CGE TRAINING MATERIALS – MITIGATION ASSESSMENT

MODULE E

Mitigation Analysis: Methods and Tools

Module Objectives and Expectations

1. **Objective:** To introduce different approaches for greenhouse gas (GHG) mitigation assessment including:

   – Reviewing the benefits and drawbacks of different approaches

   – Introducing software tools that may be useful for GHG mitigation analysis

   – Providing participants with information to help them choose an appropriate tool for their own assessments.

2. **Expectations:** Participants will have a broad but sound understanding of the key quantitative tools and methods available for GHG mitigation assessment including both integrated and sector-specific modelling tools.

   – NB: This module does not provide in-depth training in the use of any one tool

   – Separate training will likely be required for any tools selected.

Module Outline

1. Selecting an Assessment Approach

2. Energy Sector Methods and Tools for Mitigation Assessment

3. Examples of Energy Sector Modelling Tools

    – Integrated tools

    – Sector-specific tools

4. GHG Mitigation Assessment in Non-Energy Sectors

5. Examples of Non-Energy Sector Modelling Tools

6. Conclusions

Some Background…

Decision 17/CP.8, paragraph 38:

- Based on national circumstances, non-Annex(**NAI) Parties are encouraged to use whatever methods are available and appropriate** in order to formulate and prioritize programmes containing measures to mitigate climate change and that this should be done within the framework of sustainable development objectives, which should include social, economic and environmental factors.

Source: UNFCCC (2002)

MODULE E1

Selecting an Assessment Approach

What Methods are Appropriate?

- Will vary by country: many policy analysis frameworks available

- Qualitative and quantitative approaches can be used

- Most involve evaluation against a series of agreed objectives or criteria

- Can help prioritize and inform mitigation programmes

- Can be highly process-oriented with structured input from a variety of stakeholders.

- This module focuses mainly on quantitative approaches
  - See Chapters2, 3 and 13 of IPCC WG III

Mitigation Assessments

- Used to assess the scale and timing of emissions reductions, as well as financial, economic and other impacts of mitigation strategies

- Can be based on:

  - Spreadsheets, cost curves

  - Formal modeling tools (some described here)

  - Nationally developed models or tools

  - Independent consulting.

Issues in Mitigation Assessment

- Success depends less on the sophistication of models and more on the care, rigour, consistency and data quality underpinning the analysis itself.

- Consider who will undertake the analysis. Consultants provide a ready source of expertise, but this approach may do little to build capabilities within a country.

- Simple assessments where data is lacking may be sufficient: can help focus and prioritize future data collection efforts.

- Even the simplest formal models require many months and a good level of expertise.

- Don't expect modelling to be done only by analysts: requires ongoing training and strong guidance from experienced local experts.

- Ideally set up a permanent team responsible for mitigation modelling to ensure continuity of expertise.

- Strong and coordinated team needed: economists, engineers, energy and industrial engineers, agriculture and land-use change and forestry (LULUCF) experts, as appropriate.

- Close coordination with the team working on GHG inventories is critical.

MODULE E2

Methods and Tools for Mitigation Assessment in the Energy Sector

Models for Mitigation Analysis in the UNFCCC Context

- UNFCCC Guidelines do not specify which approach is best for national communications on mitigation.

- Both **Top-down** and **Bottom-up** models can yield useful complementary insights on mitigation:

  - Top-down models are most useful for studying broad macroeconomic and fiscal policies for mitigation such as carbon or other environmental taxes

  - Bottom-up models are most useful for studying options that have specific sectoral and technological implications.

Top-Down Models

- Top-down models generally rely on aggregated data and various types of macroeconomic/econometric modelling methods.

- Consumption trends forecast into future using historical trends or aggregate econometric relationships (GDP, fuel prices, etc.).

- Able to capture impacts of fiscal policies (e.g. carbon tax).

- Rely upon having good historical time-series data.

- May not be well-suited to long-range assessments since the exogenous variables (e.g. prices) are themselves poorly known in the long run.

- Not well suited for examining technology-specific issues because their structure is too abstract to capture technology trends in detail.

Types of Top-Down Models

- **CGE** (Computational General Equilibrium) models use economic data to estimate how an economy will respond to changes in policies, technologies and prices. Assumes economies approach or reach equilibrium status.

- **I/O** (Input/Output) models focus on interdependencies between different sectors of an economy. Often assume static economic structures.

- **Other Macroeconomic Models**

- **Integrated Assessment Models**: Tend to be based on physical/technological descriptions of systems and their interconnections (energy, water, land, agriculture, forestry, food, etc.). Examples include IMAGE (PBL) and PoleStar (SEI).

- Most top-down models are global in scope or specific to a particular country.

- Few are easily adaptable for use by developing countries.

Top-down → CGE

Top-down → Input-Output

Top-down → Other Macro Models

Top-down → Integrated Assessment Models
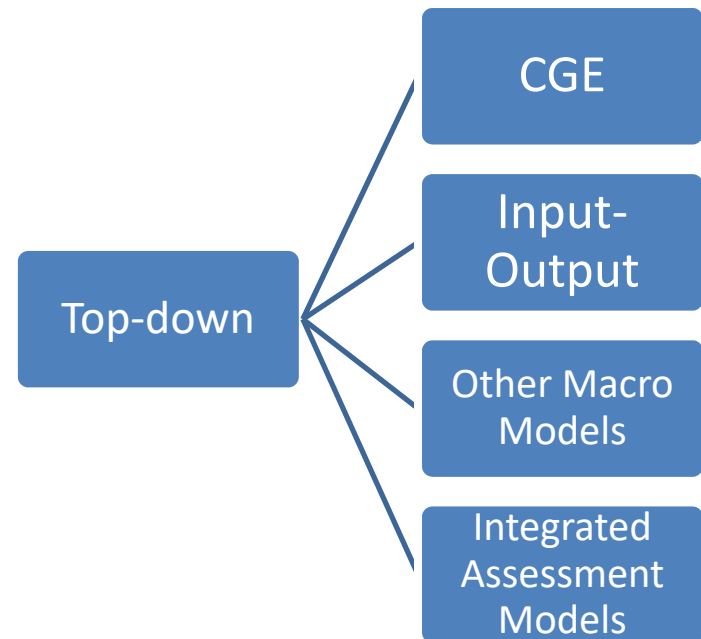
Bottom-Up Models

- Based on detailed physical accounting of system.

