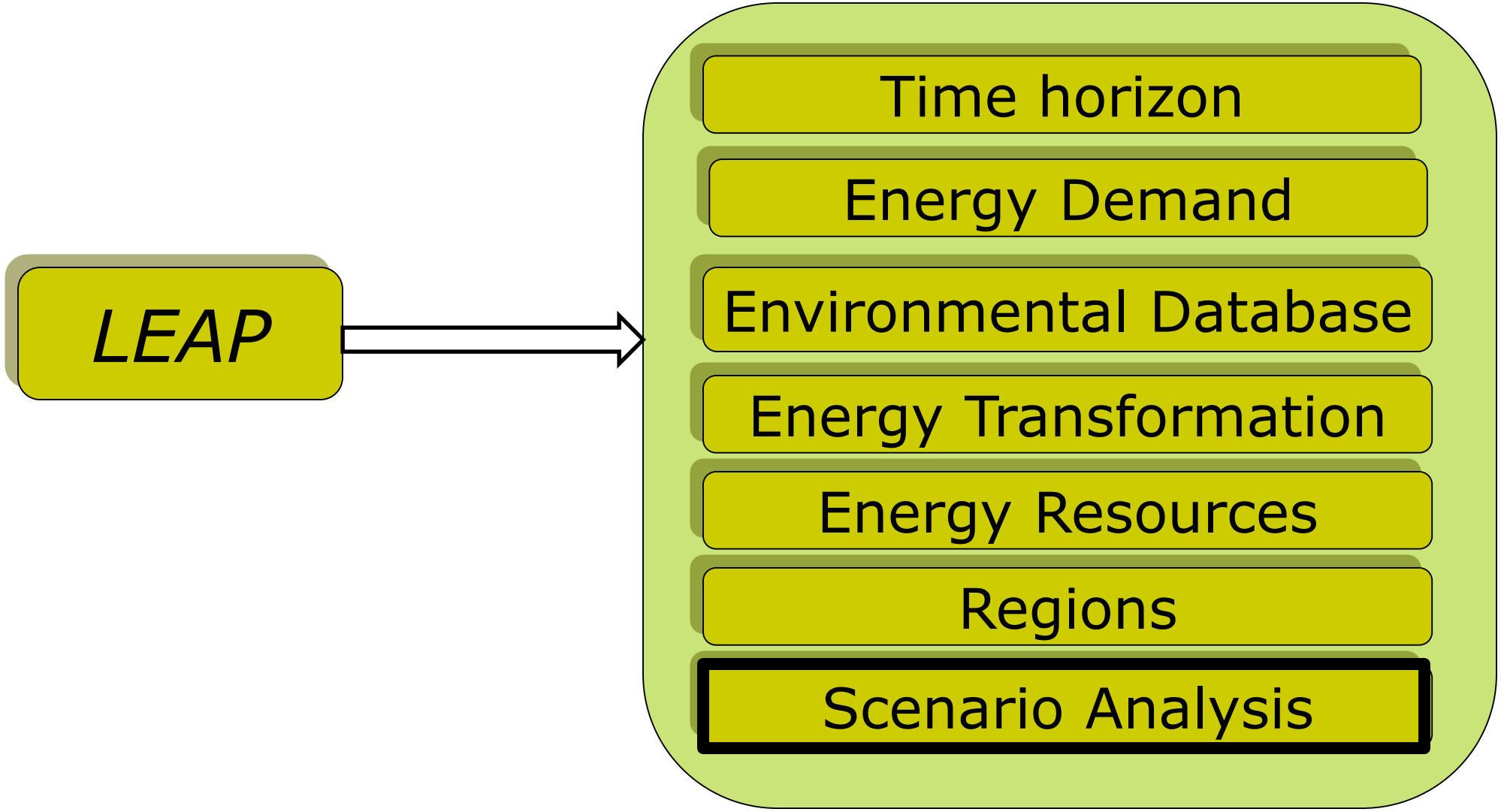
VALIDATION





- Calibrated with data from 1990 onward

LEAP-CANADA MAIN ELEMENTS



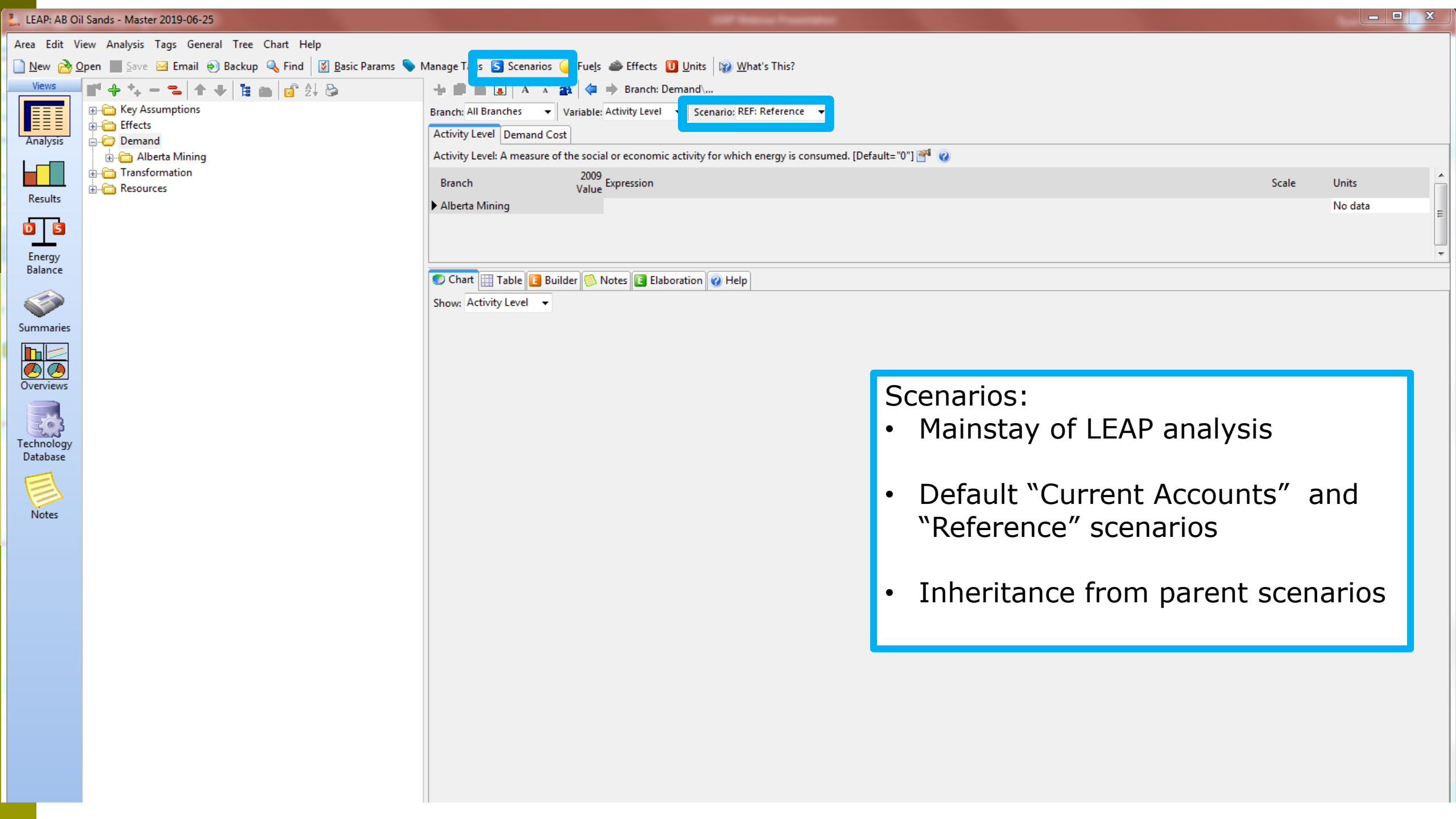
SCENARIO ANALYSIS

Develop reference scenario

Formulate alternative scenarios

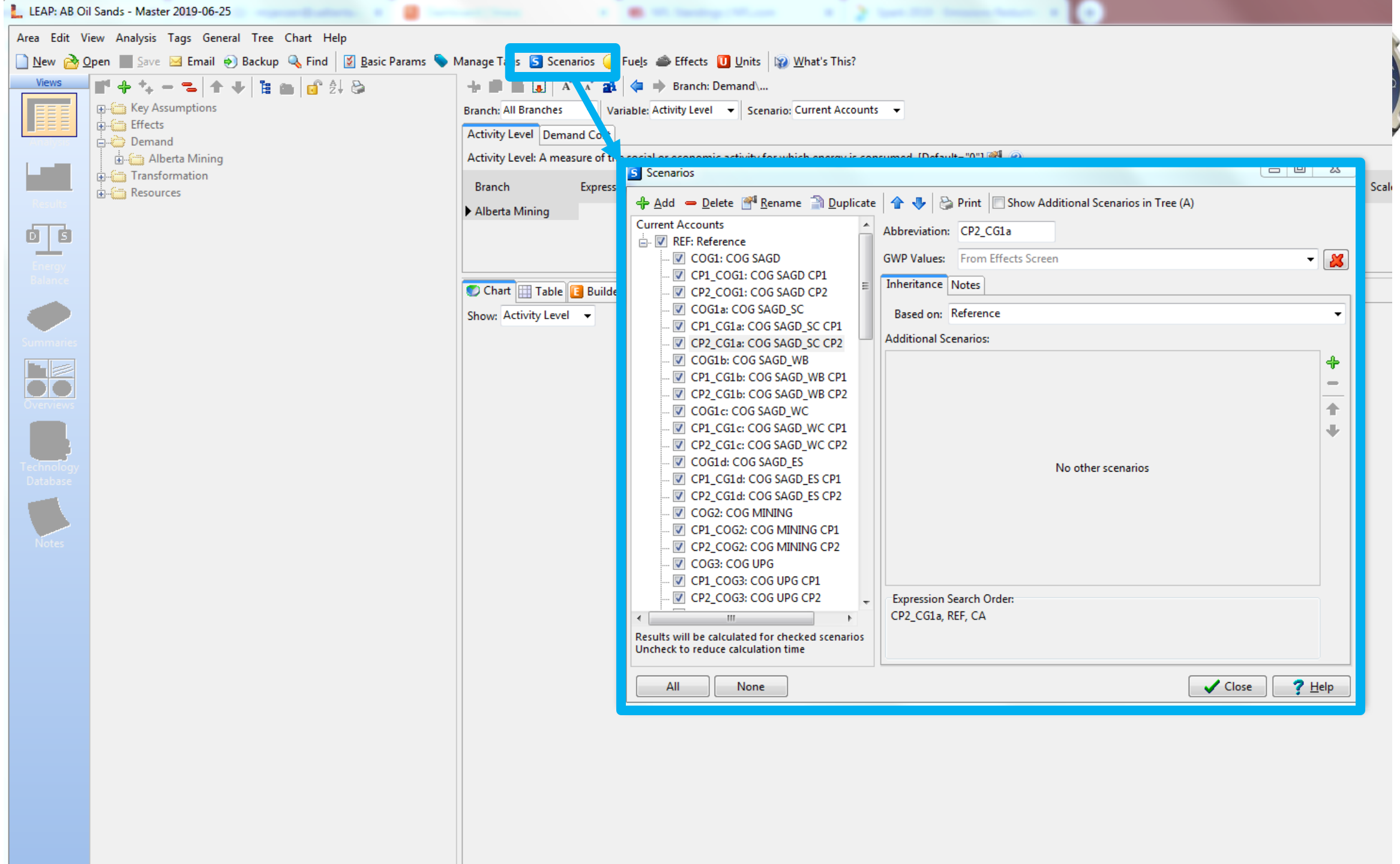
Change model inputs

Compare alternative scenario results to reference scenario results



Scenarios:

