Module 3 – Overview of modeling approaches and models

Course: Inclusive Green Economy (IGE) modelling

Date / Place / Name

OVERVIEW

1 Overview of methods

2 Overview of models

3 Interpretation of results

4 In depth review: Integrated Green Economy Modelling (IGEM) framework

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

1 Overview of Methods

UNDERSTANDING SIMULATION MODELS

A model is a simplification of reality.

It includes variables and equations and uses data.

There are three main methods for solving equations:

optimization

econometrics

simulation

The method used influences the type of data inputs required and the approach to policy analysis.

REFLECTION POINT

Have you used models before?

What type of model, and for what type of analysis?

METHODOLOGIES: OPTIMIZATION

Solves model equations by finding an optimal solution based on an “objective function”.

One or more “constraints” can be considered in the formulation of the objective function.

Optimization can lead to a snapshot (next optimal level), or a sequence of stages, with explicit time and a semi-continuous approach.

POLL

What stage of the policymaking process can profit the most from the use of **optimization models**?

A. Issue identification

B. Policy formulation

C. Policy assessment

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

METHODOLOGIES: ECONOMETRICS

Estimates the correlation between one or more variables in the system.

Uses historical trends to forecast possible future changes.

Assumes that the drivers of change of the past remain relevant (but not the only ones) for the future.

Allows the analysis to be extended to capture more indicators, if data is available.

POLL

What stage of the policymaking process can profit the most from the use of **econometric models**?

A. Issue identification

B. Policy formulation

C. Policy assessment

METHODOLOGIES: SIMULATION

Focuses on “causal-descriptive” relations.

Represents drivers of change of the past, as well as possible emerging ones for the future.

Can be top-down, such as System Dynamics, or bottom-up, such as Agent-Based Modelling.

Emphasizes how structure drives behavior (feedback loops) and shifts dominance of drivers of change.

POLL

What stage of the policymaking process can profit the most from the use of **simulation models**?

A. Issue identification

B. Policy formulation

C. Policy assessment

SUMMARY OF METHODOLOGIES

METHODOLOGY	MODEL FORMULATIONS	TIME HORIZON	ANALYSIS APPROACH	TYPE OF SIMULATION
Optimization	Constraints, objective function	Snapshot, short term	Bottom up (sectoral), Top-down (macro)	Target based, backward looking
Econometrics	Correlations, causal	Short and medium term	Top-down	Forward looking
Simulation	Causal, descriptive	Short, medium and long-term	Top-down, Bottom-up	Forward looking

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

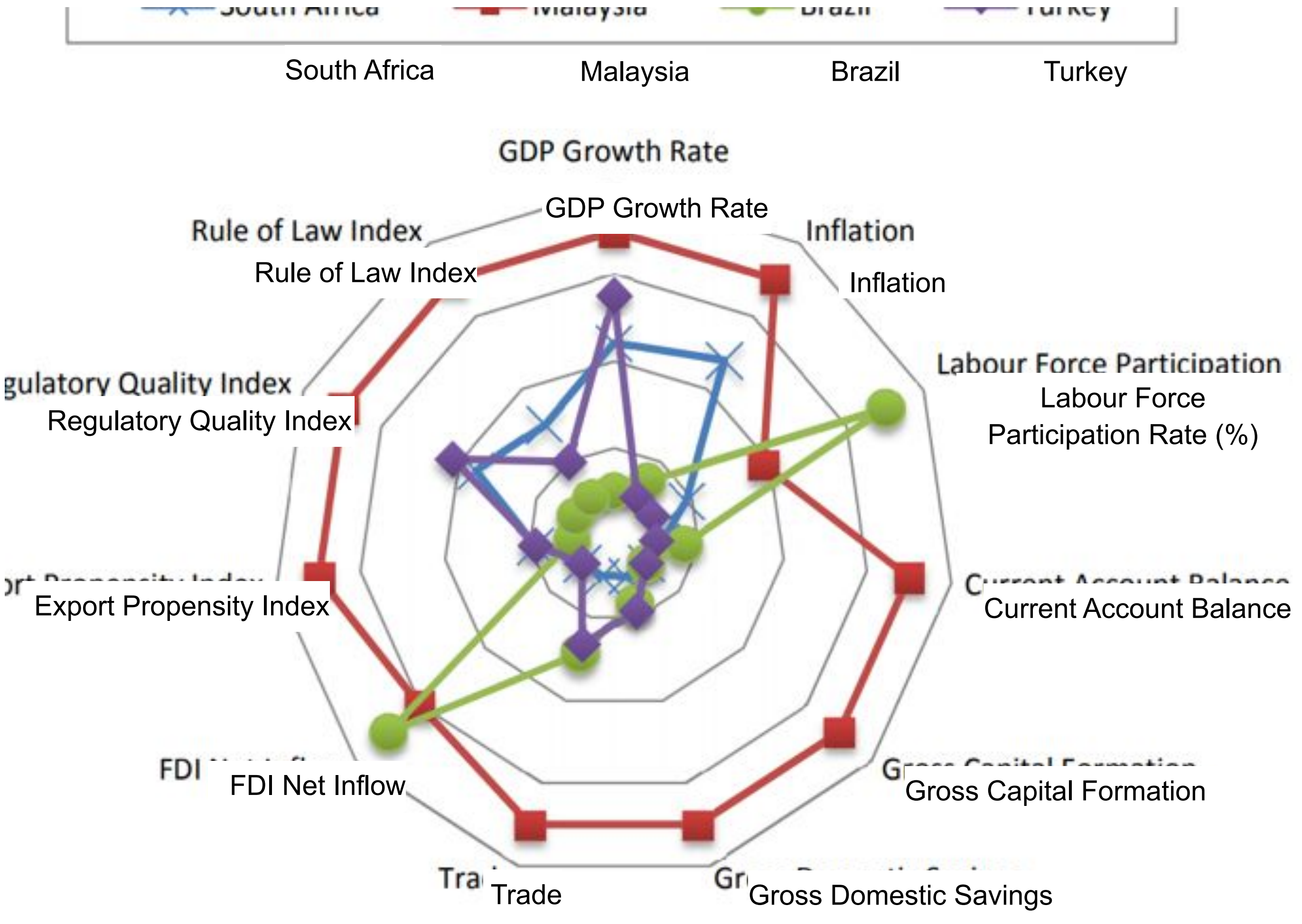
TYPES OF ASSESSMENT

ECONOMIC ASSESSMENT

Designed to support the analysis of policies, projects and investments with respect to their expected economic outcome.

An example of this type of framework is the methodology for conducting feasibility studies.

Macroeconomic Indicators

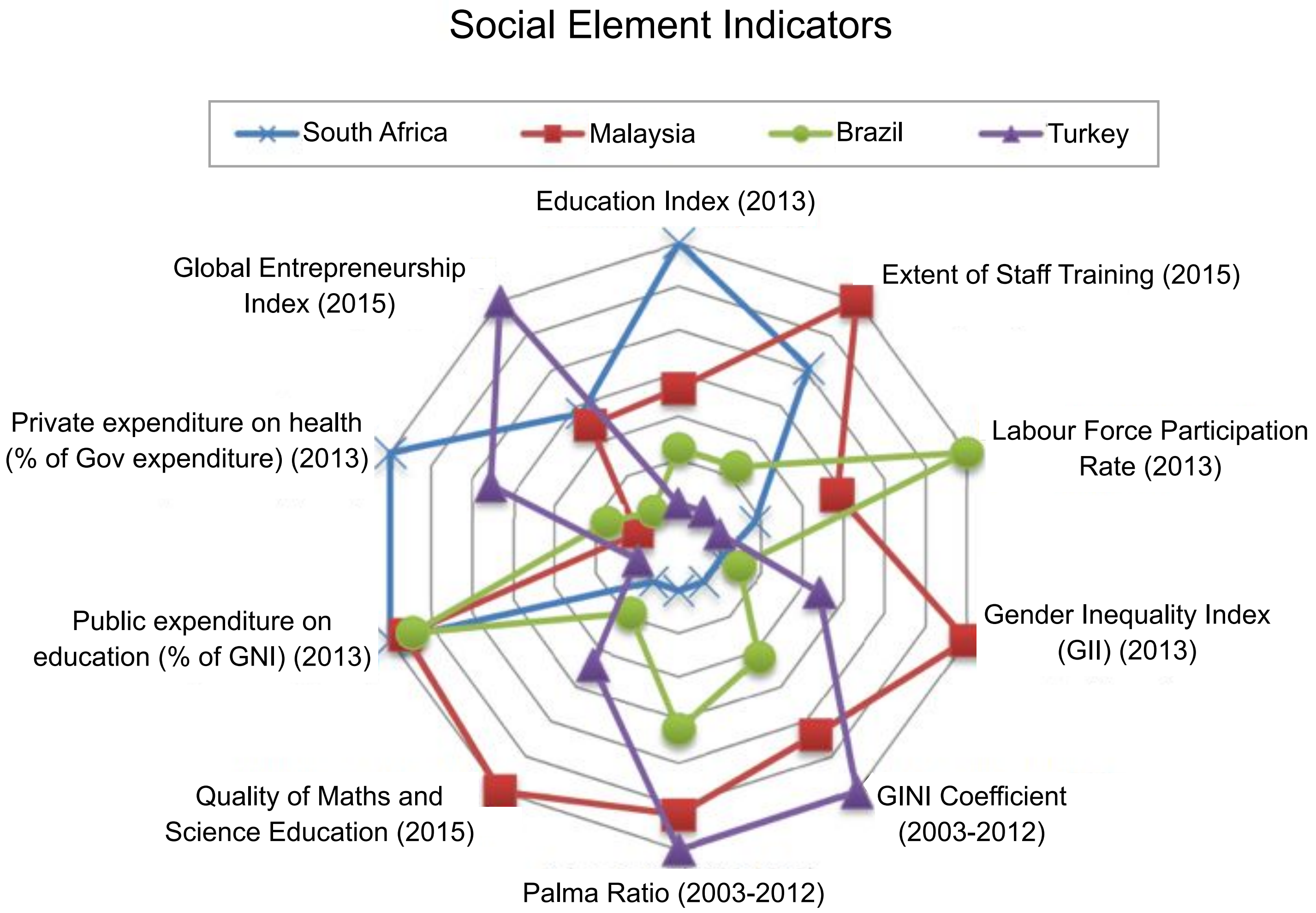


Source: ILO, 2016

SOCIAL ASSESSMENT

Provides guidance on how to evaluate policy impacts on different social groups, and review and monitor key governance indicators.

An example is Poverty and Social Impact Analysis (PSIA), which facilitates the assessment of policy inclusiveness and pro-poor orientation.