- Provide a more fundamental understanding of how systems behave and may evolve into the future, so well suited for examining potential long-term transitions.

- **Integrated Models** (for an entire country):

  - Tend to trade breadth for depth

  - Allow for modelling of interactions between sectors.

- **Sector-specific Models:**

  - Provide informed inputs into integrated models

  - Can be used on their own to evaluate high-emitting/ key sectors

Types of Bottom-Up Models

- **Optimization**: Use mathematical programming to identify configurations of energy systems that minimize the total cost of providing services.

  Examples: MARKAL/TIMES, LEAP, ~~MESSAGE~~

- **Simulation**: Simulate behaviour of consumers and producers under various signals (e.g. price, income levels) and constraints (e.g. limits on rate of stock replacement).

  Examples: ENPEP-BALANCE

- **Accounting Frameworks**: Account for physical stocks and flows in systems based primarily on engineering relationships and explicit assumptions about the future (e.g. technology improvements, market penetration rates).

  Examples: LEAP, MAED

- **Technology Screening**: Focus on how a particular technology (or set of technologies) will perform under certain constraints and can track associated costs and emissions.

  Examples: RETScreen, HOMER.

Bottom-up → Optimization, Simulation, Accounting, Technology Screening
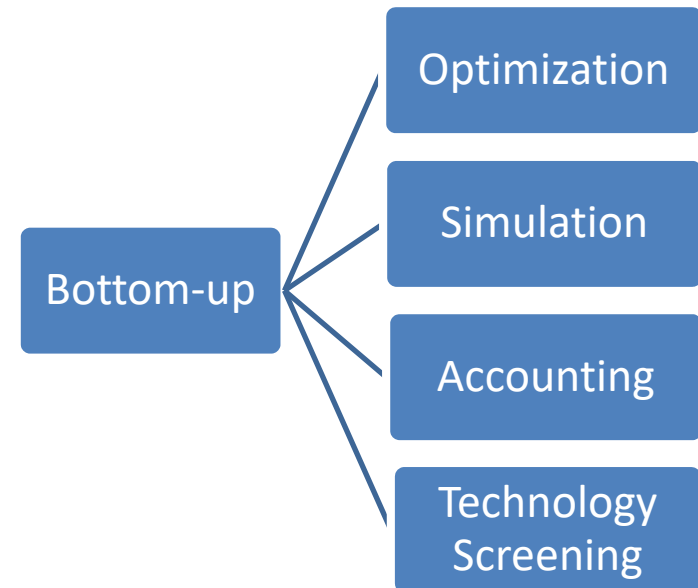
MODULE E3

Examples of Energy Sector Modeling Tools

Criteria for Inclusion of Tools in this Review

To be included, tools must be:

1. Widely applied in a variety of international settings

2. Thoroughly tested and generally found to be credible

3. Actively developed and preferably professionally supported

4. Primarily designed for GHG mitigation assessment at the national level (not global models and not models designed for a specific country).

Tools Included

- Integrated Tools
    a) ENPEP-BALANCE
    b) LEAP
    c) MARKAL/TIMES
    d) IAEA Tools (MAED)
    e) Sector-specific Tools
    f) HOMER Pro and HOMER Grid
    g) RETScreen
    h) Various Transport Models: ITDP, ICCT, GREET
    i) Various Forestry and Land Use Models
    j) Various Agriculture Models

SEI

MODULE E3A

Integrated Tools

ENPEP-BALANCE

- Energy system structure
- Base year energy flows and prices
- Energy demand and growth projections
- Technical and policy constraints

ENPEP-BALANCE

- The intersection of supply and demand curves for all energy supply forms and all energy uses in the energy network

- **Description** : A market-based simulation of the energy sector that determines how various consumers and producers may respond to changes in energy prices and other signals. Also calculates emissions of GHGs and local air pollutants.

- **Developer**: Argonne National Laboratory (ANL)

- **Licensing**: Free

- **Website:** https://ceeesa.es.anl.gov/projects/Enpepwin.html

ENPEP-BALANCE User Interface
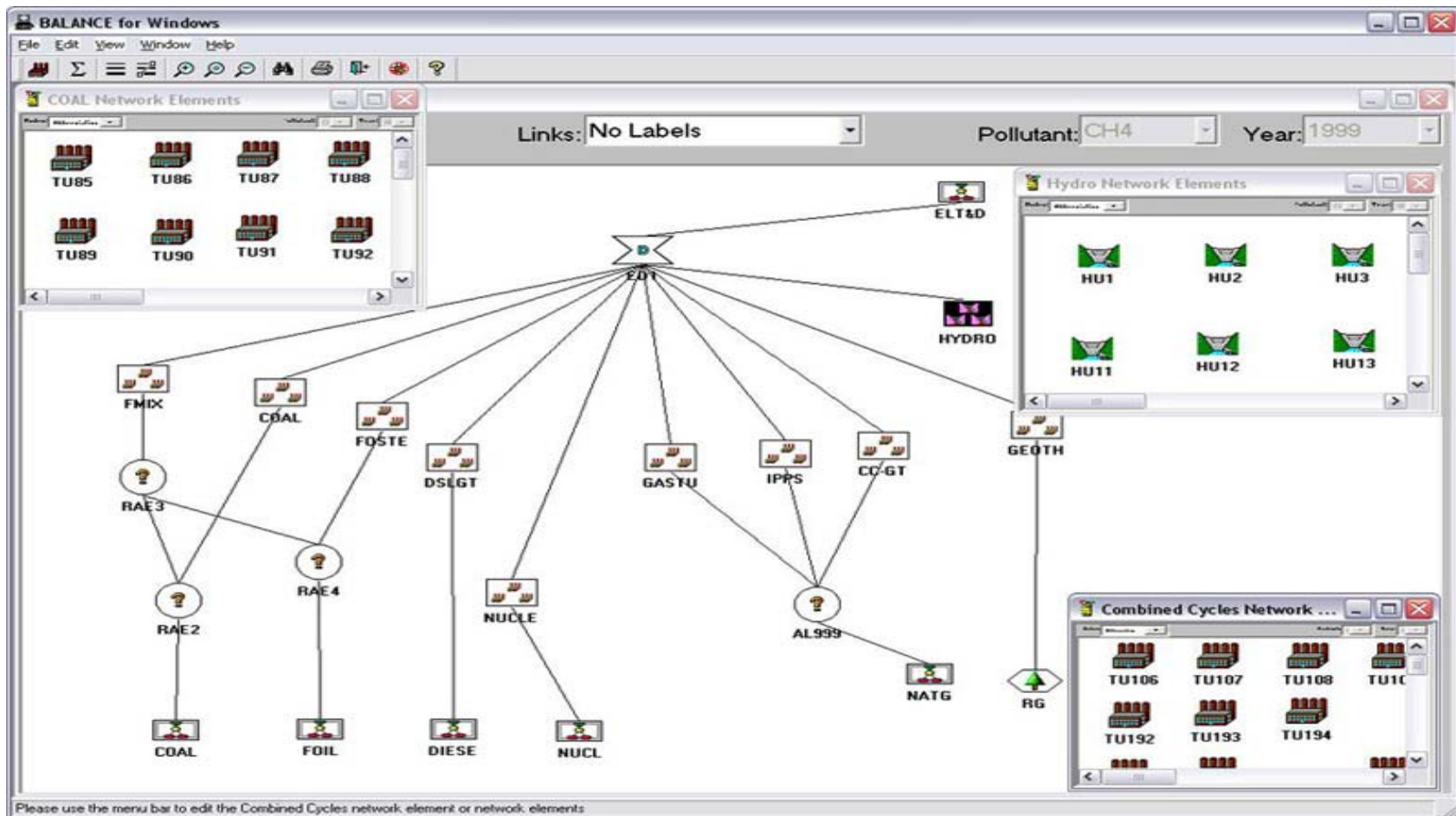
LEAP: Long-range Energy Alternatives Planning System