- Mainstay of LEAP analysis
- Default "Current Accounts" and "Reference" scenarios
- Inheritance from parent scenarios


LEAP: AB Oil Sands - Master 2019-06-25
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CP2_COG1: COG SAGD CP2
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CP1_CG1a: COG SAGD_SC CP1
CP2_CG1a: COG SAGD_SC CP2
COG1b: COG SAGD_WB
CP1_CG1b: COG SAGD_WB CP1
CP2_CG1b: COG SAGD_WB CP2
COG1c: COG SAGD_WC
CP1_CG1c: COG SAGD_WC CP1
CP2_CG1c: COG SAGD_WC CP2
COG1d: COG SAGD_ES
CP1_CG1d: COG SAGD_ES CP1
CP2_CG1d: COG SAGD_ES CP2
COG2: COG MINING
CP1_COG2: COG MINING CP1
CP2_COG2: COG MINING CP2
COG3: COG UPG
CP1_COG3: COG UPG CP1
CP2_COG3: COG UPG CP2
Results will be calculated for checked scenarios
Uncheck to reduce calculation time
All
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Abbreviation: CP2_CG1a
GWP Values: From Effects Screen
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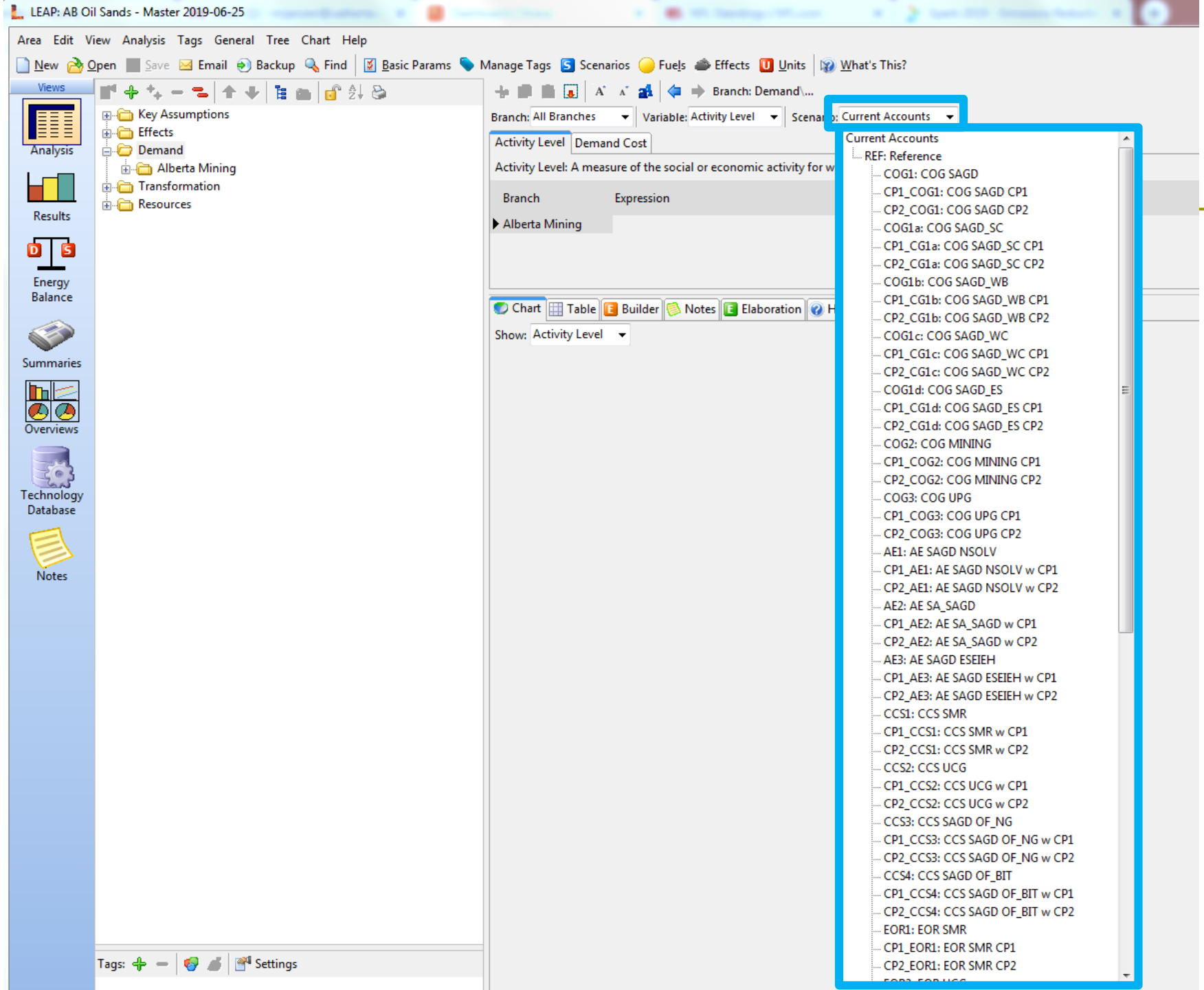
LEAP: AB Oil Sands - Master 2019-06-25
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CP2_COG1: COG SAGD CP2
COG1a: COG SAGD_SC
CP1_CG1a: COG SAGD_SC CP1
CP2_CG1a: COG SAGD_SC CP2
COG1b: COG SAGD_WB
CP1_CG1b: COG SAGD_WB CP1
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COG1c: COG SAGD_WC
CP1_CG1c: COG SAGD_WC CP1
CP2_CG1c: COG SAGD_WC CP2
COG1d: COG SAGD_ES
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CP2_CG1d: COG SAGD_ES CP2
COG2: COG MINING
CP1_COG2: COG MINING CP1
CP2_COG2: COG MINING CP2
COG3: COG UPG
CP1_COG3: COG UPG CP1
CP2_COG3: COG UPG CP2
AE1: AE SAGD NSOLV
CP1_AE1: AE SAGD NSOLV w CP1
CP2_AE1: AE SAGD NSOLV w CP2
AE2: AE SA_SAGD
CP1_AE2: AE SA_SAGD w CP1
CP2_AE2: AE SA_SAGD w CP2
AE3: AE SAGD ESEIEH
CP1_AE3: AE SAGD ESEIEH w CP1
CP2_AE3: AE SAGD ESEIEH w CP2
CCS1: CCS SMR
CP1_CCS1: CCS SMR w CP1
CP2_CCS1: CCS SMR w CP2
CCS2: CCS UCG
CP1_CCS2: CCS UCG w CP1
CP2_CCS2: CCS UCG w CP2
CCS3: CCS SAGD OF_NG
CP1_CCS3: CCS SAGD OF_NG w CP1
CP2_CCS3: CCS SAGD OF_NG w CP2
CCS4: CCS SAGD OF_BIT
CP1_CCS4: CCS SAGD OF_BIT w CP1
CP2_CCS4: CCS SAGD OF_BIT w CP2
EOR1: EOR SMR
CP1_EOR1: EOR SMR CP1
CP2_EOR1: EOR SMR CP2

SCENARIO ANALYSIS IN LEAP

OUTLINE – MODELLING SCENARIOS

Inputs for LEAP scenarios

Oil sands energy efficiency scenario

- Change existing energy intensity
- Add marginal costs
- Results

Oil sands new technology scenario

- Add new technology to demand tree
- Import activity level
- Results

Questions

SCENARIO ANALYSIS REQUIREMENTS

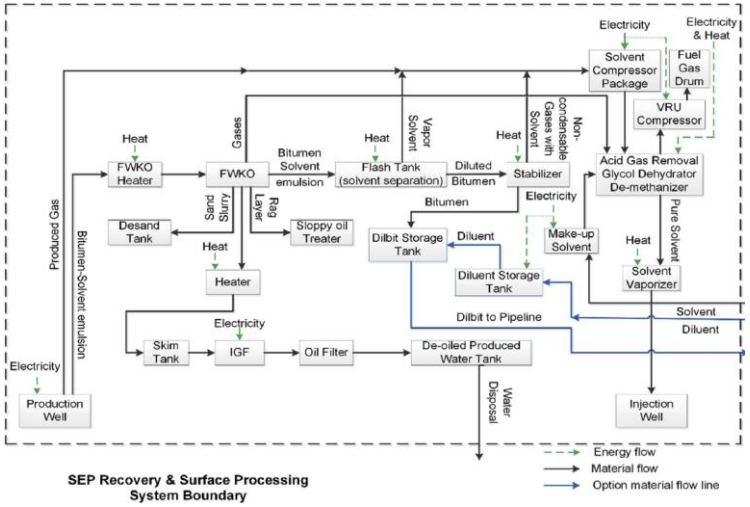
- Performance of technology
  - 2 ways – change existing technology efficiency or develop new technology
  - Quantified energy savings
  - Type of fuel consumed
  - Environmental effects of consuming that fuel (if any)

- Cost of technology
  - Key costs such as capex, opex, fuel costs, and policy costs
  - Assumptions such as internal rate of return
  - Technology lifetime

- Activity level

INPUT DEVELOPMENT FOR SCENARIOS

Process modelling



Lifecycle analysis

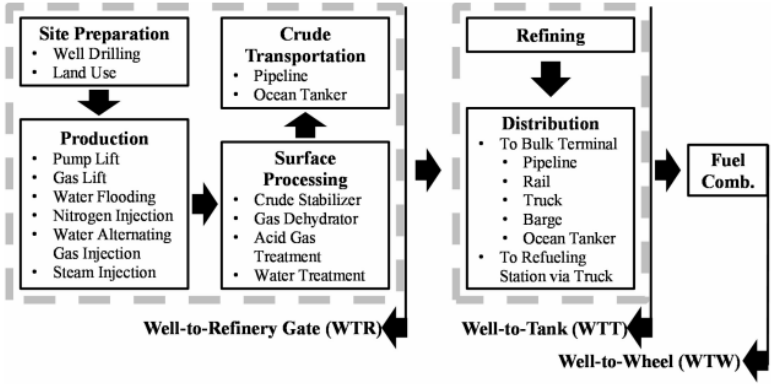


Figure 8: FUNNEL-GHG-CCO model boundary

Market penetration modelling

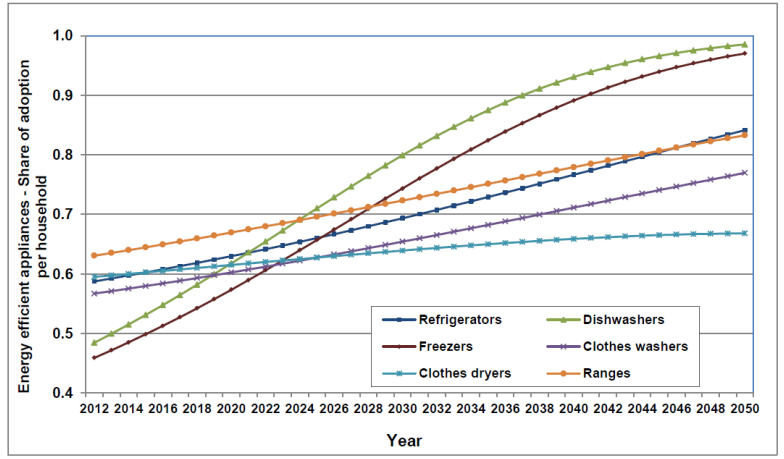


Figure 8: The adoption shares of high energy efficiency appliances (2012-2050)