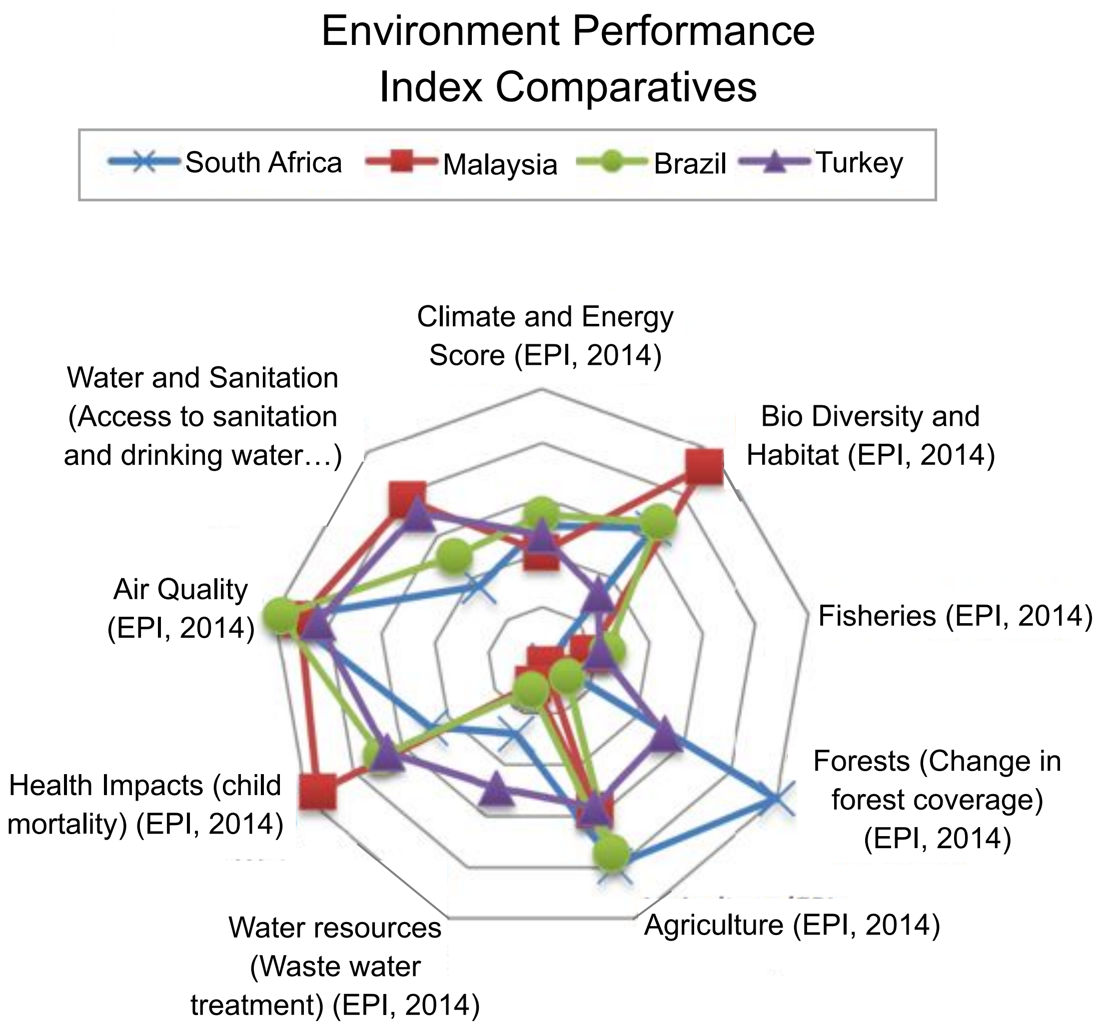


Source: ILO, 2016

ENVIRONMENTAL ASSESSMENT

Includes frameworks that combine tools for the evaluation of the environmental impacts of development strategies, policies, projects and investments.

Examples include:
(1) Strategic Environmental Assessment (SEA)
(2) Environmental Impact Assessments (EIA)



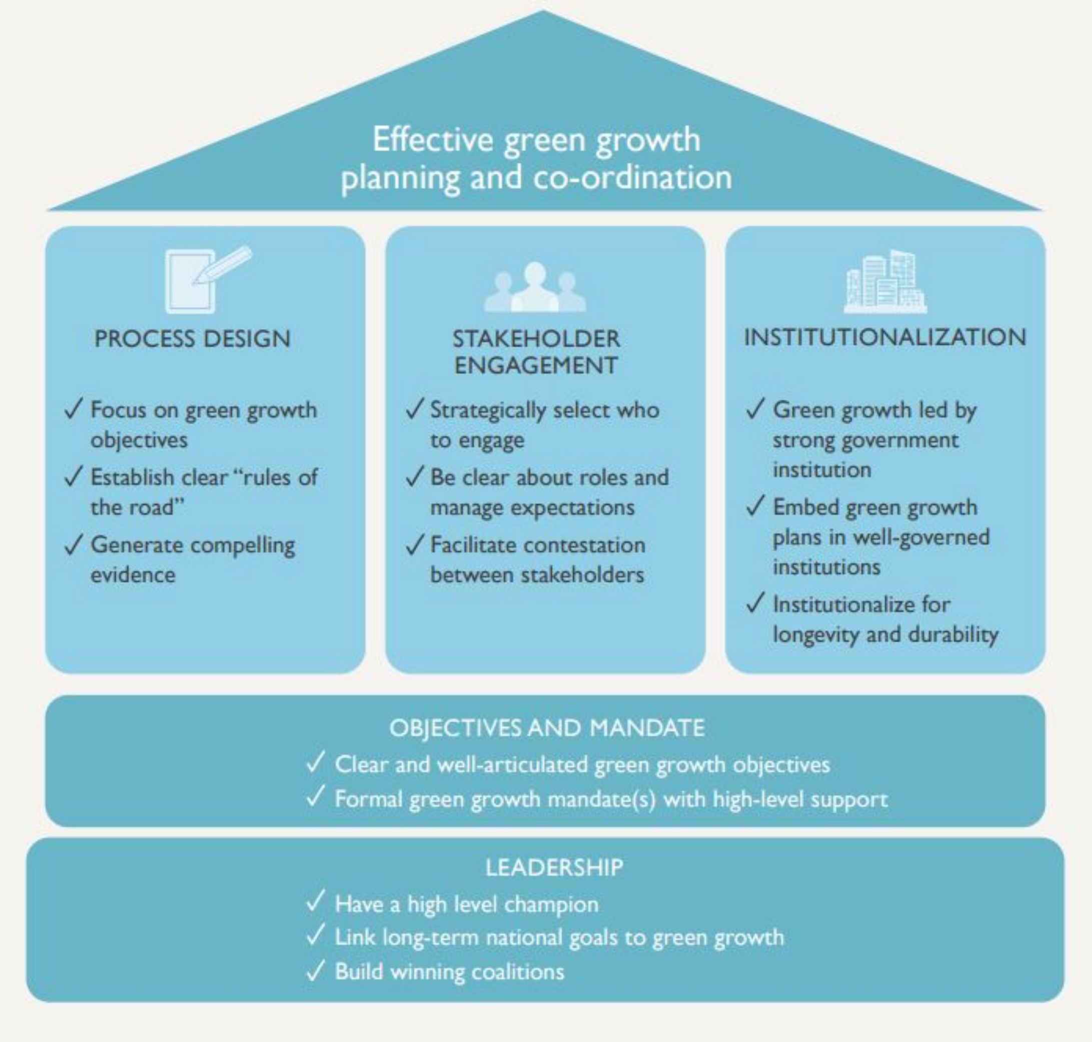
Source: ILO, 2016

GOVERNANCE ASSESSMENT

IGE policies require efficient and transparent institutional frameworks and processes at both the national and local levels.

There are six key principles: participation, fairness, decency, accountability, transparency and efficiency.

Foundations for green growth planning and co-ordination



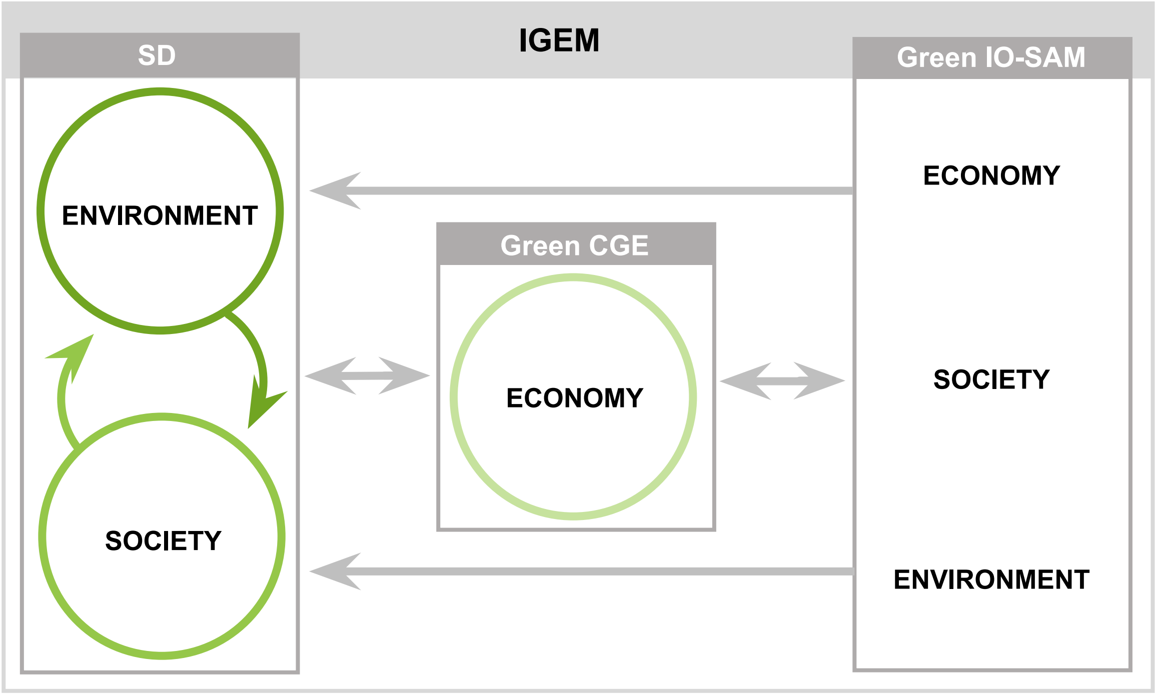
Source: GGBP, 2014

INTEGRATED ASSESSMENT

An assessment that estimates policy outcomes for various sectors, economic actors and dimensions of development, as well as over time.

As an example, Decision Support Systems (DSS) provide valuable guidance to decision makers for the integrated evaluation of IGE policies.

The structure of the integrated green economy modelling framework



Source: UNEP, 2017

2 Overview of Models

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

OVERVIEW OF MODELS

Many models are available to support the assessment of the outcomes of IGE investments.

Some capture few, some many of the characteristics of the IGE.

Both qualitative and quantitative models can be used for IGE assessments.

OVERVIEW OF MODELLING APPROACHES

Refer to the underlying mathematical theories and frameworks that can be used to create and simulate (or solve) quantitative simulation models.