Inputs:
- Macroeconomic data
- Demographic data
- Historical energy data (e.g. energy balances)
- Energy and activity assumptions for baseline and mitigation scenario(s)
- Costs
- Non-energy data

→ **LEAP** →

Outputs:
- Demand-driven energy system results
- Emissions by source, year and scenario
- Energy and emissions reductions related to baseline scenario(s)
- Cost-benefit analysis

- **Description:** Accounting and optimization model covering energy demand and energy supply. Can be used to examine both GHGs and local air pollutants from the energy sector as well as non-energy sector sources and sinks.

- **Developer**: Stockholm Environment Institute

- **Licensing**: Free for government, academic and NGOs in developing countries and free for students in any country.

- **Contact**: Dr. Charles Heaps – leap@sei-us.org

- **Website**: https://www.sei.org/featured/leap-2020-major-upgrade-for-low-emissions-analysis-tool/

SEI

Important disclosure: The author of these training materials, SEI, is also the developer of LEAP.

LEAP Structure and Calculation Flows

22
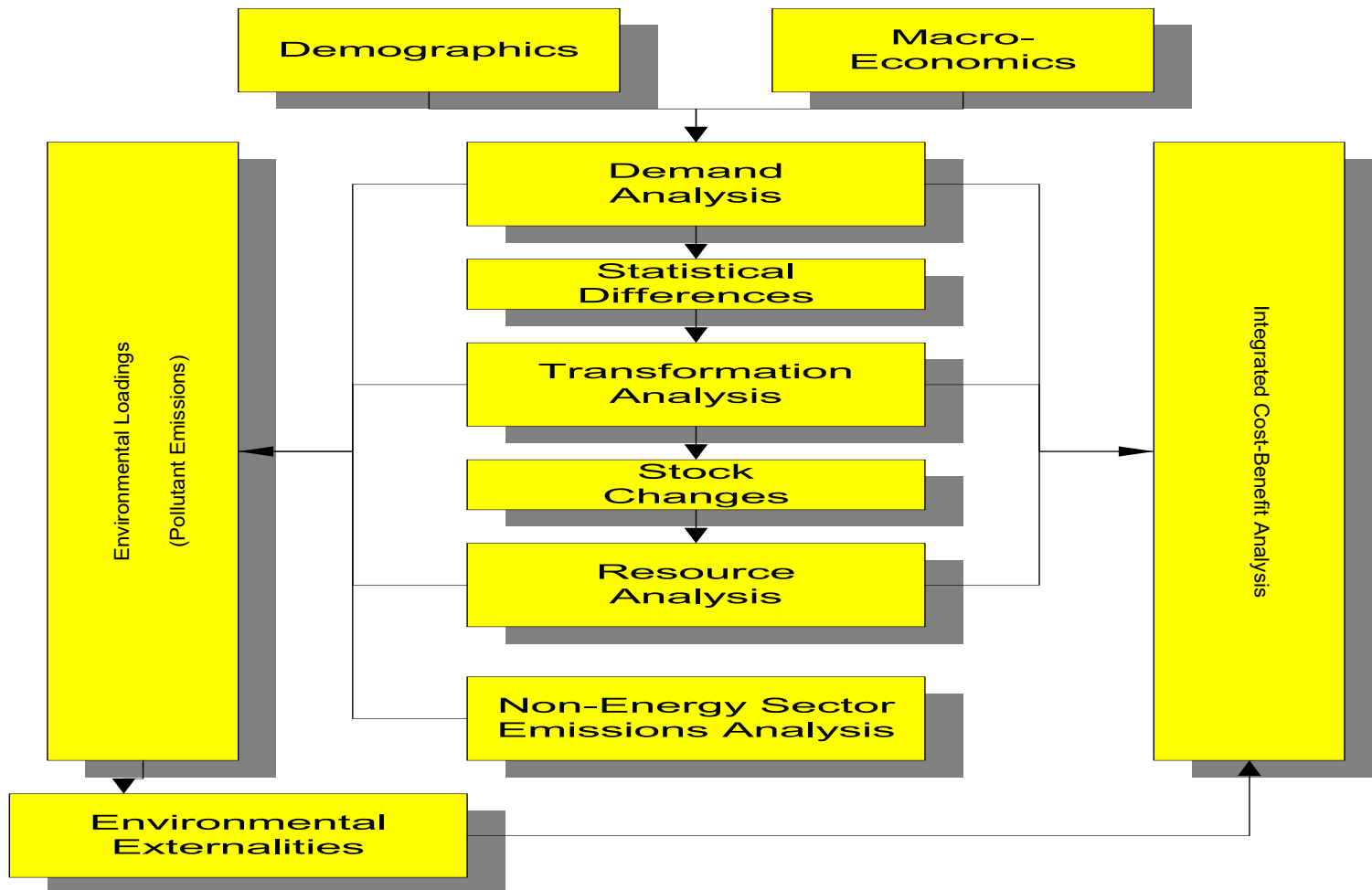
LEAP User Interface

The main menu and toolbar give access to major options.