ENERGY EFFICIENCY SCENARIO

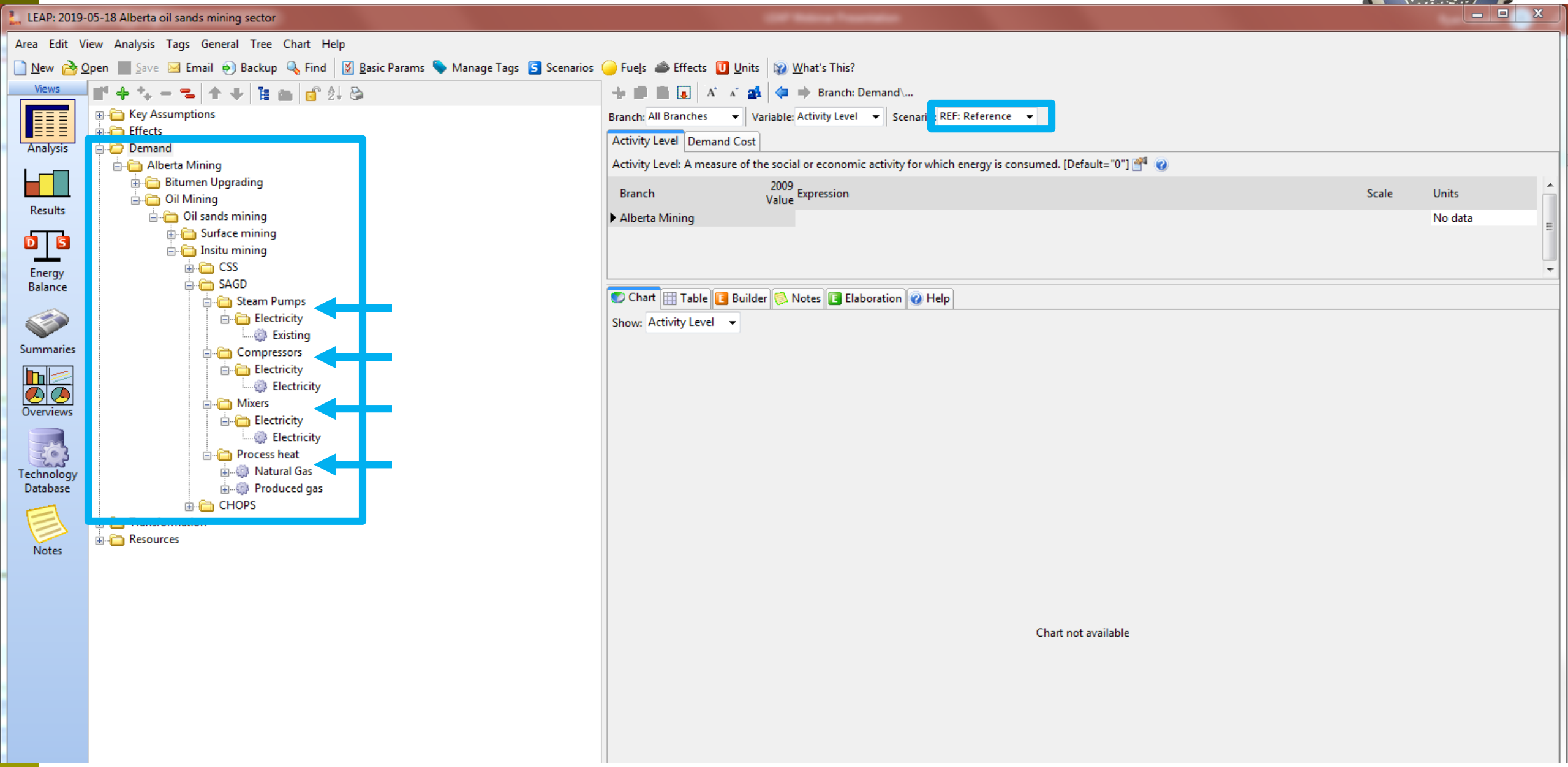
IN SITU – HEAT LOSS REDUCTION

- Efficiency improved in in situ mining processes to reduce heat losses to the earth and water. Opportunities related to efficient development of the well and capturing waste heat lost through tailings disposal

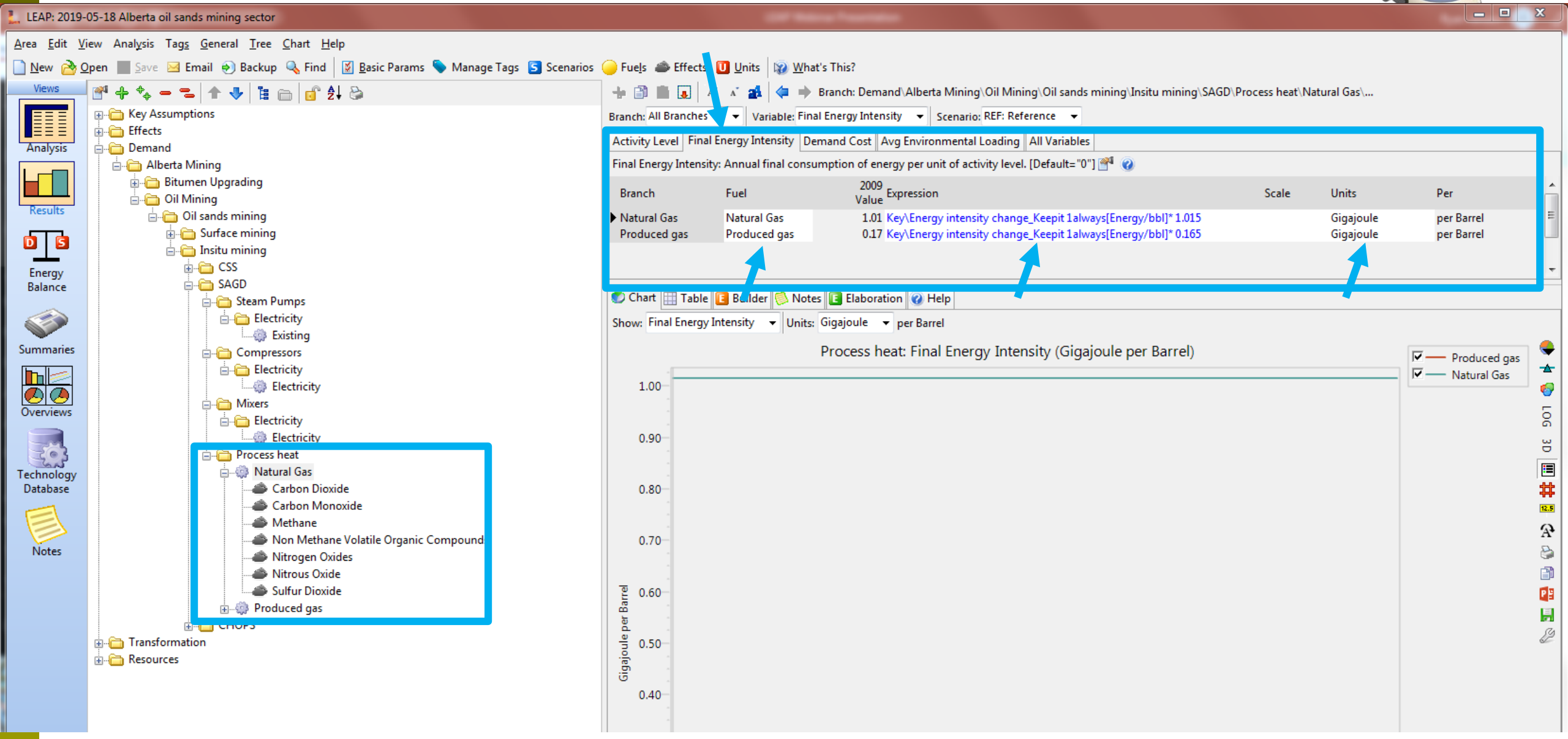
- Expected benefit
  - 0.12% reduction in heat demand
  - 0.10% reduction in electricity demand