Usefulness of models depends on their match to the definition of a green economy, which depends on the local context, the quantitative outputs they generate to effectively inform decision-making, and how easy they are to customise and use.

MODELLING USEFULNESS DEPENDS ON THEIR SUPPORT OF THE POLICYMAKING PROCESS

Ex-ante modelling can generate “what if” projections on scenarios with no action, as well as the potential impact of proposed policies.

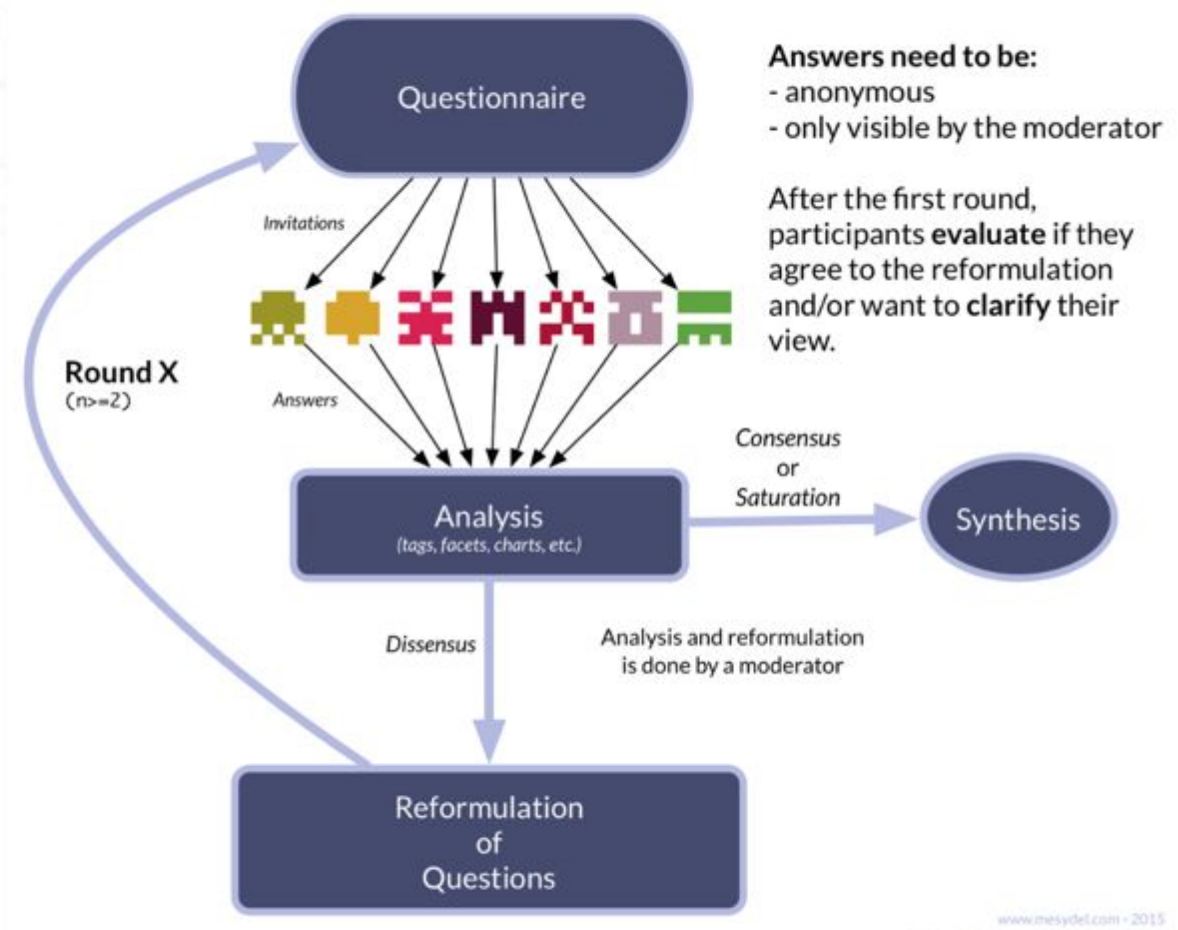
Ex-post modelling can support impact evaluation.

Improvements to the model and updated projections enhance policy decision making.

QUALITATIVE MODEL: Delphi Analysis

- **The Delphi method** consists of a multi-round survey to converge towards a common solution or view.
- At every round following the first one, the participants are given the results of the previous rounds.
- Thus, they are asked to reconsider their judgements based on the opinions of others.
- This helps them converge towards a common solution or view.

The Delphi Method



Source: Rivière, 2018

EXAMPLE

EurEnDel is the largest energy Delphi study that was ever conducted in Europe, with around 3,000 experts participating over a time frame of 30 years .

It aims to describe trends in the development of energy technologies, and to identify research and development needs in the energy sector.

DELPHI ANALYSIS

Data source(s)

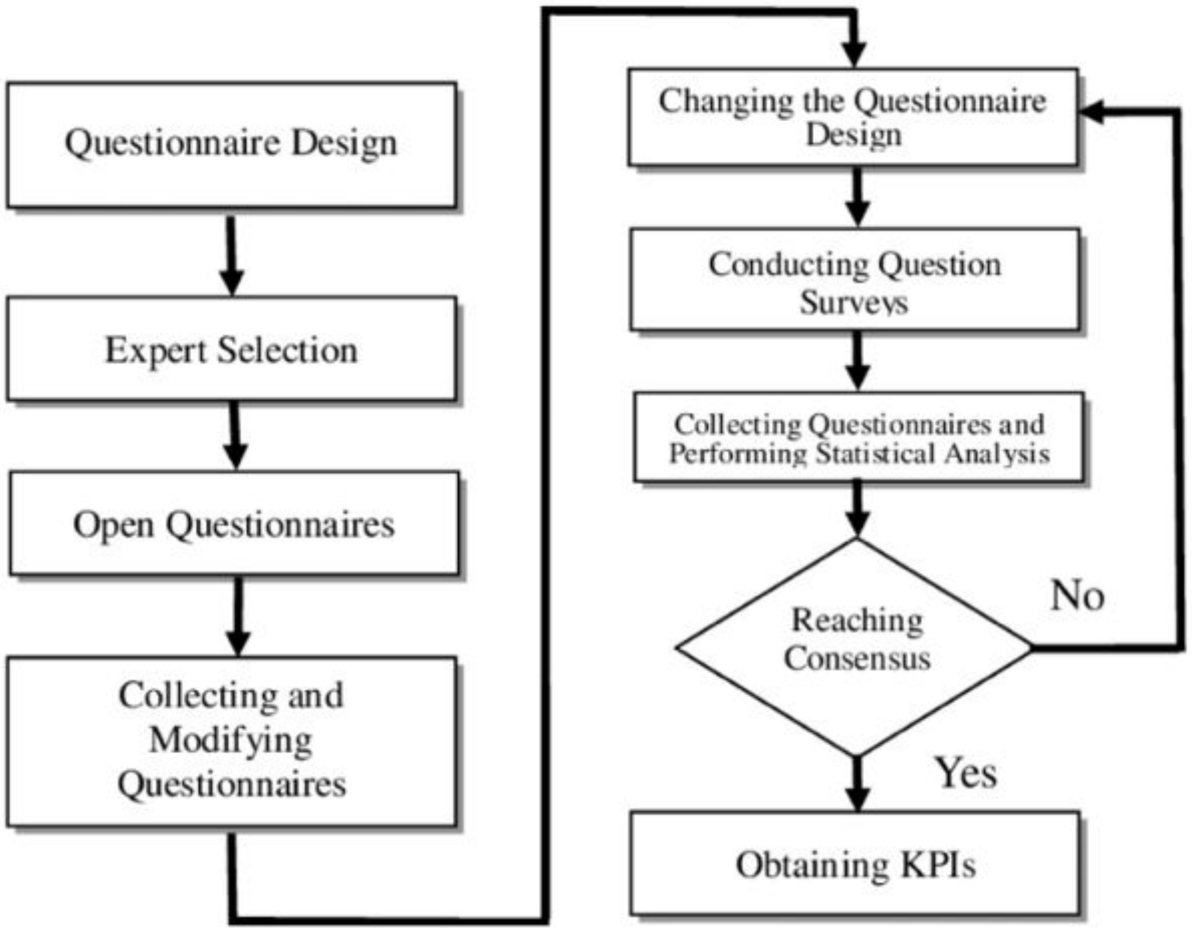
- Expert practitioners and researchers

Data Availability

- Delphi is a data collection method, which requires thorough analysis of the current situation before execution

Accessibility and Typical Users

- Highly accessible
- Results are an overview of expert opinions on specific questions or topics



Source: Cheng et al., 2011

REFLECTION POINT

What do you think is the core contribution of qualitative models in the context of an IGE assessment?

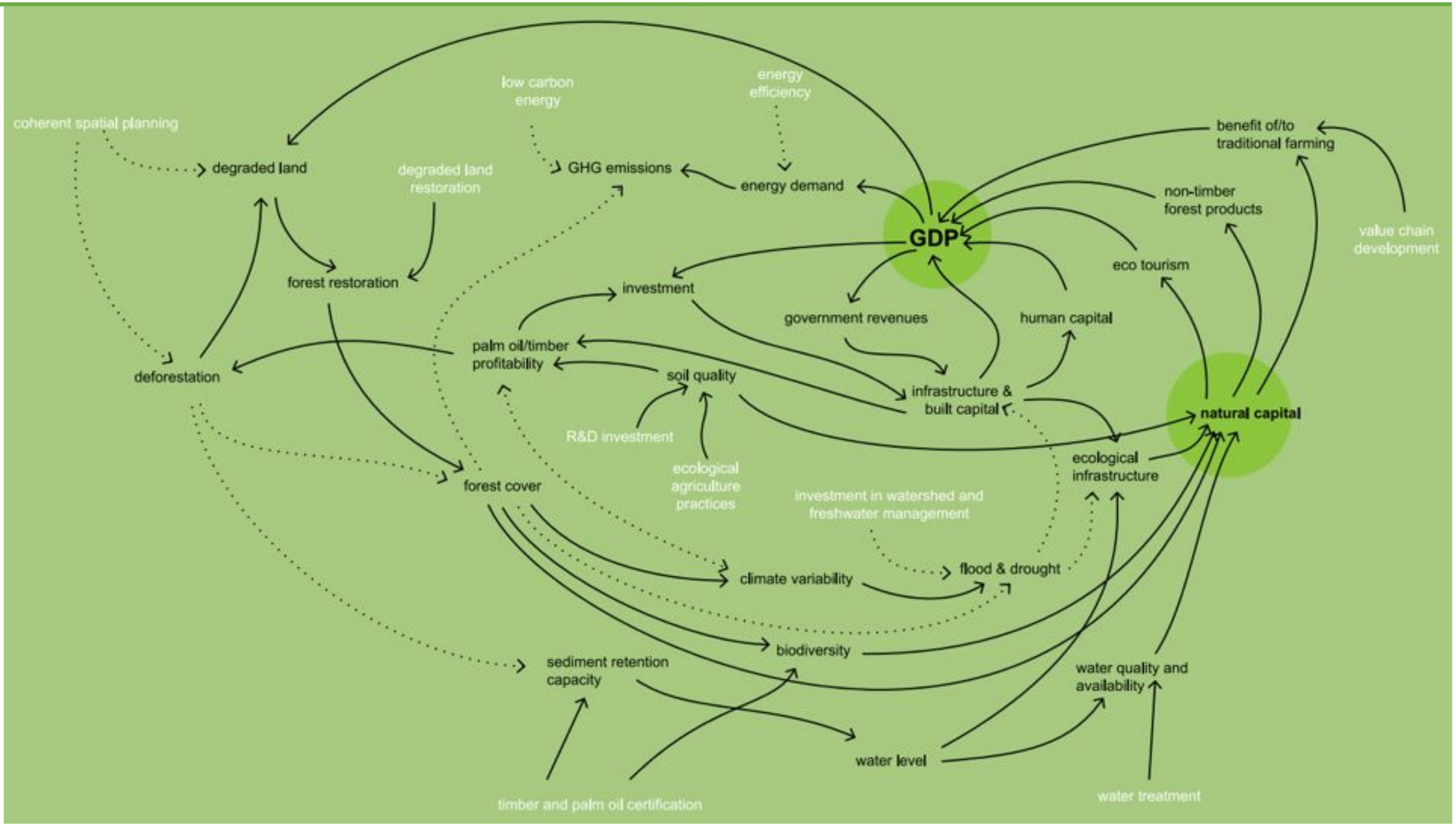
PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