Data is organized in a tree.

Select scenarios here.

Edit data by typing here.

Switch between views of the Area here.
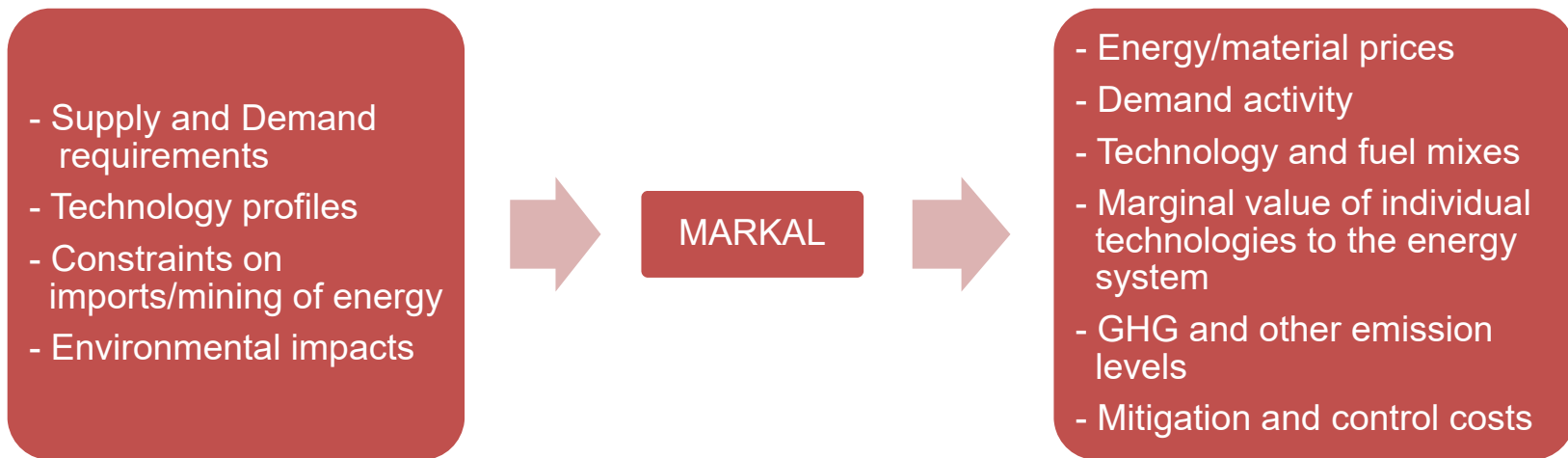
Select units and scaling factors here.

The status bar notes the current Area and View.

Data can be reviewed in chart or table format.

MARKAL/TIMES

```
┌─────────────────────────┐          ┌──────────┐          ┌─────────────────────────┐
│ - Supply and Demand     │          │  MARKAL  │          │ - Energy/material prices │
│   requirements          │  ──▶     │          │  ──▶     │ - Demand activity        │
│ - Technology profiles   │          └──────────┘          │ - Technology and fuel    │
│ - Constraints on        │                                │   mixes                  │
│   imports/mining of     │                                │ - Marginal value of     │
│   energy                │                                │   individual             │
│ - Environmental impacts │                                │   technologies to the   │
│                         │                                │   energy system         │
│                         │                                │ - GHG and other         │
│                         │                                │   emission levels       │
│                         │                                │ - Mitigation and        │
│                         │                                │   control costs         │
└─────────────────────────┘                                └─────────────────────────┘
```

- **Description** : An optimization-based model of energy systems that can also be used to calculate emissions of GHGs and local air pollutants. TIMES (The Integrated MARKAL-EFOM System) is gradually expected to replace MARKAL.

- **Developer**: International Energy Agency, Energy Technology Systems Analysis Programme (IEA/ETSAP)

- **Website**: https://iea-etsap.org/index.php/etsap-tools

The ANSWER User Interface for MARKAL

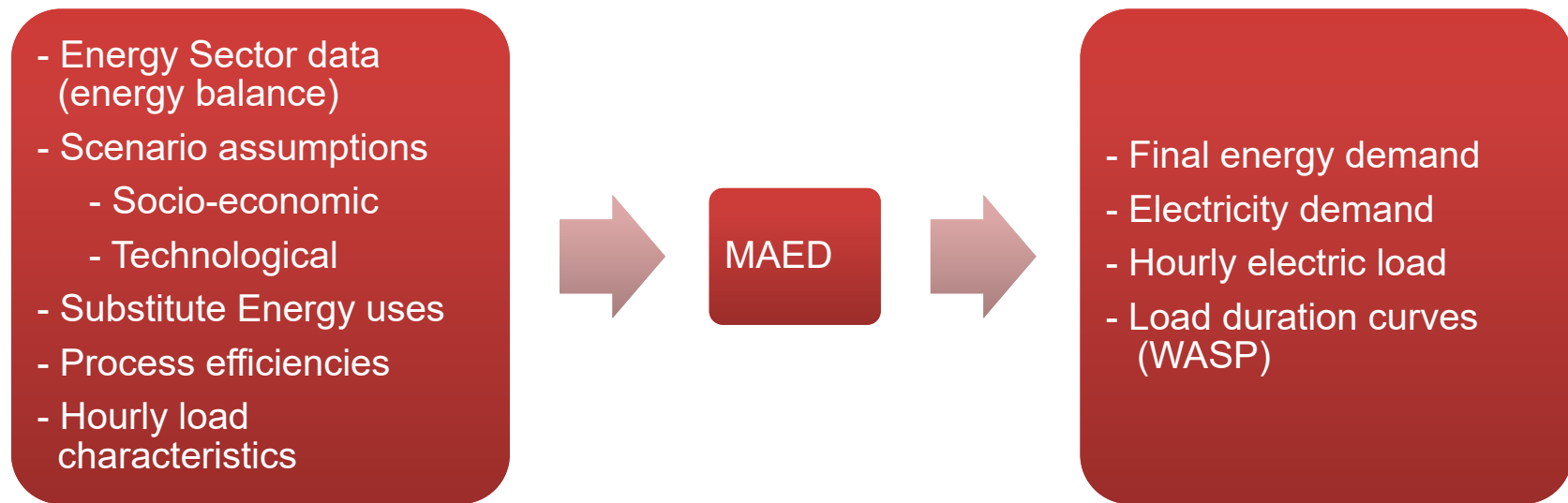Most MARKAL users work with Answer or Veda user interfaces.