- Expected cost
  - $0.02/bbl of bitumen produced over 35 years

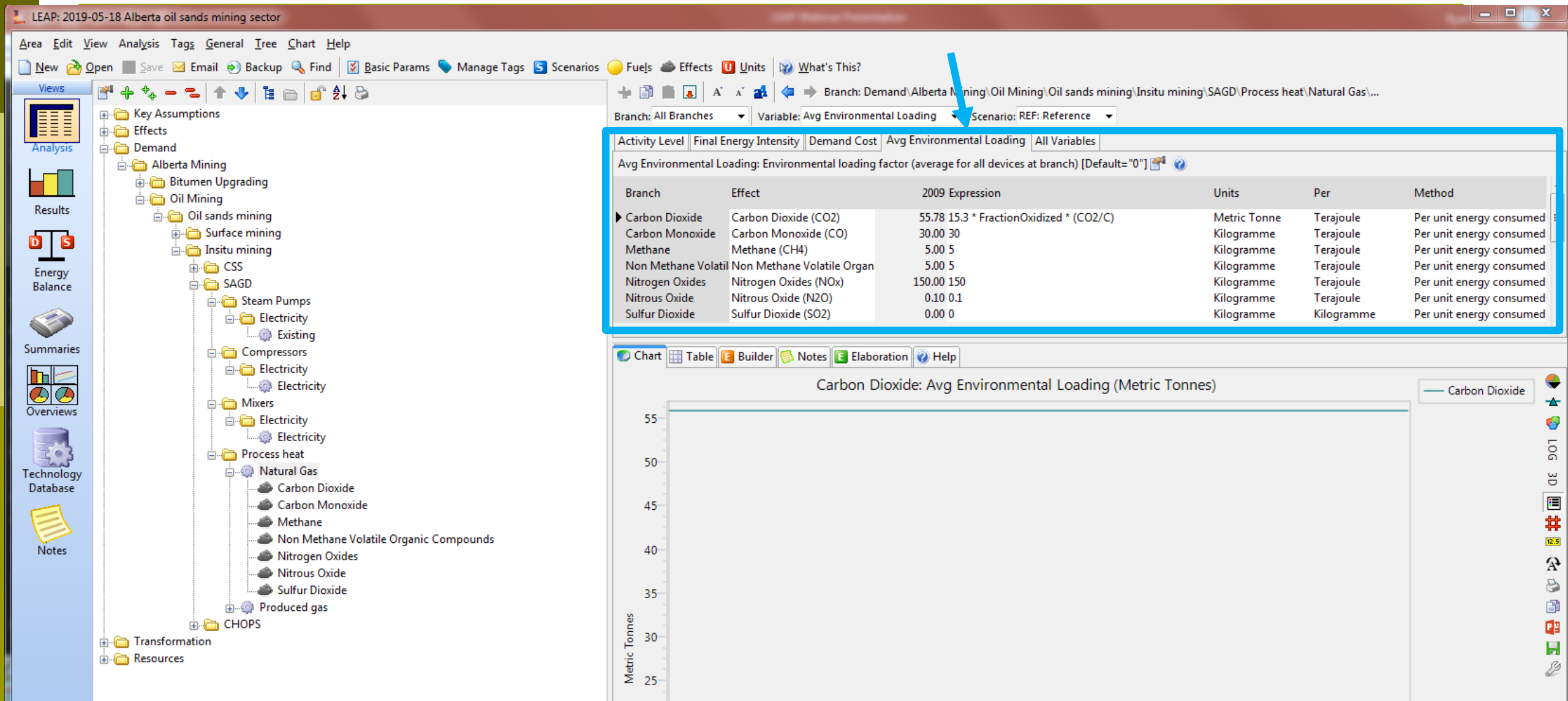
REFERENCE CASE – DEMAND TREE



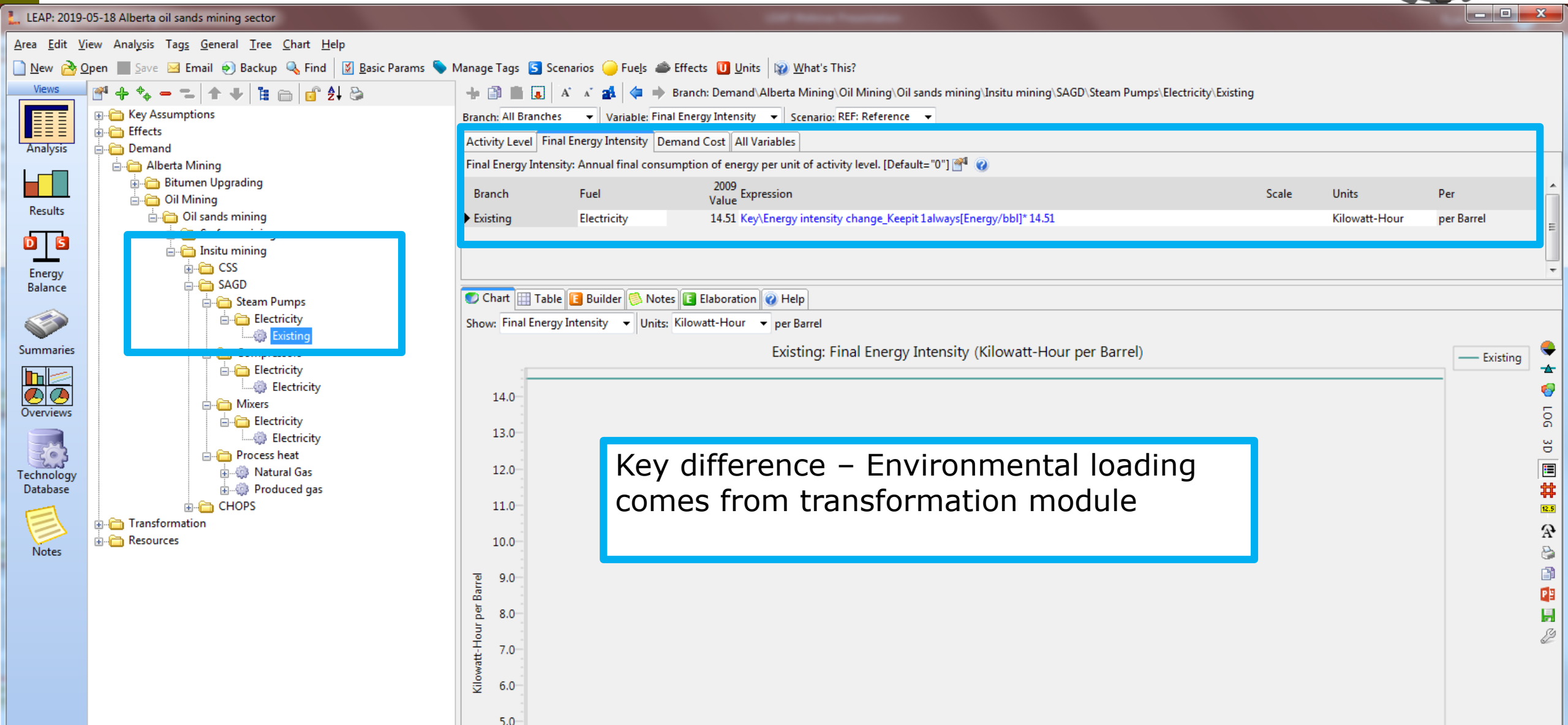
REFERENCE CASE – PROCESS HEAT ENERGY INTENSITY



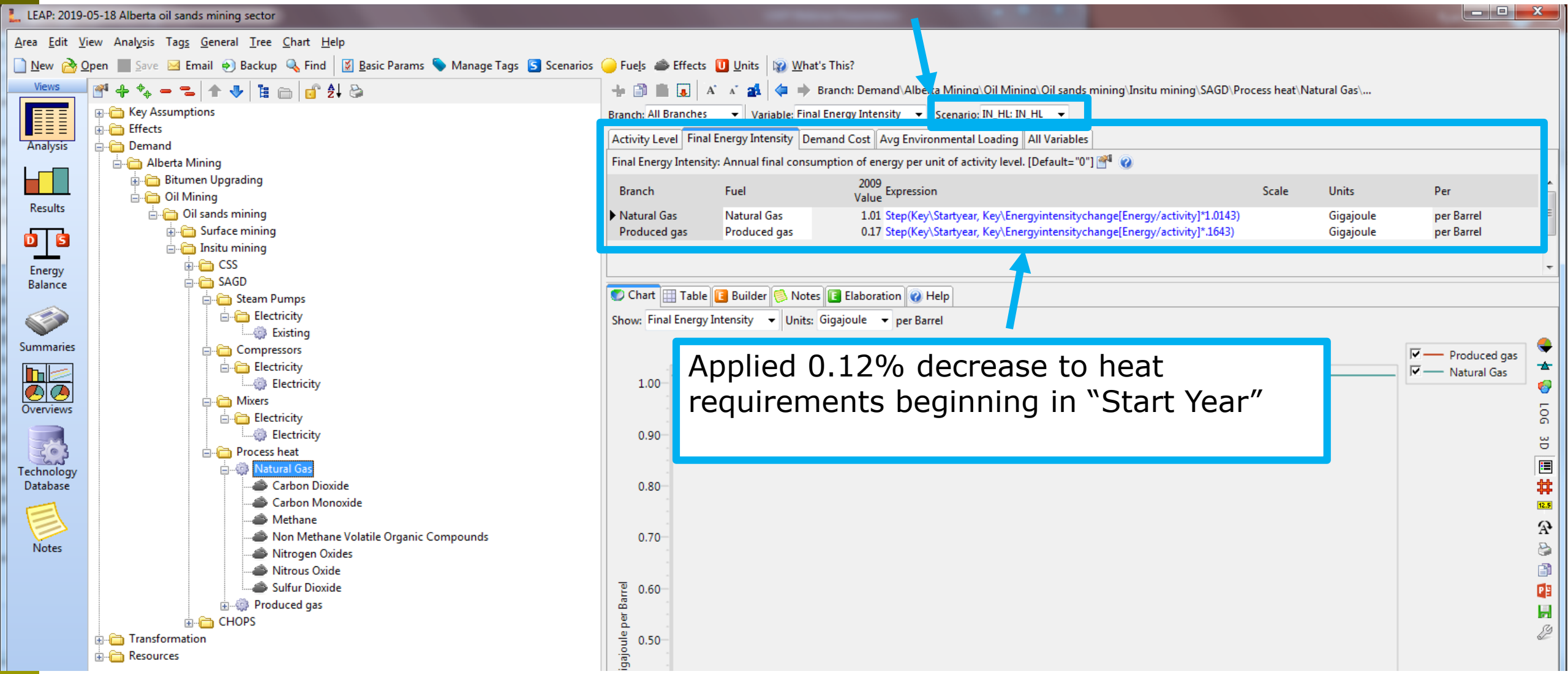
REFERENCE CASE – PROCESS HEAT ENVIRONMENTAL LOADING



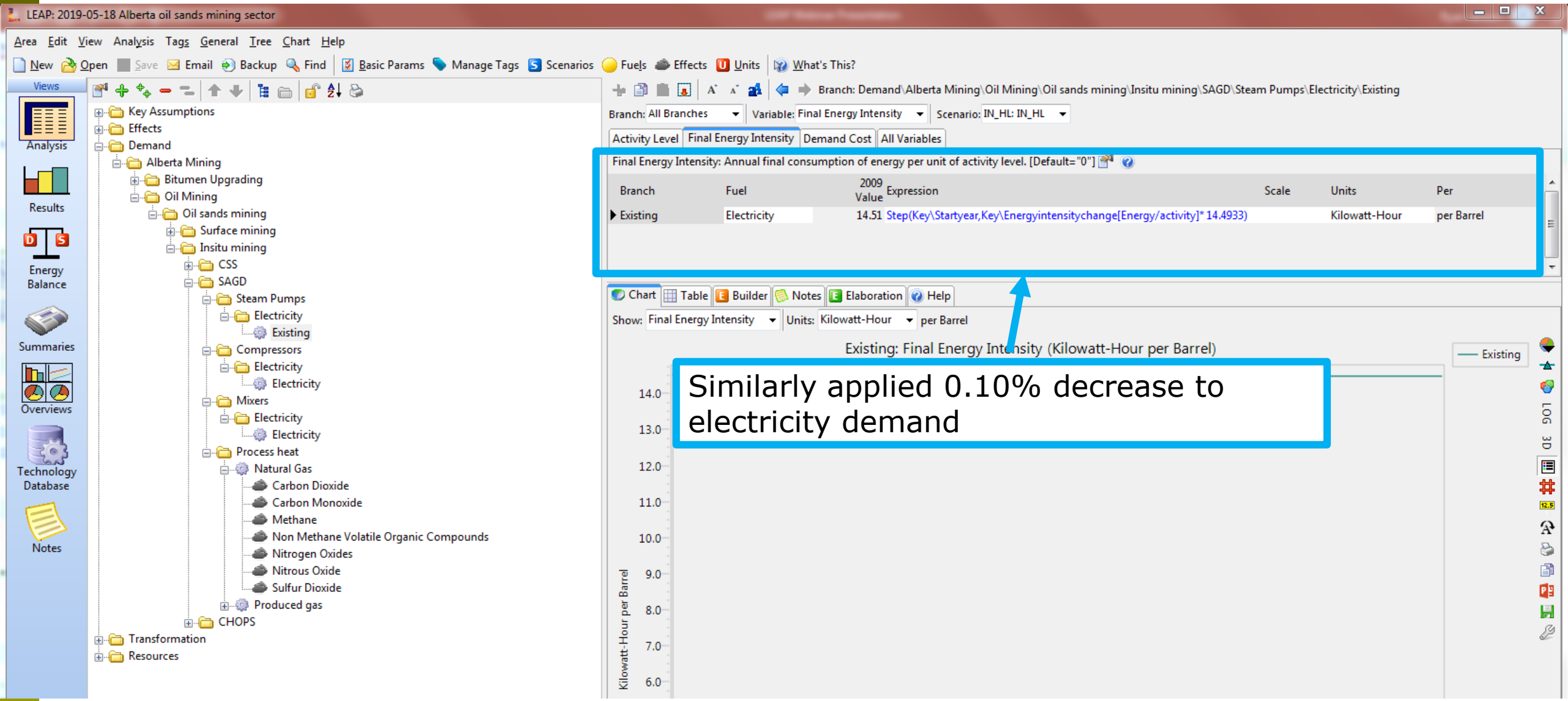
REFERENCE CASE – STEAM PUMP ENERGY INTENSITY