QUALITATIVE MODEL: Causal Loop Diagram (CLD)

- A CLD consists of variables connected by arrows denoting the causal influences among the variables. Feedback loops are also identified in the diagram.

- CLDs support the identification of policy outcomes using a systemic approach.

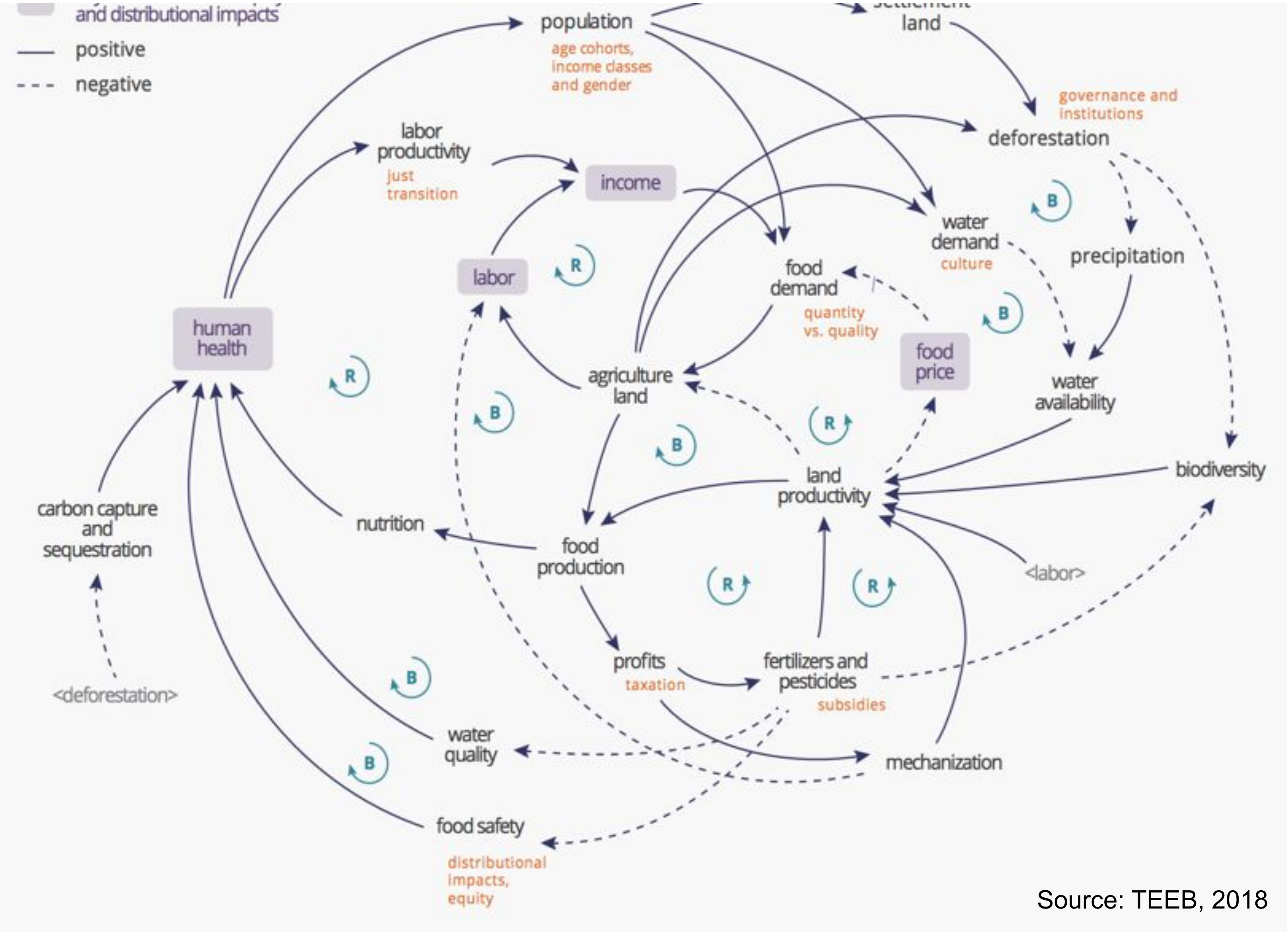
CAUSAL LOOP DIAGRAMS



Source: Van Paddenburg et. al. 2012

EXAMPLE

Illustrative Causal Loop Diagram of a generic eco-agri-food system (Source: Zhang et al. 2018)



Source: TEEB, 2018

CLDs have been used extensively to carry out qualitative assessments of policy impacts.

TEEB developed a CLD to explain the dynamics existing in the eco-agri-food system.

REFLECTION POINT

What was your experience working with CLDs?

What do you think are the main strengths and weaknesses of CLDs?

QUANTITATIVE MODEL: Sectoral Input-Output (I-O) Tables

- Represent inputs and outputs of several economic activities, physical and/or monetary.
- An input-output model replaces the data in an input-output table with equations.
- I-O models can be descriptive and prescriptive.

I-O table in symbols

Total domestic purchases of inputs

		Agriculture	Manufacturing	Services	Household demand	Private investment	Government demand	Exports	Output (sales)
Industry by industry / Total domestic production of outputs	Agriculture	O_{11}	O_{12}	O_{13}	C_1	I_1	G_1	EX_1	X_1
	Manufactur-ing	O_{21}	O_{22}	O_{23}	C_2	I_2	G_2	EX_2	X_2
	Services	O_{31}	O_{32}	O_{33}	C_3	I_3	G_3	EX_3	X_3
Gross value of output / IMPORT	Imports	M_1	M_2	M_3	M_C	M_I	M_G		M
Gross value added	Taxes minus subsidy	T_1	T_2	T_3					T
	Wages and salaries	W_1	W_2	W_3					W
	Profit[1]	$Profit_1$	$Profit_2$	$Profit_3$					Profit
Total input (payment)		X_1	X_2	X_3	C	I	G	EX	
Employment by industry		E_1	E_2	E_3					
CO2 emissions by industry		$CO2_1$	$CO2_2$	$CO2_3$					

Source: ILO,2017

EXAMPLE

Cruz (2002) applied the I-O methodology to analyze energy flows and CO_2 emissions in the Portuguese economy.

The I-O model distinguishes between energy demand by final consumers and direct and indirect energy requirements from industries.

Table 1
Primary Energy Intensities

	Corresponding to Direct Production demand		+ Corresponding to Indirect Production demand		= Corresponding to Total Production demand		+ Corresponding to Direct Consumption Demand		= Corresponding to Final Demand			
	C		$C(A+A^2+...)$		$C(I-A)^{-1}$		P		**Total Primary Energy Intensity**		*Tt. Primary Energy Intensities' "Ranking"*	
unit: toe / million PTE	(1) coal	(2) oil	(3) coal	(4) oil	(5) coal	(6) oil	(7) coal	(8) oil	(9) coal	(10) oil	*coal*	*oil*
01 Agriculture, hunting and related service activit.	0.00	0.37	0.11	0.48	0.11	0.85	0.00	0.00	0.11	0.85	20	14
02 Forestry, logging and related service activities	0.00	0.23	0.02	0.09	0.02	0.32	0.00	0.00	0.02	0.32	36	26
03 Fishing and related service activities	0.00	1.05	0.03	0.28	0.03	1.34	0.00	0.00	0.03	1.34	34	9
04 Mining and manufacture of coal by-products	8.87	0.18	0.31	0.57	9.18	0.76	102.42	0.00	111.60	0.76	1	15
05 Extr. crude petroleum ..., and manuf. refined petroleum products	0.00	2.52	0.08	0.51	0.08	3.03	0.00	52.26	0.08	55.29	24	1
6A Fossil fuel electricity generation	9.13	12.60	0.07	0.24	9.20	12.85	0.00	0.00	9.20	12.85	2	2
6B Hydroelectricity	0.00	0.00	0.01	0.04	0.01	0.04	0.00	0.00	0.01	0.04	38	38
6C Electricity Distribution	0.00	0.00	4.16	5.82	4.16	5.82	0.00	0.00	4.16	5.82	3	5
07 Gas production and distribution	0.00	4.63	0.49	2.53	0.49	7.15	0.00	0.00	0.49	7.15	7	4
08 Water supply	0.00	0.00	0.73	1.04	0.73	1.04	0.00	0.00	0.73	1.04	6	12
09 Extraction and manuf. of ferrous and non-ferrous ores and metals	1.10	0.32	0.84	1.01	1.93	1.33	0.00	0.00	1.93	1.33	4	10
10 Extraction and manuf. of non-metallic minerals	0.96	0.78	0.47	0.95	1.43	1.73	0.00	0.00	1.43	1.73	5	8
11 Manuf. of chemicals and chemical products	0.02	1.95	0.18	0.61	0.20	2.55	0.00	0.00	0.20	2.55	13	6
12 Manufacture of fabricated metal products	0.00	0.06	0.32	0.58	0.32	0.64	0.00	0.00	0.32	0.64	9	20