IAEA Energy Modelling Tools

- IAEA Modelling Suite:
  - MAED (for energy demand)
  - MESSAGE for supply optimization
  - SIMPACTS: Simplified approach for estimating impacts of electricity generation
  - FINPLAN: Model for financial analysis of electric sector expansion plans
- **Developer**: International Atomic Energy Agency
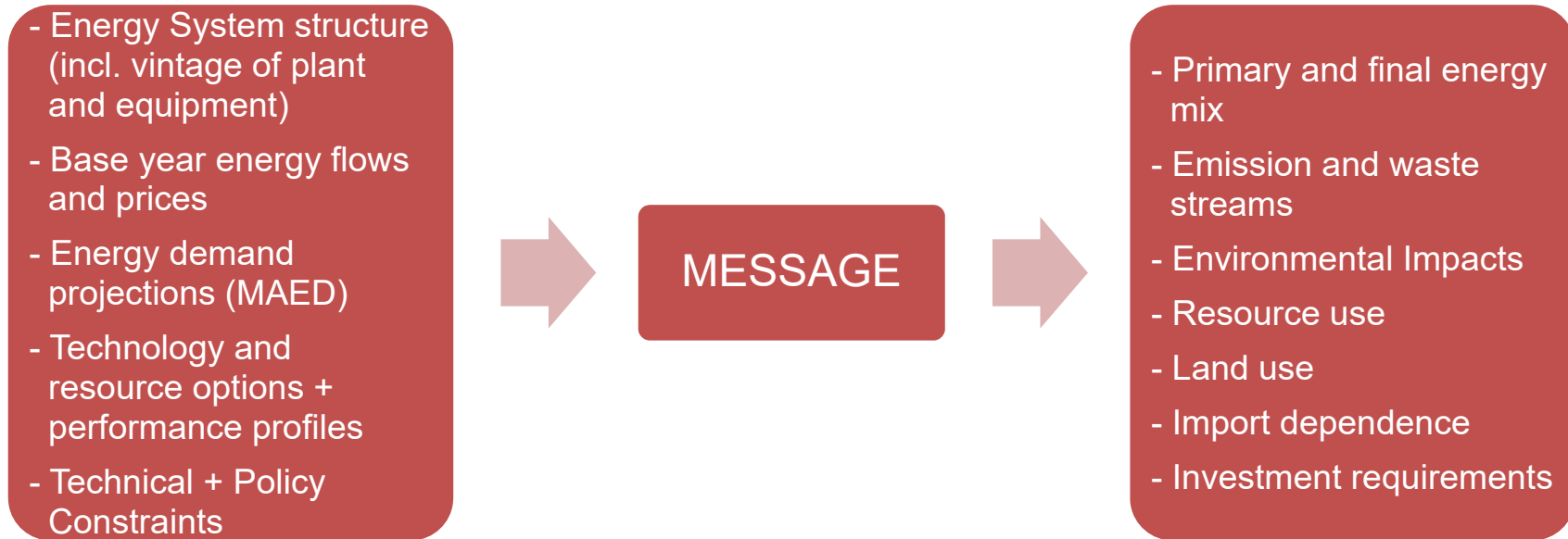- **Licensing**: Free: available to IAEA partner governments.
- **Website**: https://www.iaea.org/topics/energy-planning/energy-modelling-tools

IAEA-MAED

Input		Output

- Energy Sector data (energy balance)
- Scenario assumptions
   - Socio-economic
   - Technological
- Substitute Energy uses
- Process efficiencies
- Hourly load characteristics
	MAED	- Final energy demand
		- Electricity demand
		- Hourly electric load
		- Load duration curves (WASP)

- **MAED: Model for Analysis of Energy Demand**

- Excel-based accounting framework for analyzing medium- to long-term demand scenarios of socioeconomic, technological and demographic development

- Includes pre-defined economic sectors: Industry (incl. Agriculture, Construction, Mining and Manufacturing), Transport, Services, Households

IAEA-MESSAGE

Inputs:

- Energy System structure (incl. vintage of plant and equipment)
- Base year energy flows and prices
- Energy demand projections (MAED)
- Technology and resource options + performance profiles
- Technical + Policy Constraints

MESSAGE

Outputs:

- Primary and final energy mix
- Emission and waste streams
- Environmental Impacts
- Resource use
- Land use
- Import dependence
- Investment requirements

- **MESSAGE: Model for Energy Supply Systems and their General Environmental impacts**

- Optimization model used to helps design long-term strategies through analyzing optimal energy mixes, investment needs, energy security, technology learning, etc. Can also be used to calculate emissions of GHGs and local air pollutants.

MODULE E3B

Sector Specific Tools

RETScreen

Project-specific inputs		RETScreen		Static Results
- Location data - Meteorological data - Equipment data - Cost data - Financial data	→		→	- Lifecycle costs - GHG emissions - Pre-screened technology inputs for integrated models

- **Description**: Evaluates the energy production, life-cycle costs and GHG emissions reductions from renewable energy and energy efficient technologies. Intended primarily for single project-level analysis (screening/feasibility) rather than for national-level integrated analyses.

- **Developer**: Natural Resources Canada

- **Licensing**: Free

- **Website**: https://openei.org/wiki/RETScreen_Clean_Energy_Project_Analysis_Software

RETScreen Interface

HOMER

Input		Process		Output
- Resource availability - Technology Costs - Performance parameters of electric generating technologies - Demand load curves	→	HOMER	→	Power system configurations sorted by net present cost

- **Description** : Energy sector optimization/screening tool used to assess how variable resources (e.g. wind and solar) can be optimally integrated with conventional energy systems. Typically applied for small scale systems. Can be helpful as a way to screen electricity generation expansion plans.