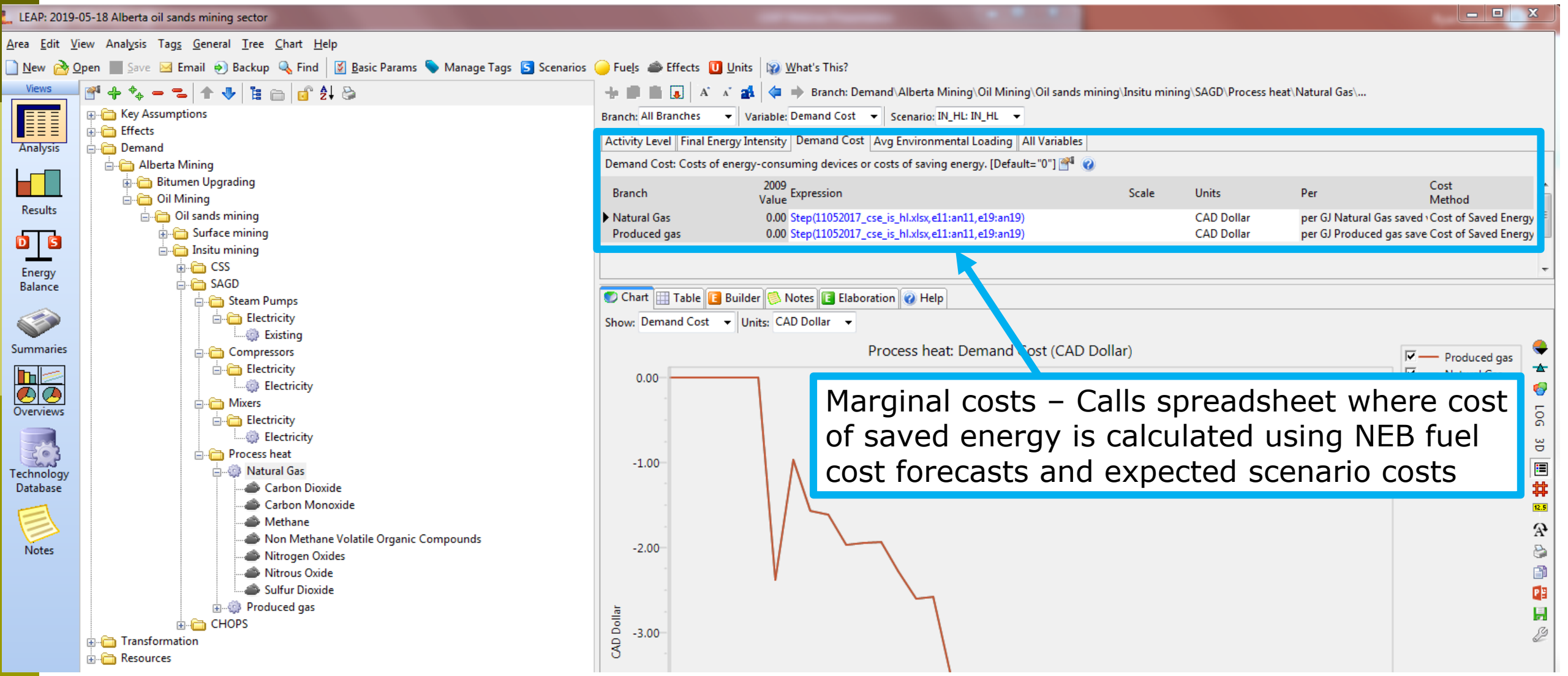
SCENARIO – PROCESS HEAT ENERGY INTENSITY



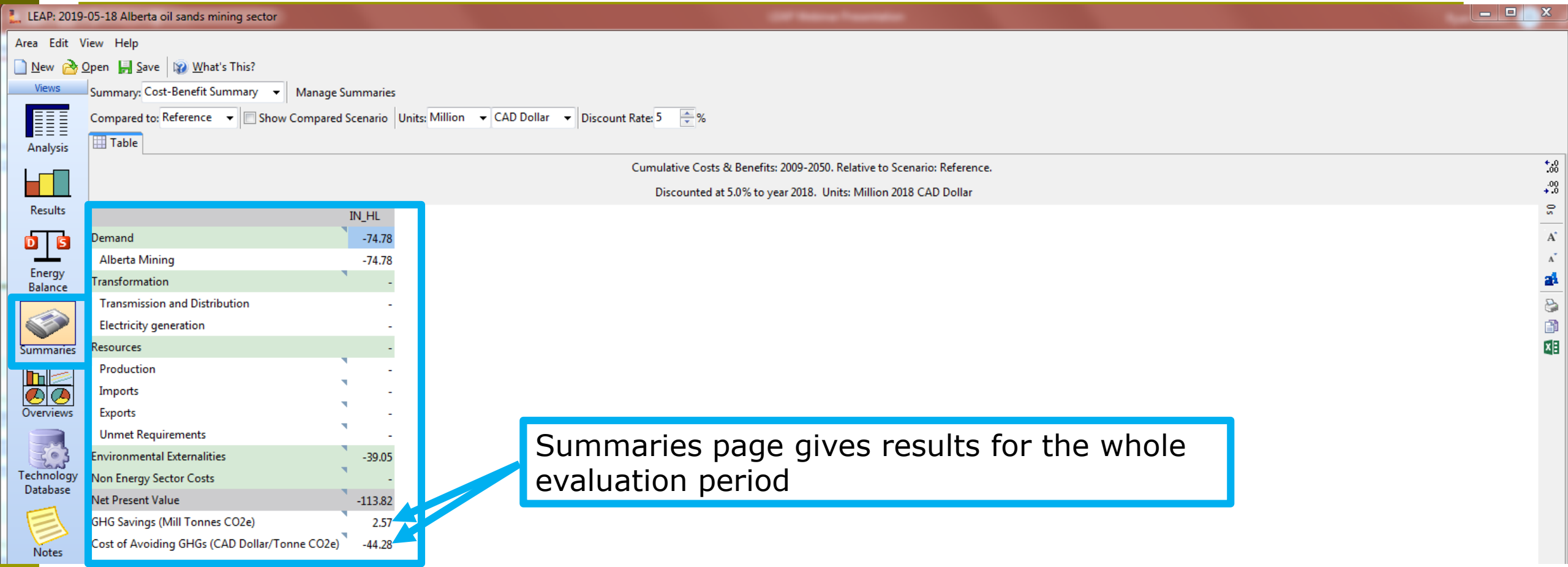
SCENARIO – STEAM PUMP ENERGY INTENSITY



SCENARIO – COST ANALYSIS

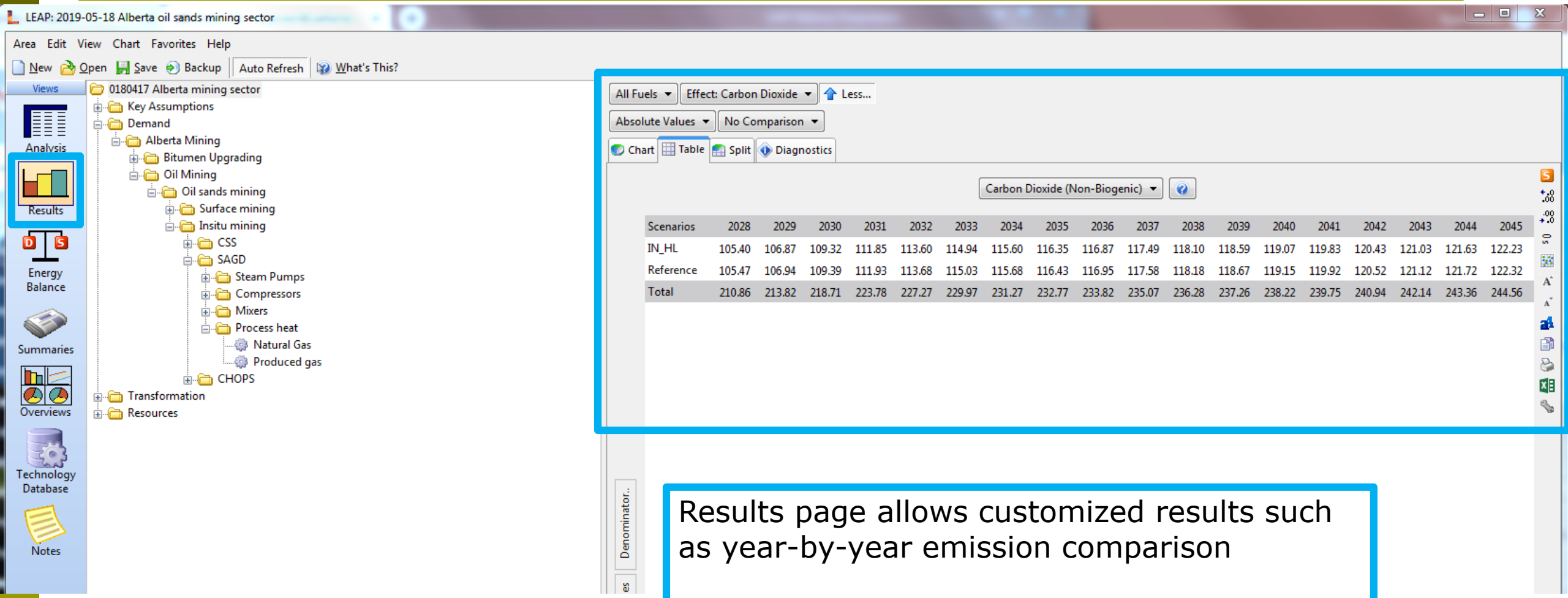


SCENARIO – RESULTS



Summaries page gives results for the whole evaluation period

SCENARIO – RESULTS



Scenarios	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
IN_HL	105.40	106.87	109.32	111.85	113.60	114.94	115.60	116.35	116.87	117.49	118.10	118.59	119.07	119.83	120.43	121.03	121.63	122.23
Reference	105.47	106.94	109.39	111.93	113.68	115.03	115.68	116.43	116.95	117.58	118.18	118.67	119.15	119.92	120.52	121.12	121.72	122.32
Total	210.86	213.82	218.71	223.78	227.27	229.97	231.27	232.77	233.82	235.07	236.28	237.26	238.22	239.75	240.94	242.14	243.36	244.56

Results page allows customized results such as year-by-year emission comparison

All results can be exported to Excel sheets for further analysis

RENEWABLE ENERGY SCENARIO

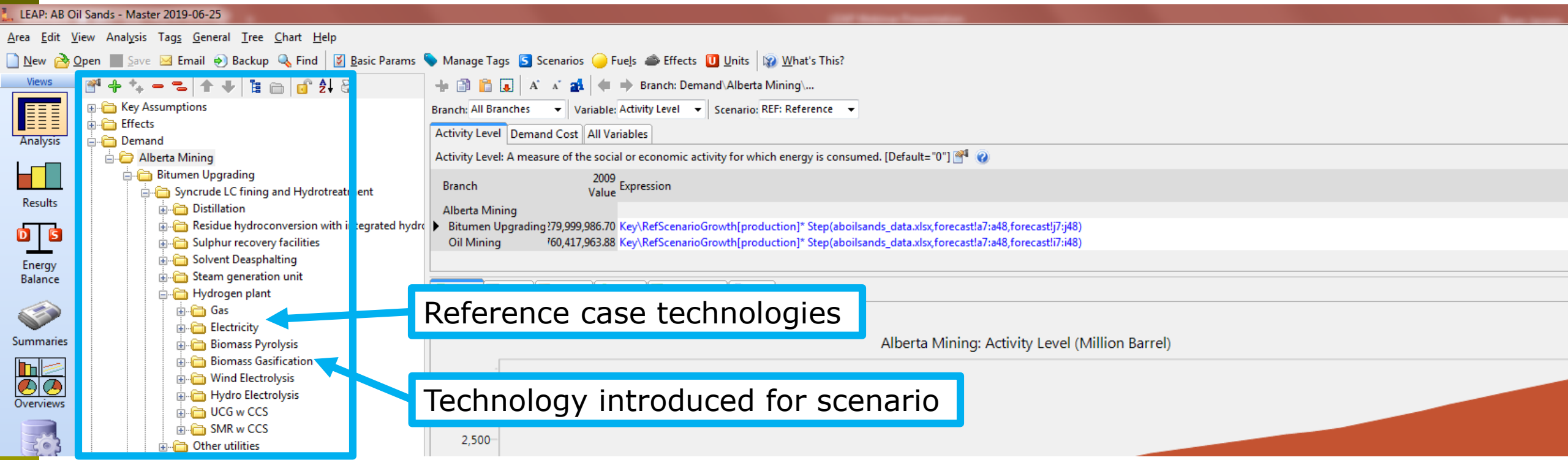
UPGRADING – BIOMASS GASIFICATION

- Investigating the opportunity to produce hydrogen for upgraders using gasification of biomass instead of methane with a steam methane reforming process.