Source: Cruz, 2002

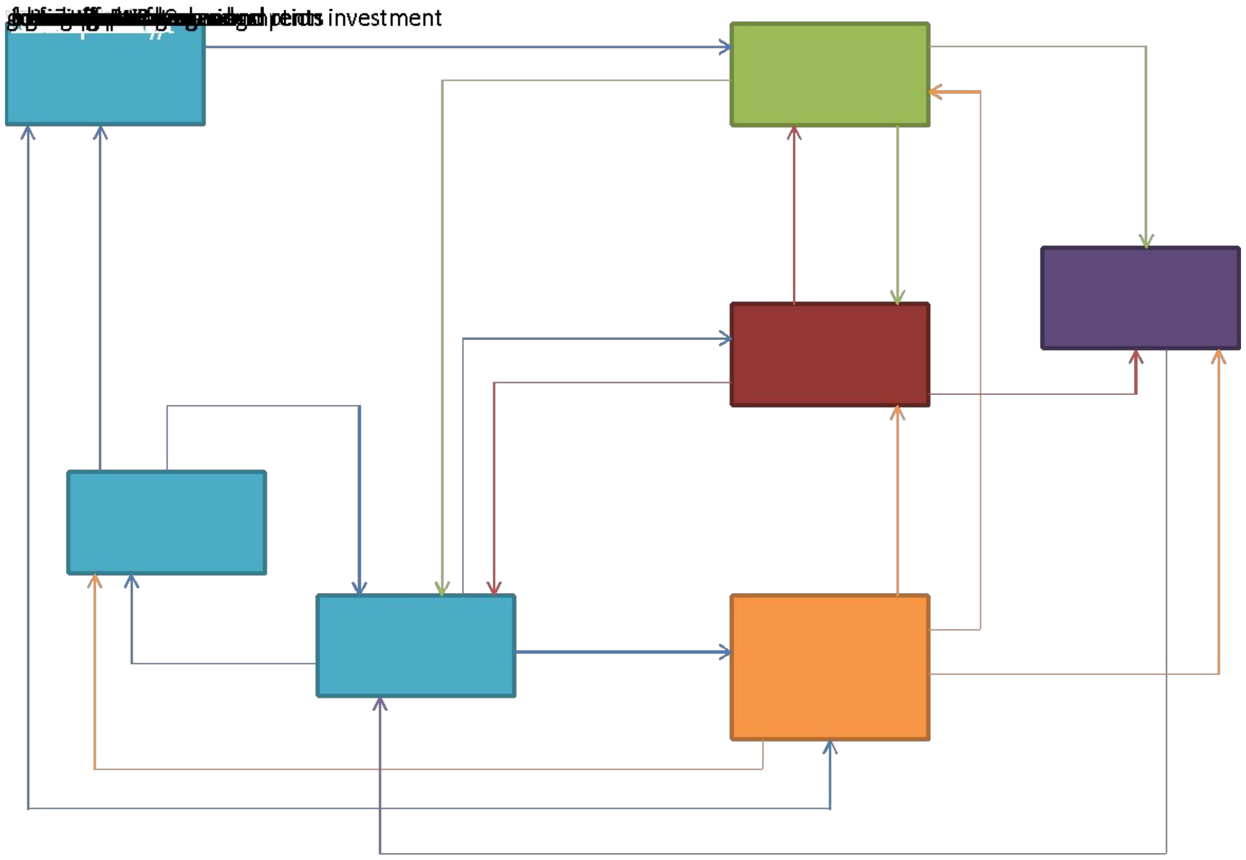
REFLECTION POINT

What do you think is the most useful application of I-O models?

Sectoral level (e.g. for industries) or macroeconomic?

QUANTITATIVE MODEL: Computable General Equilibrium (CGE)

- Models supply and demand behaviour across all markets in an economy.
- Widely used to analyse the aggregate welfare and distributional impacts of policies.
- Optimize the benefits for various economic actors.



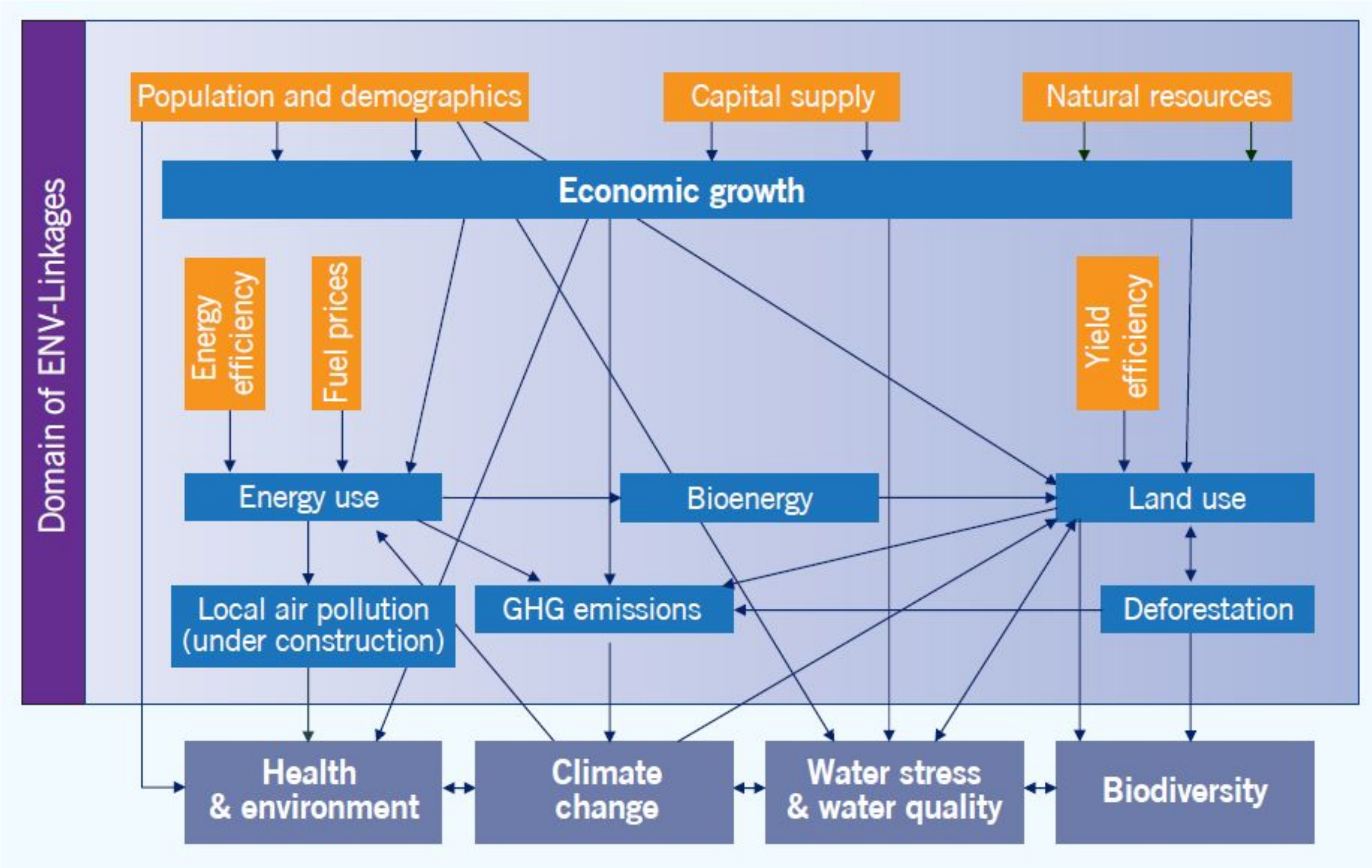
Source: Banerjee, Onil, 2019.

EXAMPLE

The ENV-Linkages model is a multi-sectoral and multi-regional dynamic CGE model, based on microeconomic foundations.

It is used to generate the results for the OECD Environment Outlook to 2050.

It uses the Global Trade Analysis Project (GTAP) as data input.



Source: OECD, 2012.

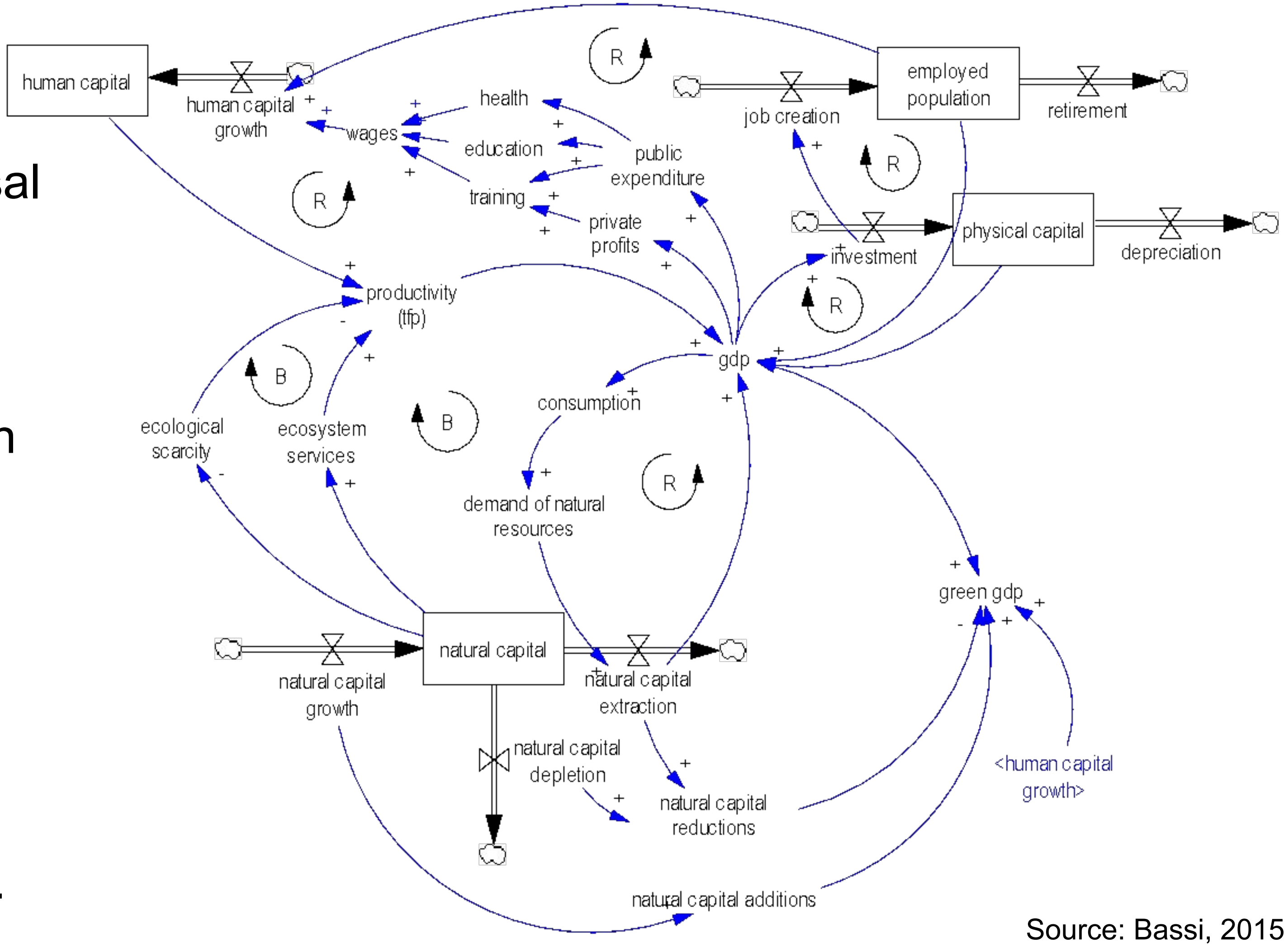
REFLECTION POINT

The concept of equilibrium is frequently debated.