- **Developer**: NREL/HOMER Energy LLC

- **Licensing, Support**: Free

- **Website**: https://www.homerenergy.com/products/pro-vs-grid.html

HOMER Interface
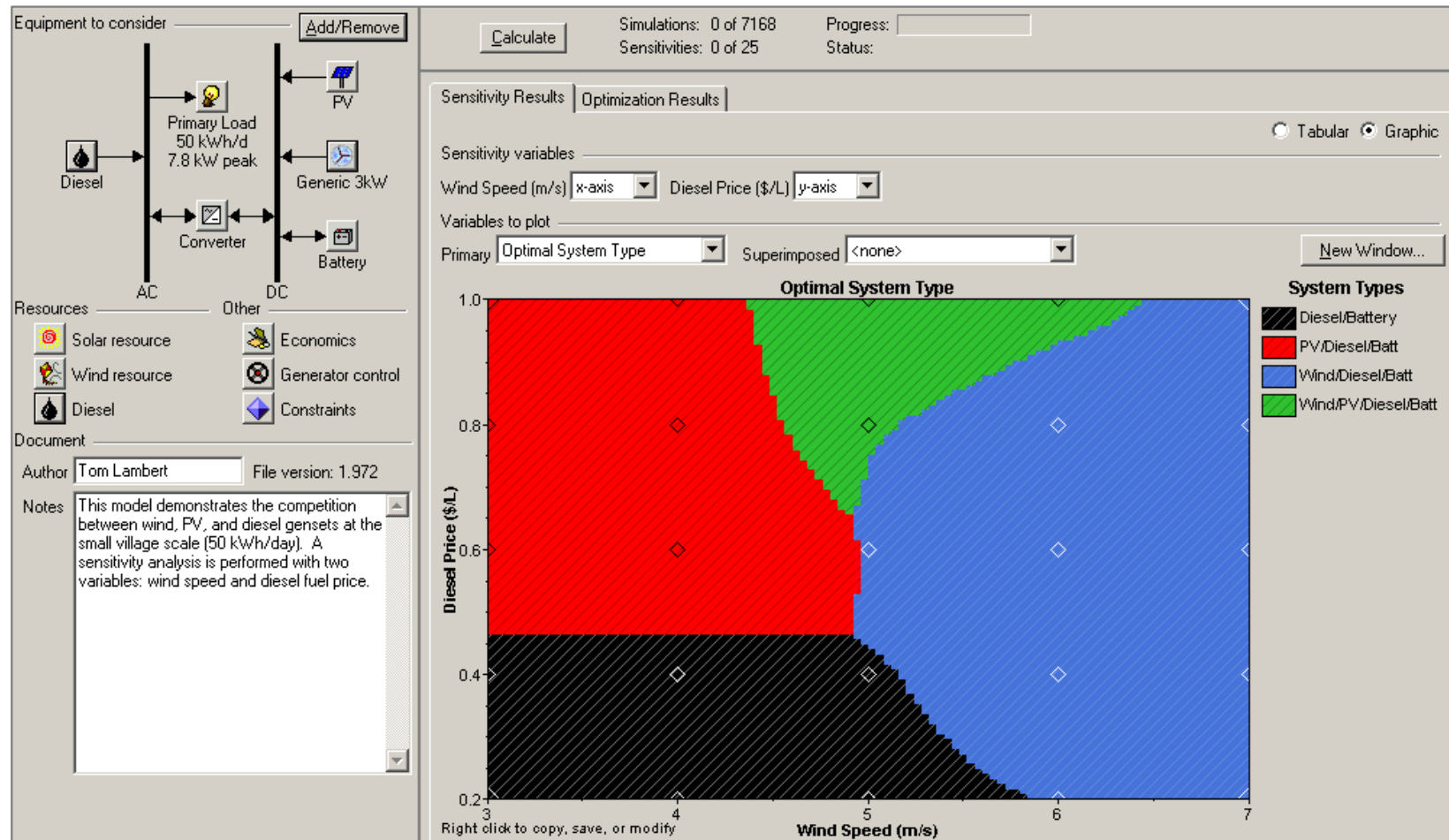
Transportation Models

- **ITDP** – Institute for Transportation and Development Policy has 11 project-specific spreadsheet models to evaluate GHG emissions from transport policies (a manual was developed for GEF projects). These include cycleways, bus rapid transit, eco-driving, walkability improvement, parking, and railways. https://www.itdp.org/2011/01/20/manual-and-sketch-models-for-calculating-ghg-benefits-now-online/

- **ICCT** – International Council on Clean Transportation – The Global Transportation Roadmap is a spreadsheet tool that identifies trends in the transportation sector and assesses impacts of different policy options based on a well-to-wheel approach. http://www.theicct.org/transportation-roadmap/

- **GREET -** ANL's free Excel-based tool which calculates energy and emissions impacts of advanced vehicle technologies (e.g. hybrid, electric, fuel-cell vehicles) and new transportation fuels (e.g. natural gas fuels, biofuels). http://greet.es.anl.gov/

VEHICLE CYCLE (GREET 2 Series)

FUEL CYCLE (GREET 1 Series)