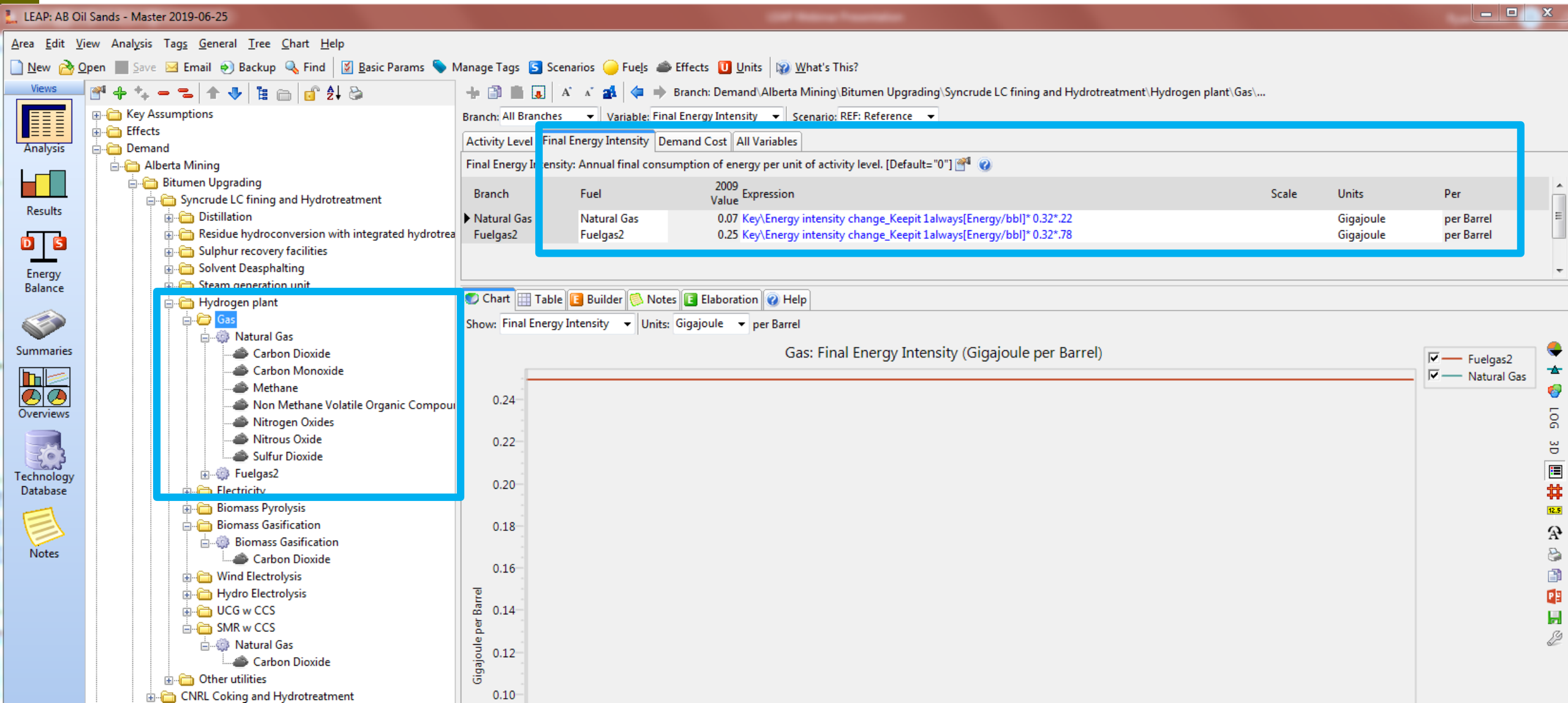
- Expected benefit
  - 86% reduction in GHG emissions
  - Accounts for energy required to collect, transport, and process biomass

- Expected cost
  - \$2.20/kg H_2 produced
  - Includes full 20-year lifetime cost (capex, opex, feedstock)