To what extent do you see it as a realistic assumption for economic models?

QUANTITATIVE MODEL: System Dynamics

- Integrated quantitative approach (causal descriptive) utilized to understand situations for complex issues.
- Methodology that allows the integration of social, economic and environmental indicators.
- The pillars are feedback, delays and non-linearity.
- Models can be top-down or bottom-up.

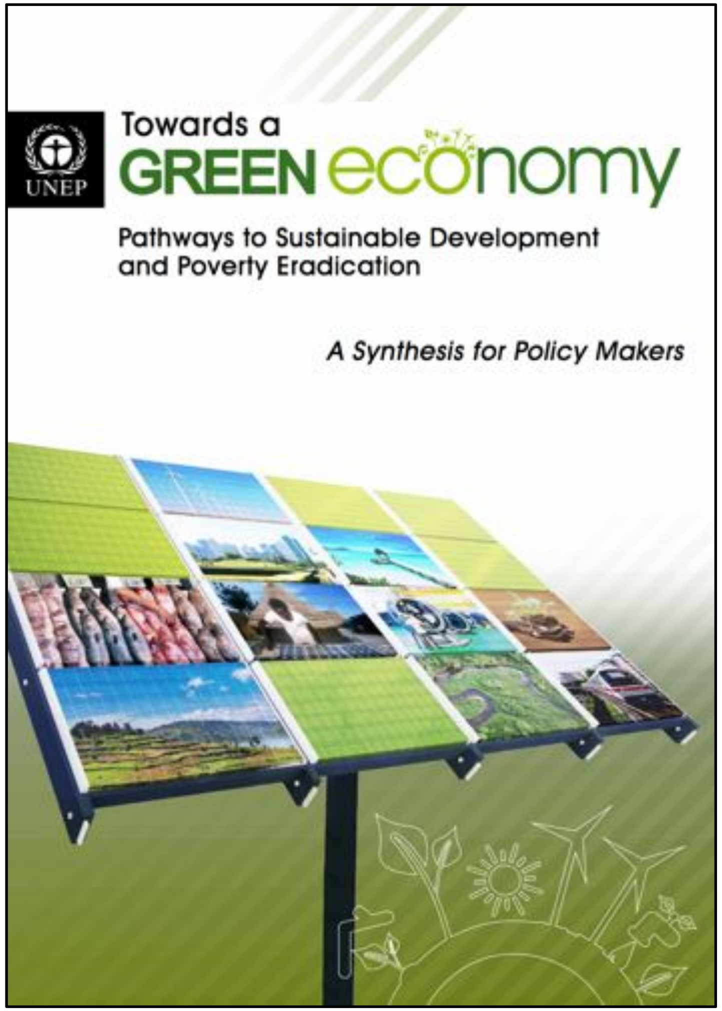


Source: Bassi, 2015

EXAMPLE

- The model developed for the Green Economy Report is a System Dynamics model that largely draws upon the Threshold 21 family of models.
- It integrates variables and data at the macro level, while allowing for sectoral disaggregation.
- Simulates the main short-, medium- and longer-term impacts of investing in a green economy.

UNEP Green Economy Report



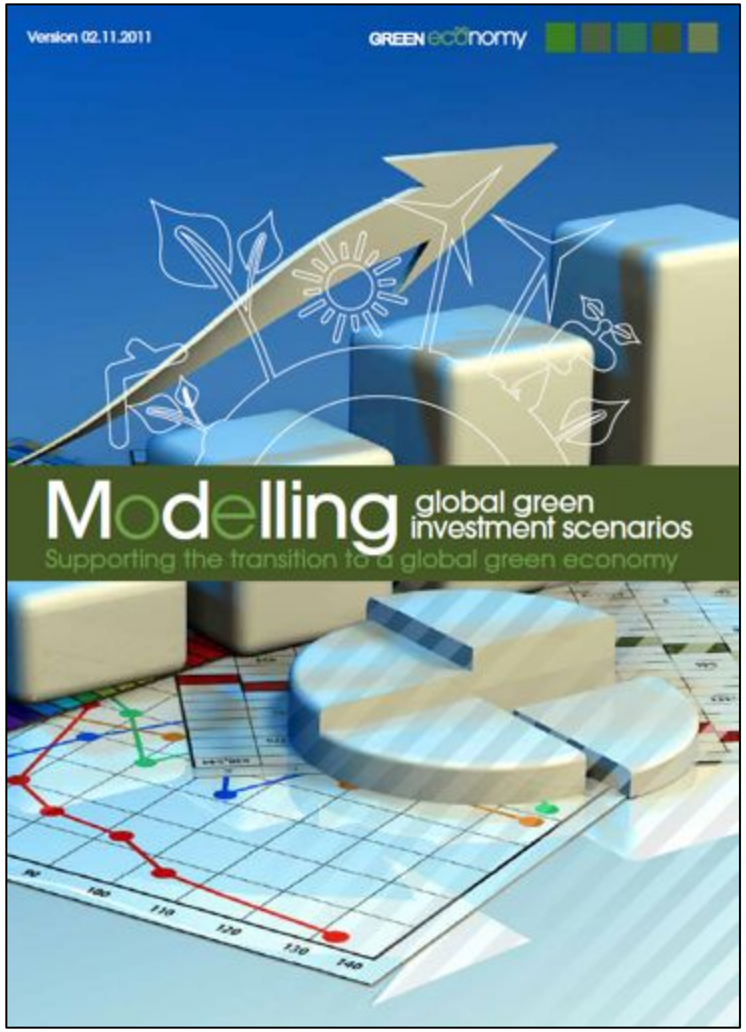
Source: UNEP, 2011

GLOBAL GREEN ECONOMY MODELLING WITH SYSTEM DYNAMICS

- An attempt to shed light on the benefits of Green Economy interventions at the global level.

- First modelling exercise of this kind, using a systems approach in a GE context.

UNEP Global Green Investment Scenarios



Source: UNEP, 2012

POLL

System Dynamics has been used very often for IGE, Circular Economy and Climate Adaptation assessments. Why?

A. Highly standardized approach and model.

B. Strong stakeholder engagement to conceptualize and create the model, creating local ownership.

C. Useful method for “knowledge integration”, which allows to better represent the IGE concept in a model.

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

COMPLEMENTARITY IS CRITICAL FOR MODELLING USEFULNESS

A transition to an Inclusive Green Economy requires a combination of policy interventions with crosscutting impacts.

Complementarity strengthens the analysis and addresses some of the weaknesses of each methodology with inputs from others.

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

3 Interpretation of Model Results

REFLECTION POINT: How the underlying method influences model results

Do you remember what the three methods were?

How do you think they influence the results of a model?

HOW THE UNDERLYING METHOD INFLUENCES MODEL RESULTS

Static models

- Tend to overestimate policy impacts (lack of feedback).
- These include I-O (e.g. SAM) and linear models.

Optimization models

- Tend to underestimate policy impacts (when producing a snapshot).
- These include CGE models, energy optimization models.

Dynamic models

- Capture short-term impacts (otherwise seen as possible overestimate).
- Capture medium to longer term impacts (otherwise seen as possible underestimate).

EXAMPLE: MODELLING THE IMPACTS OF SUBSIDY REFORM

Problem statement:
Is keeping subsidies inefficient and costs too much?

1. Fossil fuel subsidy removal increases energy prices.

2. 100% reallocation of subsidy savings improves all key indicators relative to business as usual (BAU), but it does not reduce public deficit.

Fossil fuel subsidies in Thailand: trends, impacts, and reforms.

Source: ADB, 2015

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

EXAMPLE: MODELLING THE IMPACTS OF SUBSIDY REFORM

Problem statement:
Who will be impacted if we remove subsidies?

3. No compensation has negative impacts on all households, but it reduces emissions and lowers public deficit.

Problem statement:
What are the impacts of providing compensation?

4. Reallocation to all households shows generally better impacts than compensating only the bottom 40%, but it is not as effective in lowering public deficit.

MODELLING APPROACH

Three groups of models used:

Social Accounting Matrix (SAM) for short-term economic impacts (static assessment), including detailed distributions analysis;

CGE and macroeconometric model for assessing macroeconomic impacts, short, medium and longer term;

MARKAL models for assessing impacts for the energy sector.

Sectoral and geographically disaggregated impact analysis for households (e.g., savings).

Reallocation of funding. Distributional effects and opportunities.

Economic flows across the key actors of the economy.