WELL TO PUMP
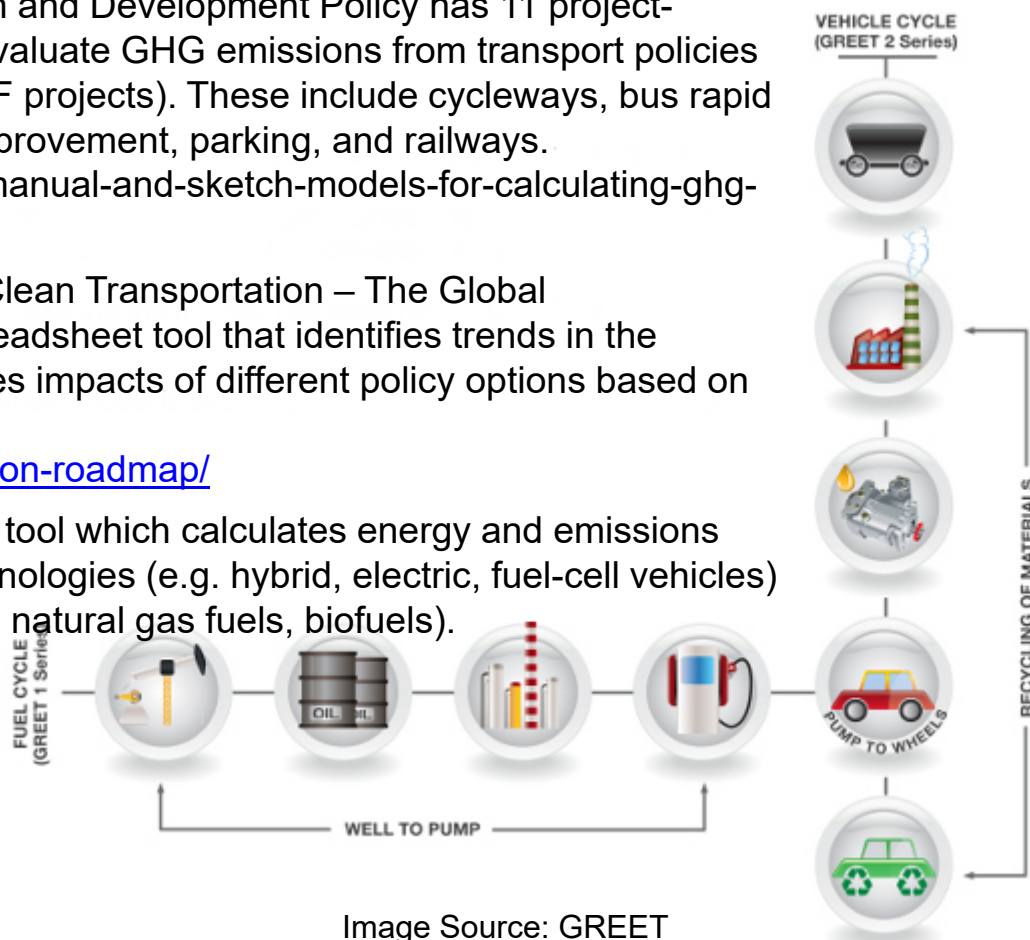
PUMP TO WHEELS

RECYCLING OF MATERIALS

Image Source: GREET

MODULE E4

GHG Mitigation Assessment in Non-Energy Sectors

GHG Mitigation Assessment in Non-Energy Sectors

- Land-use, land-use change and forestry (LULUCF) (consider the availability of land and its products):
    - Forestry
    - Agriculture
    - Rangelands and grasslands
- Waste management.

Basic Steps for Mitigation Assessment in All Non-Energy Sectors

1. Establish current inventory of emissions (preferably based on national GHG inventories) and identify emissions intensities per unit of key driving variables.

2. Develop baseline scenario by projecting key driving variables into the future and considering any likely changes in emissions intensities assuming continuation of current policies.

3. Identify key mitigation options in each sector.

4. Screen mitigation options based on costs, mitigation potential and other national development and environmental priorities.

5. Construct mitigation scenarios by considering potential for reducing baseline emissions by application of selected mitigation options.

Steps in Assessing Land-Use Change

- Step 1: Base year:
  - Evaluate current land availability
  - Determine current demand for biomass products (fuel wood, timber, crops, etc.)
  - Determine current supplies of biomass products
- Step 2: Baseline scenario: project land uses, demands and supplies into the future given current, considering:
  - Demographic trends such as human population and its growth rate, rural/urban distribution, and dependence on land resources
  - Economic factors such as income level, technological development, dependence on exports of land-based products, and rates of economic growth.
  - Type and intensity of land use, such as shifting versus permanent agriculture, or clear-cutting versus selective harvesting
  - Biophysical factors such as soil productivity, topography and climate.
- Step 3: Reconcile the land and product availability with the demand for products.
- Step 4: Mitigation scenario: examine impacts of mitigation options by considering how they will alter baseline trends.

LULUCF Mitigation

- **Maintaining existing stocks**
  - Forest protection and conservation
  - Increased efficiency in forest management. Harvesting and product utilization.
  - Bio-energy initiatives (i.e. use of sustainably grown biomass for fossil fuel substitution).
- **Expanding carbon sinks**
  - Afforestation
  - Reforestation
  - Enhanced regeneration
  - Agroforestry
  - Urban and community forestry:

# Steps in a Comprehensive Mitigation Analysis Process (COMAP)

The COMAP process is designed to identify least-cost ways of providing forest products and services, while reducing GHGs emitted or increasing carbon sequestered in the land-use change and forestry sector.

Steps:

1. Screening of mitigation options

2. Assessing current and future land available for mitigation Identifying options which can be implemented on available lands