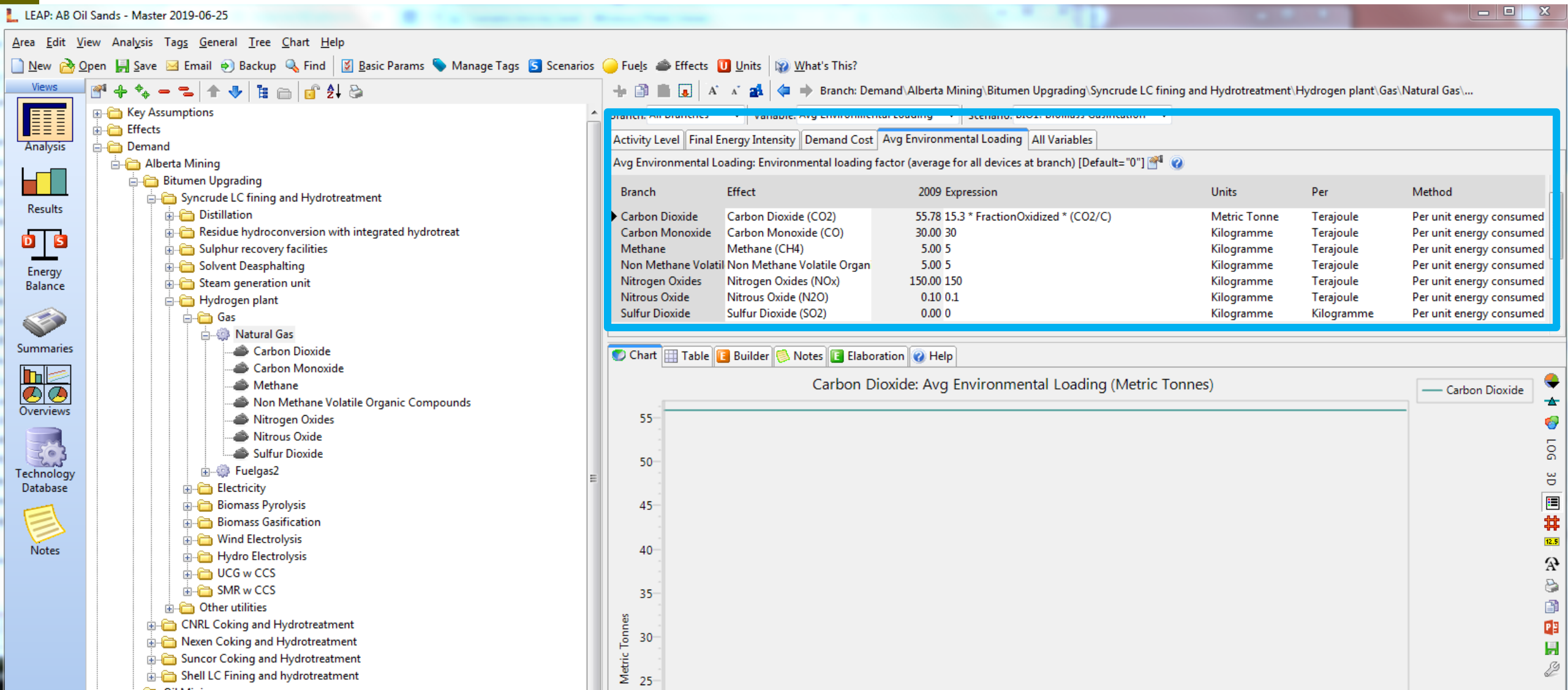
REFERENCE CASE – DEMAND TREE



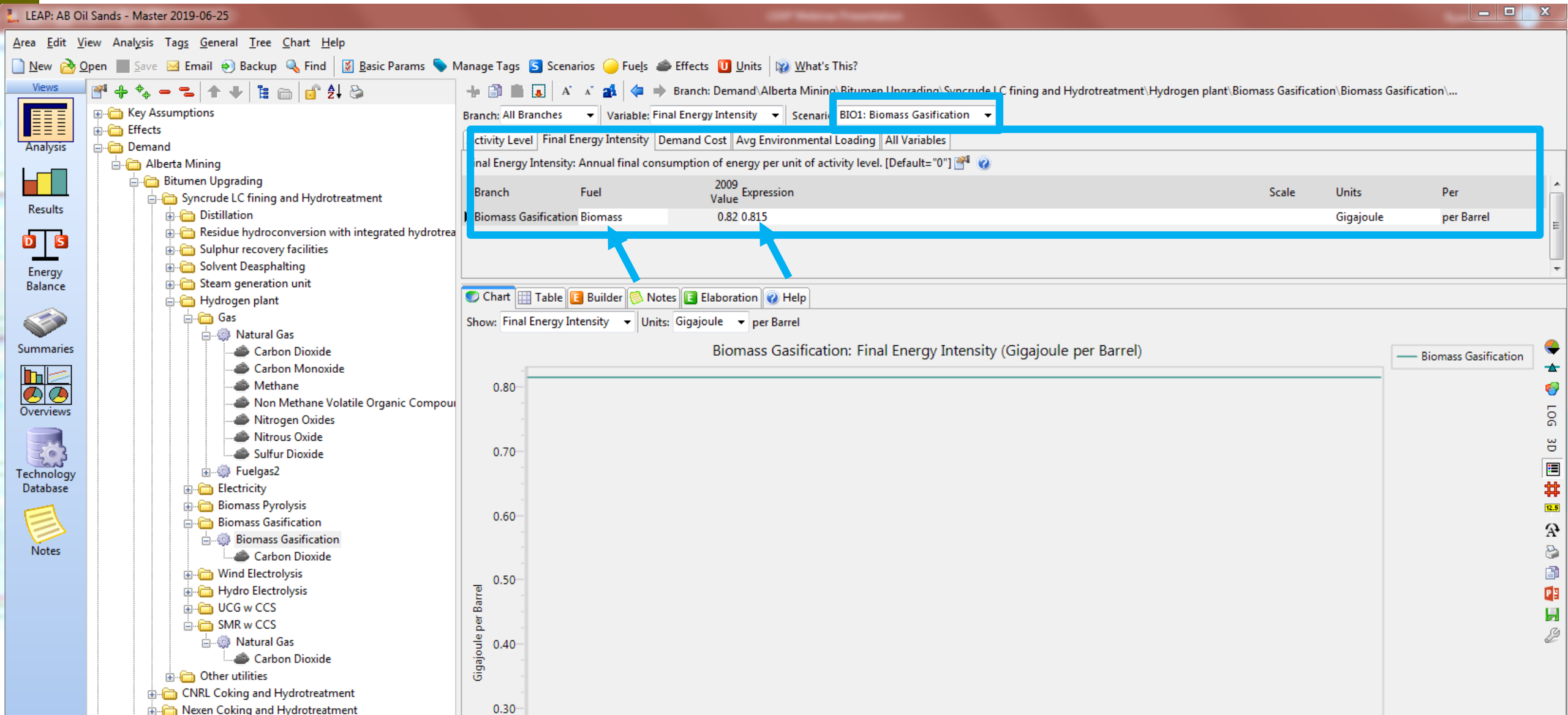
REFERENCE CASE – ENERGY INTENSITY



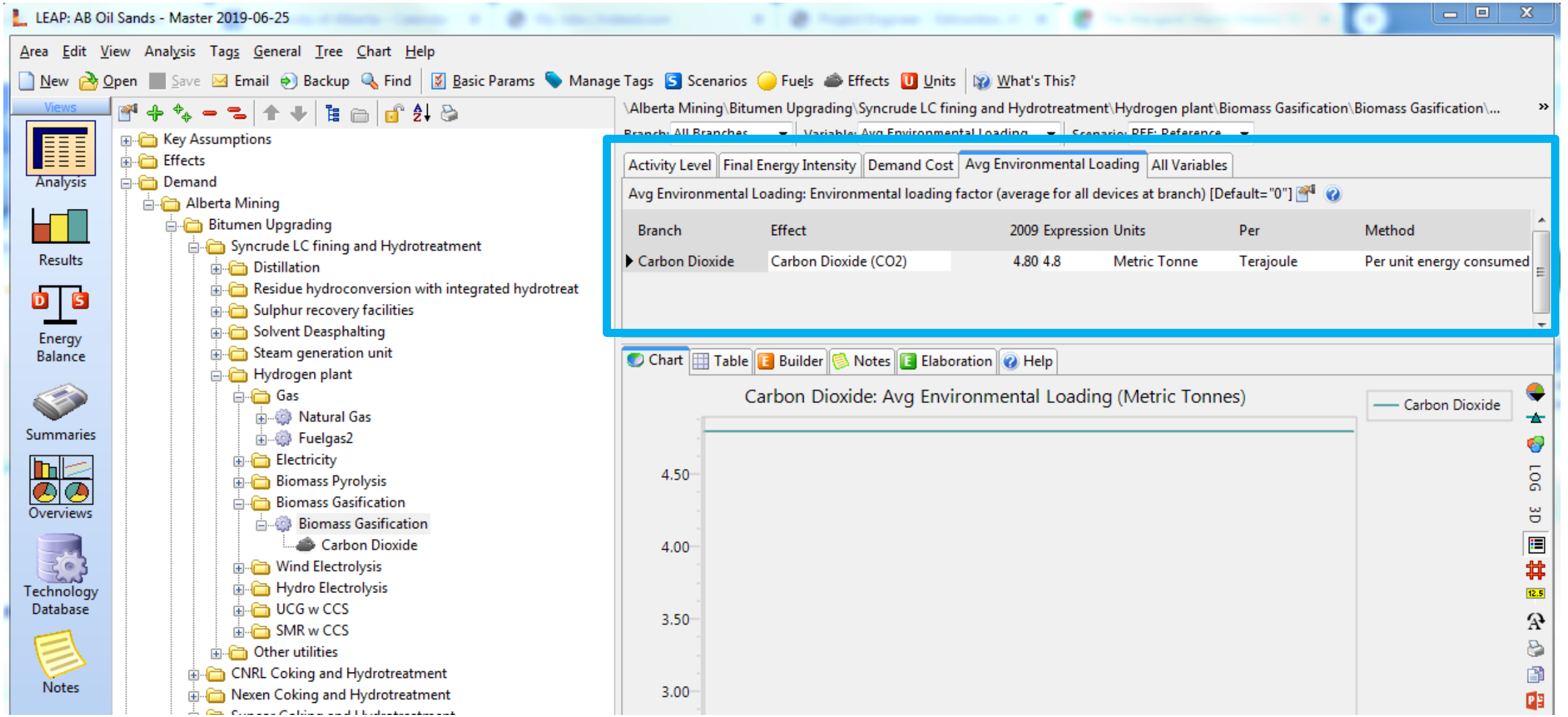
REFERENCE CASE –ENVIRONMENTAL LOADING



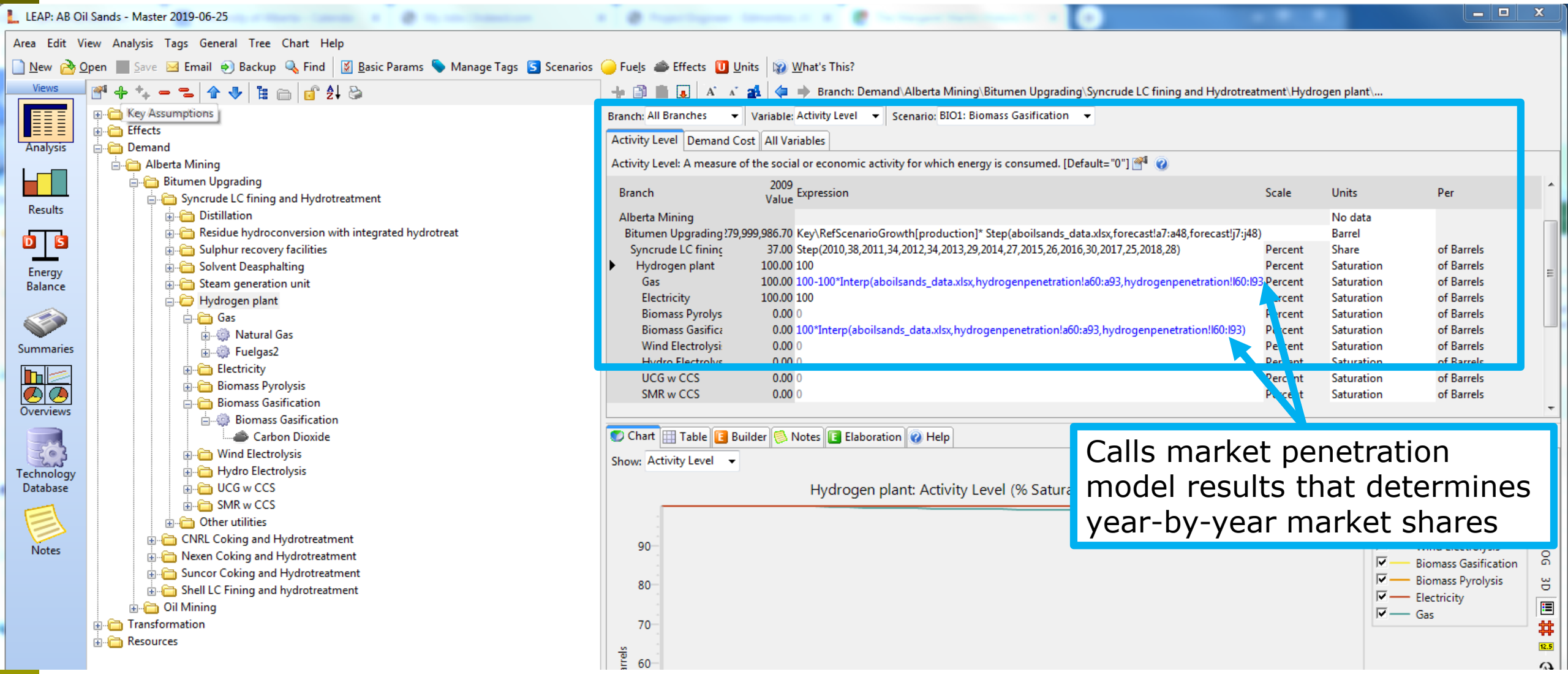
SCENARIO – ENERGY INTENSITY



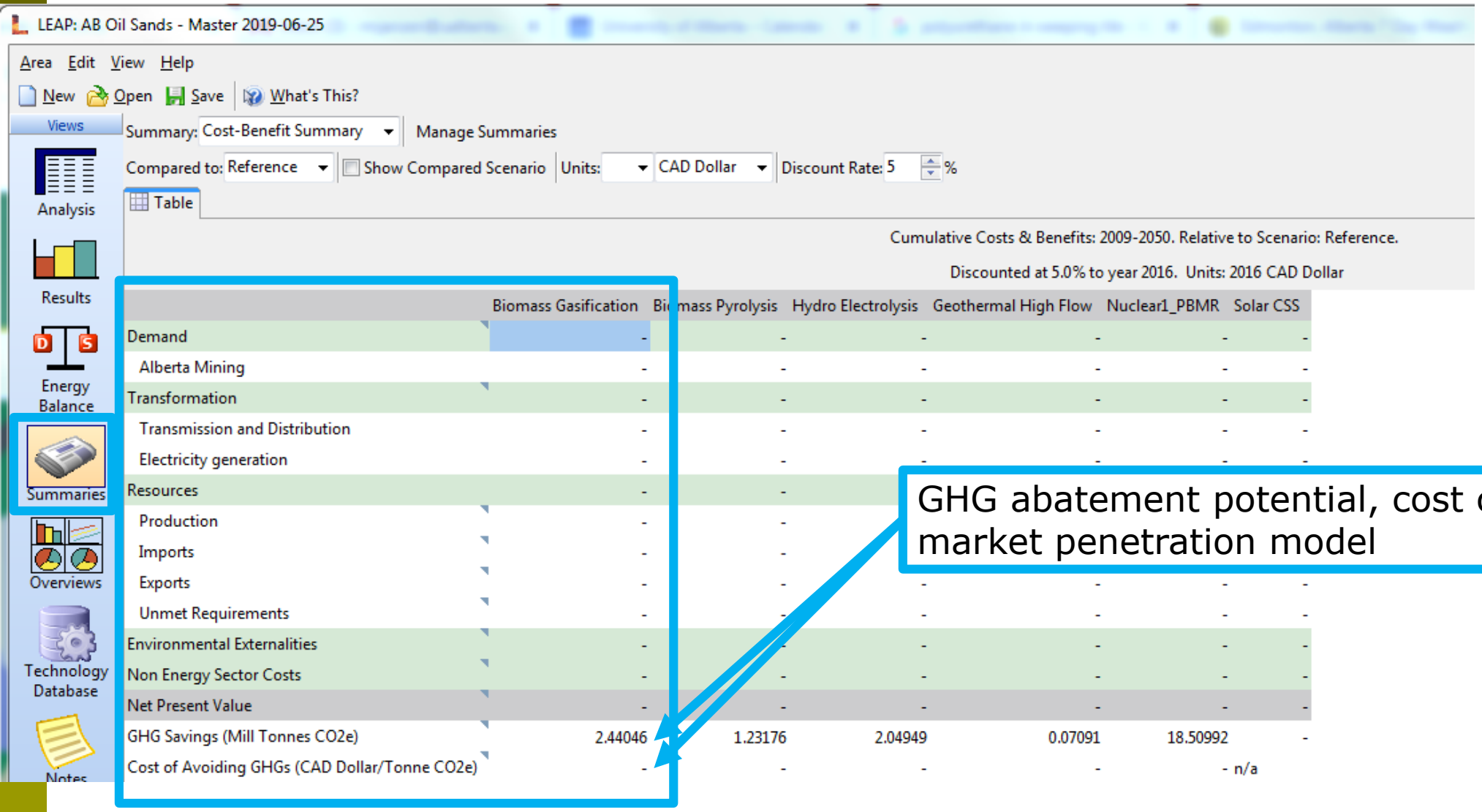
SCENARIO–ENVIRONMENTAL LOADING



SCENARIO–ACTIVITY LEVEL



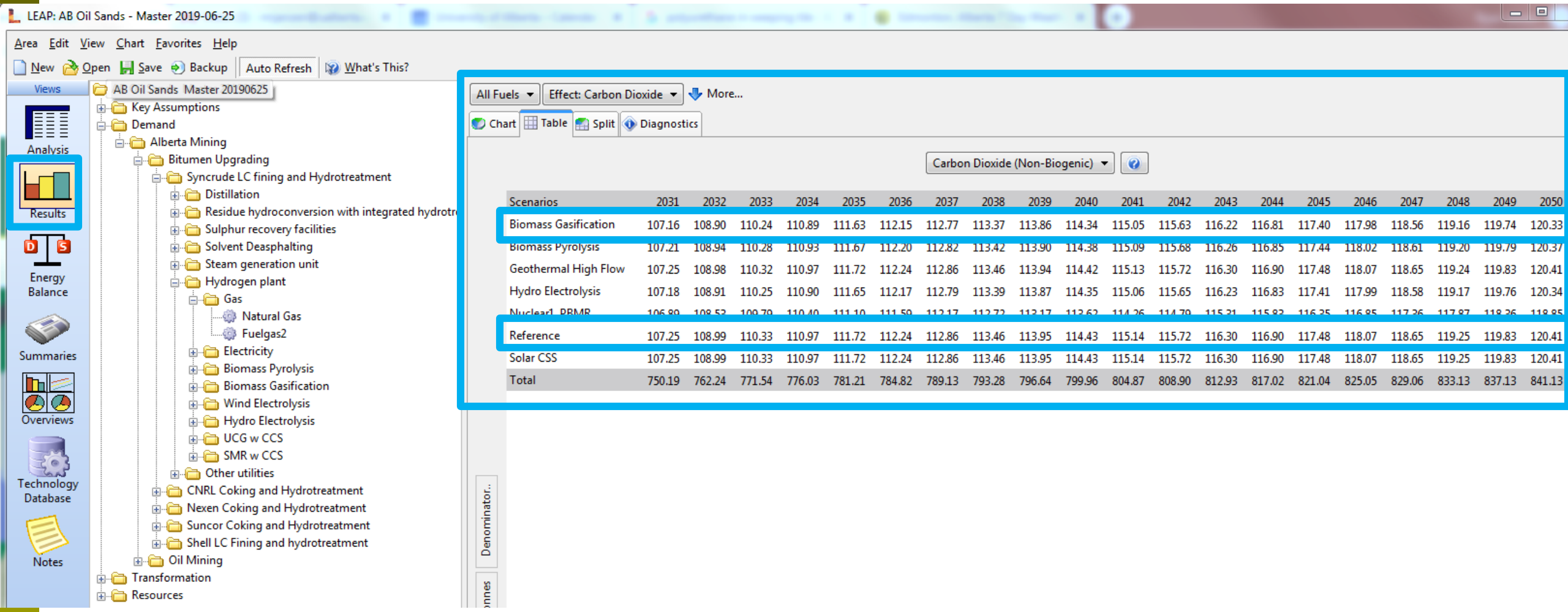
SCENARIO – RESULTS



	Biomass Gasification	Biomass Pyrolysis	Hydro Electrolysis	Geothermal High Flow	Nuclear1_PBMR	Solar CSS
Demand	-	-	-	-	-	-
Alberta Mining	-	-	-	-	-	-
Transformation	-	-	-	-	-	-
Transmission and Distribution	-	-	-	-	-	-
Electricity generation	-	-	-	-	-	-
Resources	-	-				
Production	-	-				
Imports	-	-				
Exports	-	-	-	-	-	-
Unmet Requirements	-	-	-	-	-	-
Environmental Externalities	-	-	-	-	-	-
Non Energy Sector Costs	-	-	-	-	-	-
Net Present Value	-	-	-	-	-	-
GHG Savings (Mill Tonnes CO2e)	2.44046	1.23176	2.04949	0.07091	18.50992	-
Cost of Avoiding GHGs (CAD Dollar/Tonne CO2e)	-	-	-	-	-	n/a

GHG abatement potential, cost calculated in market penetration model

SCENARIO – RESULTS



Scenarios	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Biomass Gasification	107.16	108.90	110.24	110.89	111.63	112.15	112.77	113.37	113.86	114.34	115.05	115.63	116.22	116.81	117.40	117.98	118.56	119.16	119.74	120.33
Biomass Pyrolysis	107.21	108.94	110.28	110.93	111.67	112.20	112.82	113.42	113.90	114.38	115.09	115.68	116.26	116.85	117.44	118.02	118.61	119.20	119.79	120.37
Geothermal High Flow	107.25	108.98	110.32	110.97	111.72	112.24	112.86	113.46	113.94	114.42	115.13	115.72	116.30	116.90	117.48	118.07	118.65	119.24	119.83	120.41
Hydro Electrolysis	107.18	108.91	110.25	110.90	111.65	112.17	112.79	113.39	113.87	114.35	115.06	115.65	116.23	116.83	117.41	117.99	118.58	119.17	119.76	120.34
Nuclear1_PBMR	106.89	108.53	109.79	110.40	111.10	111.59	112.17	112.72	113.17	113.62	114.26	114.79	115.31	115.83	116.25	116.85	117.26	117.87	118.26	118.85
Reference	107.25	108.99	110.33	110.97	111.72	112.24	112.86	113.46	113.95	114.43	115.14	115.72	116.30	116.90	117.48	118.07	118.65	119.25	119.83	120.41
Solar CSS	107.25	108.99	110.33	110.97	111.72	112.24	112.86	113.46	113.95	114.43	115.14	115.72	116.30	116.90	117.48	118.07	118.65	119.25	119.83	120.41
Total	750.19	762.24	771.54	776.03	781.21	784.82	789.13	793.28	796.64	799.96	804.87	808.90	812.93	817.02	821.04	825.05	829.06	833.13	837.13	841.13

LEAP SCENARIO ANALYSIS - SUMMARY

- LEAP always used to determine GHG abatement potential of new technologies
- Also used for cost comparisons and optimization scenarios
- Data can easily be exported for further analysis and comparison
- Easy to understand where results are coming from, simple to update, and relatively easy to test under different conditions

LIST OF OUR RESEARCH WITH LEAP

PUBLICATIONS, IN-REVIEW PAPERS

GHG mitigation assessments:

- Subramanyam V, Kumar A, Talaei A, Mondal MAH. Energy efficiency improvement opportunities and associated greenhouse gas abatement costs for the **residential sector**, *Energy,* 2017, 118: 795-807.
- Subramanyam V, Ahiduzzaman M, Kumar A. Greenhouse gas emissions mitigation potential in the **commercial and institutional sector**, *Energy and Buildings,* 2017, 140: 295-304.
- Bonyad M, Shafique HU, Mondal MAH, Subramanyam V, Kumar A, Ahiduzzaman M. Development of a framework for the assessment of energy demand-based greenhouse gas mitigation options for the **agriculture sector**, *Transactions of the ASABE,* 2018, 61:763.