SAM

Social Accounting Matrix

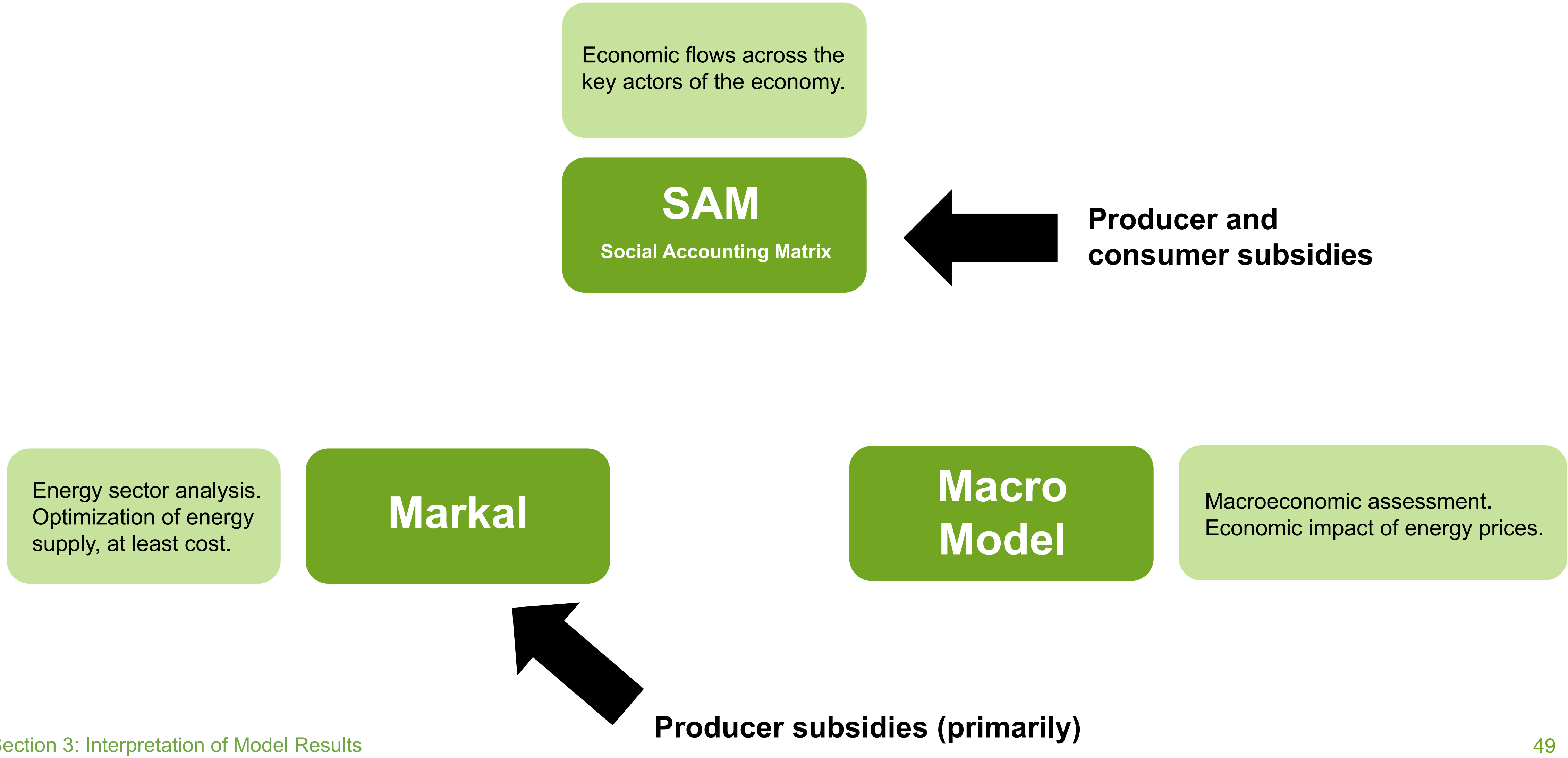
Energy sector analysis. Optimization of energy supply, at least cost.

Markal

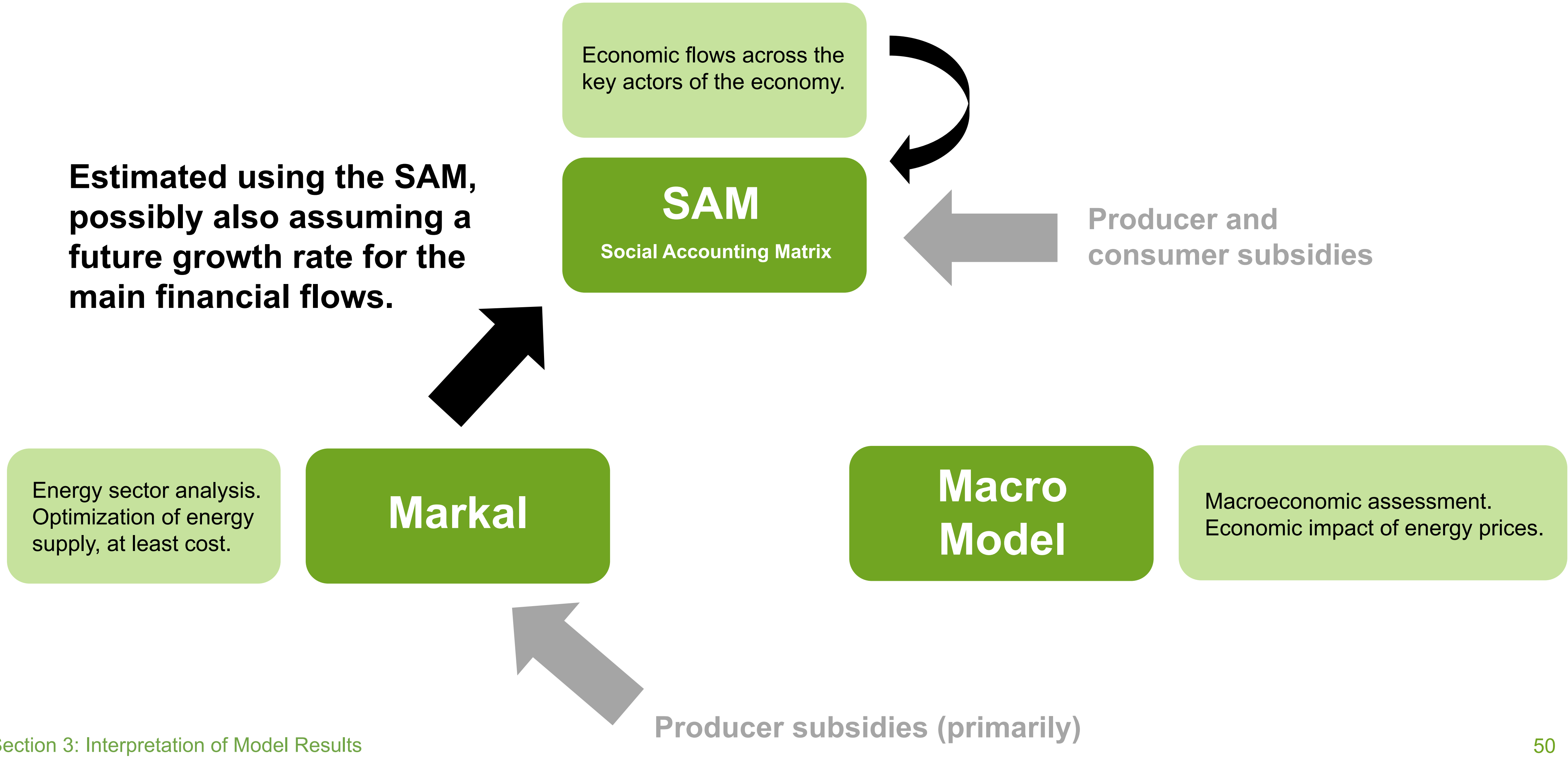
Macro Model

Macroeconomic assessment. Economic impact of energy prices.