3. Estimating emission reductions and/or carbon sequestration per unit area

4. Estimating total and unit costs and benefits

5. Developing future GHG and cost scenarios

6. Evaluating the cost-effectiveness of options and scenarios

7. Exploring policies, institutional arrangements and incentives necessary for implementation.

The COMAP Process
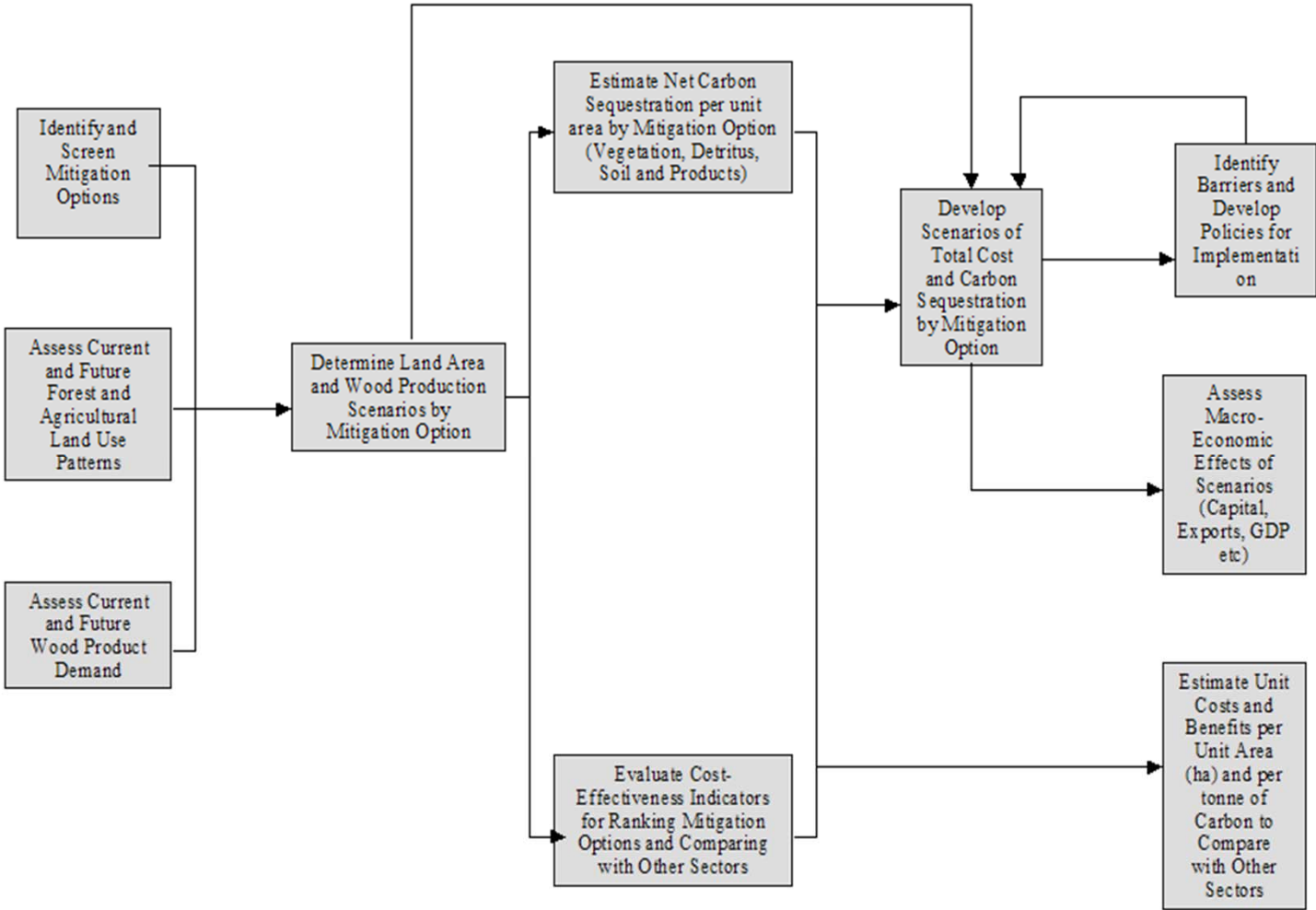
Rangelands and Grasslands Mitigation

- Two main approaches which can be used for GHG mitigation assessment:
  - Evaluate individual projects and/or programmes within existing rangeland management plans, and identify measures or policies which could be applied to meet stated goals
  - Perform a comprehensive assessment of the rangeland sector and its role in a country's formal and informal economy, including that of providing environmental services such as climate change mitigation.

Steps in Rangeland and Grassland Mitigation Assessment

- **Base year:**
  - Inventory of current rangeland area, vegetation, soil types, and current demand for forage, fuel-wood, etc.
  - Evaluate current condition (health) of ecosystem types
  - Assess rangeland ecosystem charge.

- **Baseline:**
  - Assess future land area available for domestic grazing animals and wildlife given the demand for land by other sectors
  - Assess future demand for forage, fuel-wood, agriculture or other uses of rangeland ecosystems
  - Project future land areas as well as livestock and wildlife production under current policies.

- **Screen mitigation options:**
  - Estimate potential for reducing GHG emissions and/or sequestering carbon for each option considered
  - Estimate costs and non-GHG benefits of each option
  - Identify potentially attractive mitigation options
  - Estimate potential carbon sequestration or GHG reduction for each mitigation option.

- **Mitigation scenarios:**
  - Construct alternative scenarios by combining favored mitigation options.

Rangeland/Grassland Mitigation Options

- Rehabilitation of degraded rangelands
- Reducing livestock numbers
- Changing the mix of animals
- Changing animal distribution through salt placement, development of water sources, or fencing
- Improving quality of animal diets
- Other farming practices such as the application of herbicides, use of mechanical methods to rehabilitate unhealthy rangelands and watershed-scale developments.

Agricultural GHG Mitigation

Key sectors to consider:

- **Animal husbandry**: reducing CH_4 emissions from enteric fermentation through:
  - Better production efficiency: improved nutrition, production enhancing agents, improved genetic characteristics, improved animal reproduction.
  - Capturing CH_4 through better manure management: covered lagoons, digesters, etc.

- **Rice cultivation:** reducing CH_4 through modified growing practices (better nutrient and water management).

- **Fertilizer application:** reducing nitrogen (N)-gas emissions through better fertilizer management.

- **Soil carbon:** reducing CO_2 emissions or sequester CO_2 through alternative tilling and other practices.

Waste Management

- **Landfills:** Reducing CH_4 from existing landfills by:
  - Capturing and combusting landfill gas (which also offsets energy use in other sectors)
  - Use of practices such as composting, recycling and incineration to reduce need for landfilling.

- **Wastewater treatment:** Reducing CH_4 emissions by:
  - Aerobic wastewater treatment systems
  - Recovery and utilization of methane from anaerobic digestion of wastewater or sludge. If wastes are digested)under controlled anaerobic conditions, the resulting methane and other gases can be recovered and utilized as an energy source.

- Example of a waste model:
  - **Waste Reduction Model (WARM):** Calculates GHG emissions in baseline and alternative waste management practices (source reduction, recycling, combustion, composting, and landfilling). WARM recognizes 46 types of materials (aluminum cans, clay bricks, fly ash, food scraps, leaves, mixed plastics, office paper, personal computers, tires, etc.). Available as web-based calculator or Excel spreadsheet.

    http://www.epa.gov/climatechange/waste/calculators/Warm_home.html

MODULE E6

Conclusions

Conclusions: Choosing an Approach

- The most "appropriate" method for a team depends on available resources, modelling experience, country circumstances and key sectors

- Both qualitative methods and quantitative tools can help prioritize and inform mitigation programmes

- Most involve evaluation against a series of agreed objectives or criteria

- Qualitative methods can be used both prior to, and subsequent to, quantitative/modeling analysis

- Most mitigation modelling has so far focused on bottom-up approaches due to the lack of off-the-shelf econometric models

- Sophisticated models can be useful where expertise and data are relatively plentiful otherwise, simpler, more user-friendly tools may be more suitable

- Sector-specific tools can complement integrated models: helping to screen options before inclusion in overall integrated scenarios and helping to provide additional more detailed insights into suitability of options