- Talaei A, Ahiduzzaman M, Kumar A. Assessment of Long-term energy efficiency improvement and greenhouse gas emissions mitigation potentials in the **chemical sector**, *Energy,* 2018; 153: 231-47.
- Talaei A, Pier D, Iyer AV, Ahiduzzaman M, Kumar A. Assessment of long-term energy efficiency improvement and greenhouse gas emissions mitigation options for the **cement industry**, Energy, 2019, 170:1051-1066.
- Katta AK, Davis M, Subramanyam V, Dar AF, Mondal MAH, Ahiduzzaman M, Kumar A. Assessment of energy demand-based greenhouse gas mitigation options for Canada's **oil sands**, *Journal of Cleaner Production,* 2019, 241: 118306.
- Talaei A, Oni O, Ahiduzzaman M, Roychaudhuri PS, Rutherford J, Kumar A. Assessment of the impacts of process-level energy efficiency improvement on the greenhouse gas mitigation potential in the **petroleum refining sector**, *Energy*, In Press, 2019.
- Talaei A, Ahiduzzaman M, Kumar A. Potential for energy efficiency improvement and greenhouse gas mitigation from Canada's **iron and steel industry**, 2019*. (in review)*
- Katta AK, Davis M, Kumar A. Assessment of greenhouse gas mitigation options for the **iron, gold, and potash mining sectors**, 2019. (in review)

Energy assessments:

- Subramanyam V, Paramshivan D, Kumar A, Mondal MAH. **Using Sankey diagrams to map energy flow** from primary fuel to end use, *Energy Conversion and Management*, 2015, 91: 342-52.
- Davis M, Ahiduzzaman M, Kumar A. How will **Canada's greenhouse gas emissions change by 2050**? A disaggregated analysis of past and future greenhouse gas emissions using bottom-up energy modelling and Sankey diagrams*, Applied Energy*, 2018, 220: 754-86.
- Davis M, Ahiduzzaman M, Kumar A. **Mapping Canadian energy flow** from primary fuel to end use, *Energy Conversion and Management*, 2018, 156: 178-91.
- Davis M, Ahiduzzaman M, Kumar A. How to model a complex national energy system? **Developing an integrated energy systems framework for long-term energy and emissions analysis**, *International Journal of Global Warming, 2019, Vol. 17, No. 1*.
- Katta AK, Davis M, Kumar A. Development of disaggregated energy use and greenhouse gas emission footprints in **Canada's iron, gold, and potash mining sectors**, *Resources, Conservation and Recycling,* In Press, 2019.

CURRENT WORK

- GHG mitigation assessments
  - Pulp and paper sector of Alberta
  - Pulp and paper sector of Canada
  - Electricity generation scenario analysis for Alberta
  - Assessment of oil sands GHG reduction options – renewables, CCUS, cogeneration, nuclear, electrification, and emerging technologies
  - Crude oil pipelines
- Water use impacts
  - Future water use scenarios in Alberta
  - Canadian electricity generation
  - Oil and gas water footprints in Canada

ACKNOWLEDGMENTS

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We are also grateful to representatives from Alberta Innovates, Suncor Energy Inc., Cenovus Energy Inc., Natural Resources Canada, and Environment and Climate Change Canada for their valuable inputs and comments in various forms.

As a part of the University of Alberta's Future Energy Systems (FES) research initiative, this research was made possible in part thanks to funding from the Canada First Research Excellence Fund (CFREF).

Thank you/Questions

For further information:

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NSERC/Cenovus/Alberta Innovates Industrial Research Chair in Energy and Environmental Systems Engineering

Cenovus Energy Endowed Chair in Environmental Engineering

Deputy Director – Future Energy Systems

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E-mail: **Amit.Kumar@ualberta.ca**
Website: **www.energysystems.ualberta.ca**