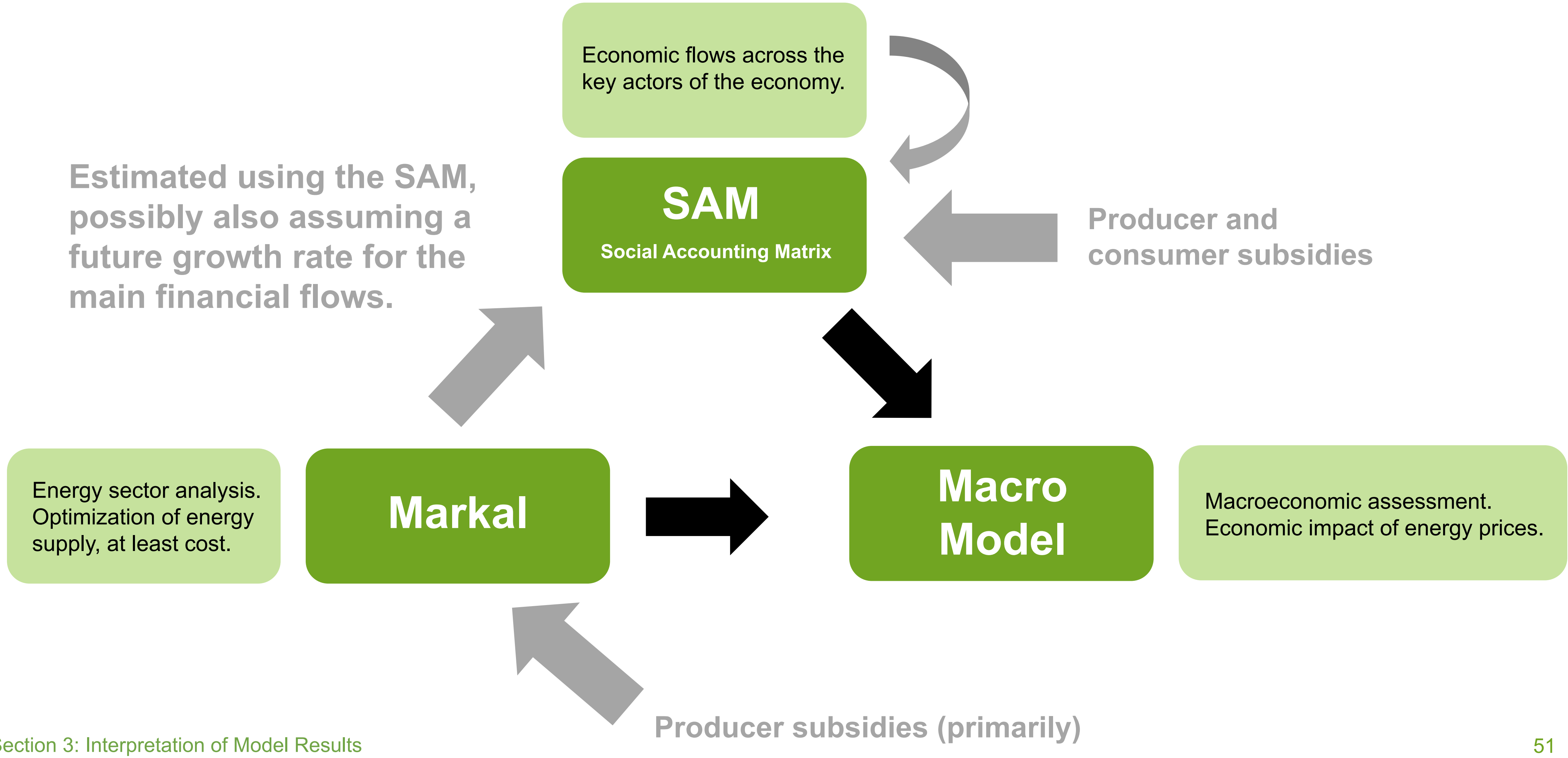
DIRECT IMPACTS



INDIRECT IMPACTS



INDUCED IMPACTS

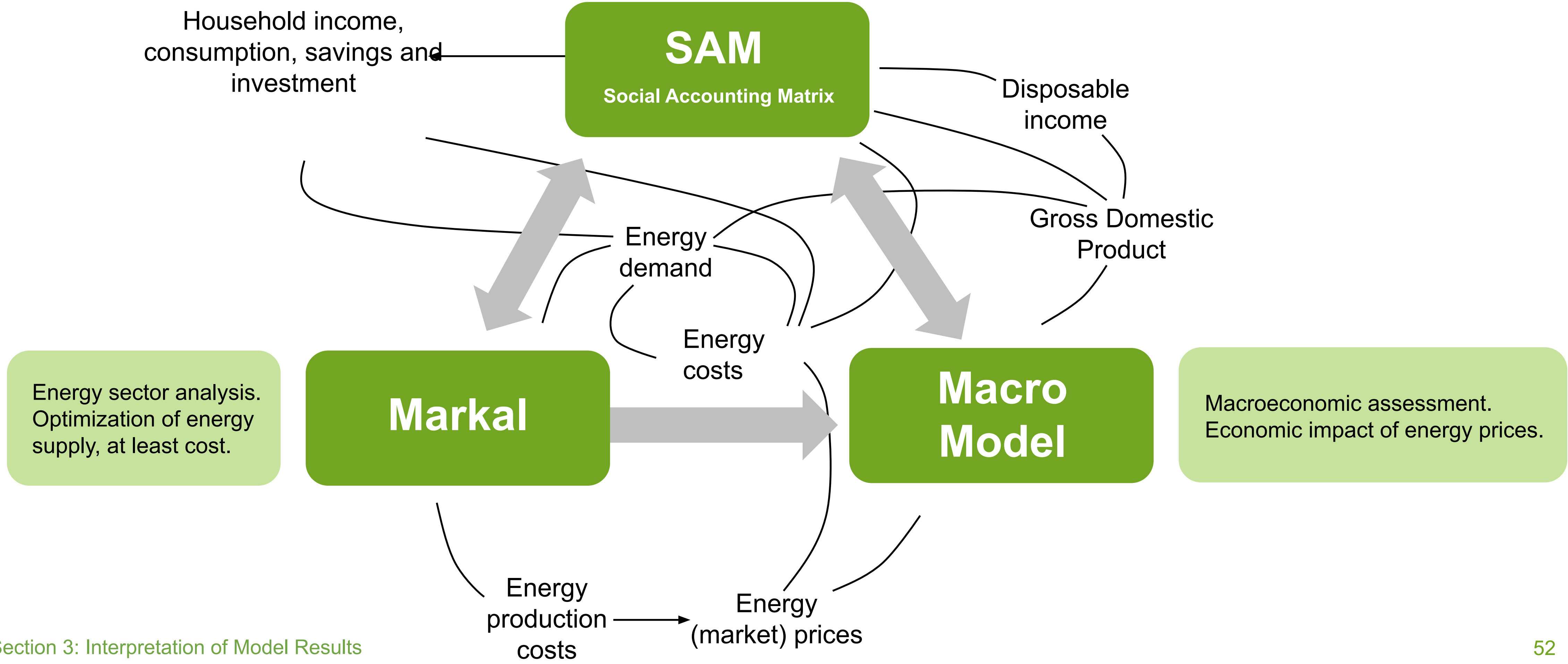


PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

Sectoral and geographically disaggregated impact analysis for households (e.g., savings).

Reallocation of funding. Distributional effects and opportunities.

Economic flows across the key actors of the economy.



MAIN CHARACTERISTICS OF THE MODELS CHOSEN – INDIA EXAMPLE

Model	Base year	Household and sectoral disaggregation	Energy sources	Impacts modelled	Reallocation assumptions
India					
SAM	2007-08 with subsidy adjustment	5 rural and 4 urban (employment-based) household groups; 78 economic sectors.	Oil, gas, coal and electricity.	Direct and indirect	Compensation to households and reallocation to government budget
MARKAL	2011	Rural and urban households; residential, commercial, industrial (with energy-intensive manufacturing sectors) and transport.	Detailed primary and secondary energy supply.	Direct	No compensation and reallocation
E3MG	2011	42 economic sectors, 5 rural and 4 urban (employment-based) household groups	Primary and secondary energy supply (22 different users of 12 different fuel types).	Direct	Compensation to households and budget/deficit reduction

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

MAIN CHARACTERISTICS OF THE MODELS CHOSEN

Model	Base year	Household and sectoral disaggregation	Energy sources	Impacts modeled	Reallocation assumptions
India					
SAM	2007-08 with subsidy adjustment	5 rural and 4 urban (employment-based) household groups; 78 economic sectors.	Oil, gas, coal and electricity.	Direct and indirect	Compensation to households and reallocation to government budget
MARKAL	2011	Rural and urban households; residential, commercial, industrial (with energy-intensive manufacturing sectors) and transport.	Detailed primary and secondary energy supply.	Direct	No compensation and reallocation
E3MG	2011	42 economic sectors, 5 rural and 4 urban (employment-based) household groups	Primary and secondary energy supply (22 different users of 12 different fuel types).	Direct	Compensation to households and budget/deficit reduction
Indonesia					
SAM	2008 with subsidy adjustment	4 rural and 4 urban (employment-based) household groups; 25 economic sectors.	LPG, NGV, gasoline, diesel, kerosene and electricity.	Direct and indirect	Compensation to households and reallocation to government budget
MARKAL	2010	Agriculture, construction, households;, commercial, industrial (with energy-intensive manufacturing sectors) and transport – with four "regions" reflecting Java, Kalimantan, Sumatra, and other islands.	Detailed primary and secondary energy supply.	Direct	No reallocation
E3MG	2011	42 economic sectors, 5 rural and 4 urban (employment-based) household groups	Primary and secondary energy supply (22 different users of 12 different fuel types).	Direct	Compensation to households and budget/deficit reduction
Thailand					
SAM	2010	Agriculture and non-agriculture, household groups by decile; 10 employment groups; 79 economic sectors.	18 sectors, including diesel, natural gas and electricity	Direct and indirect	Compensation to households and reallocation to government budget
MARKAL	2007 with subsidy adjustment	Rural and urban households; residential, commercial, industrial (with energy-intensive manufacturing sectors) and transport.	Detailed primary and secondary energy supply.	Direct	No reallocation
CGE	2007 with subsidy adjustment	65 economic sectors (24 agricultural and 41 non-agricultural), 200 household income groups	Petroleum (gasoline, diesel and natural gas).	Direct	Compensation to households and budget/deficit reduction

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

Comparative assessment of results

		India	Indonesia	Thailand
SAM: Short-term (2012), full compensation to all HH, remainder to gov. expenditure	GDP	-0.4	-1.3	2.02
Macro: Long-term (2020), compensation to all HH, remainder to gov. deficit	GDP	0.04	-0.09	-1
	% change in CPI	0.58	3.15	-1

Comparative assessment of results

		India	Indonesia	Thailand
MARKAL long-term ~2030	GHG emissions (% change)	-1.8	-5.1%	-2.8%
E3MG long-term ~2030	GHG emissions (% change)	-1.3	-9.3%	n/a

REFLECTION POINT

When asked to perform a policy assessment, do you begin with:

1. What model can I use?

2. How can I adapt my model?

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

4 In depth review: Integrated Green Economy Modelling (IGEM) framework

BACKGROUND

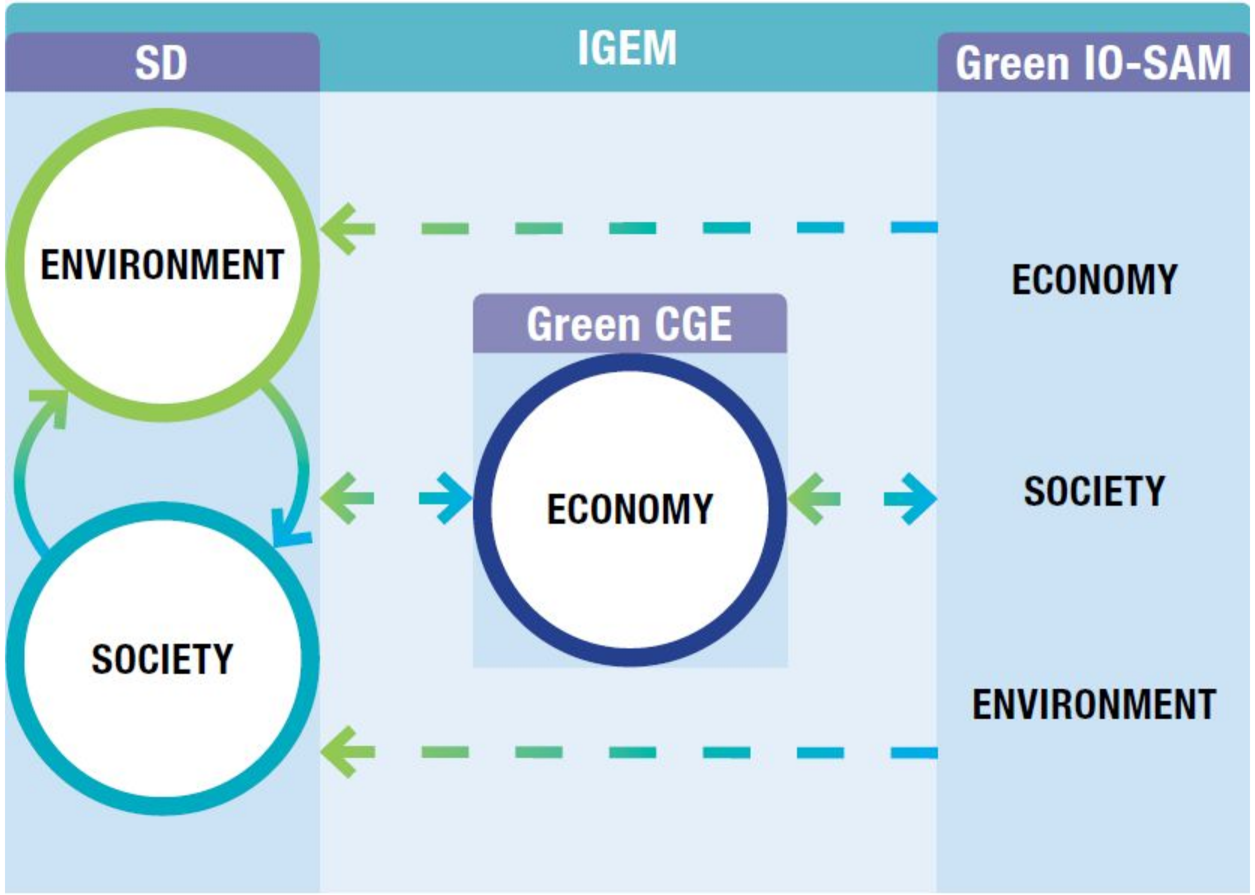
- Since the launch of the Green Economy Report (GER) in 2011, UNEP has supported countries in developing Green Economy Policy Assessments (GEPAs).
- GEPAs have been carried out in South Africa, Kenya, Rwanda, Senegal, Burkina Faso, Uruguay, Ghana, Mauritius, Mozambique, Peru, and Mongolia.

WHAT IS THE IGEM FRAMEWORK?

The **Integrated Green Economy Modelling (IGEM)** was designed to:

- Answer increasingly complex requests from governments;
- Support countries with solid quantitative tools to inform the design and implementation of green economy policies;
- Advance the process of implementing and monitoring some of the Sustainable Development Goals (SDGs).

DIAGRAM OF THE IGEM FRAMEWORK SHOWING THE LINKAGES BETWEEN THE SD, CGE AND I-O SAM MODELS



Source: PAGE, 2017

STEP 1: CREATE AN EXPANDED (OR GREEN) I-O

Disaggregating an I-O table with a green sector

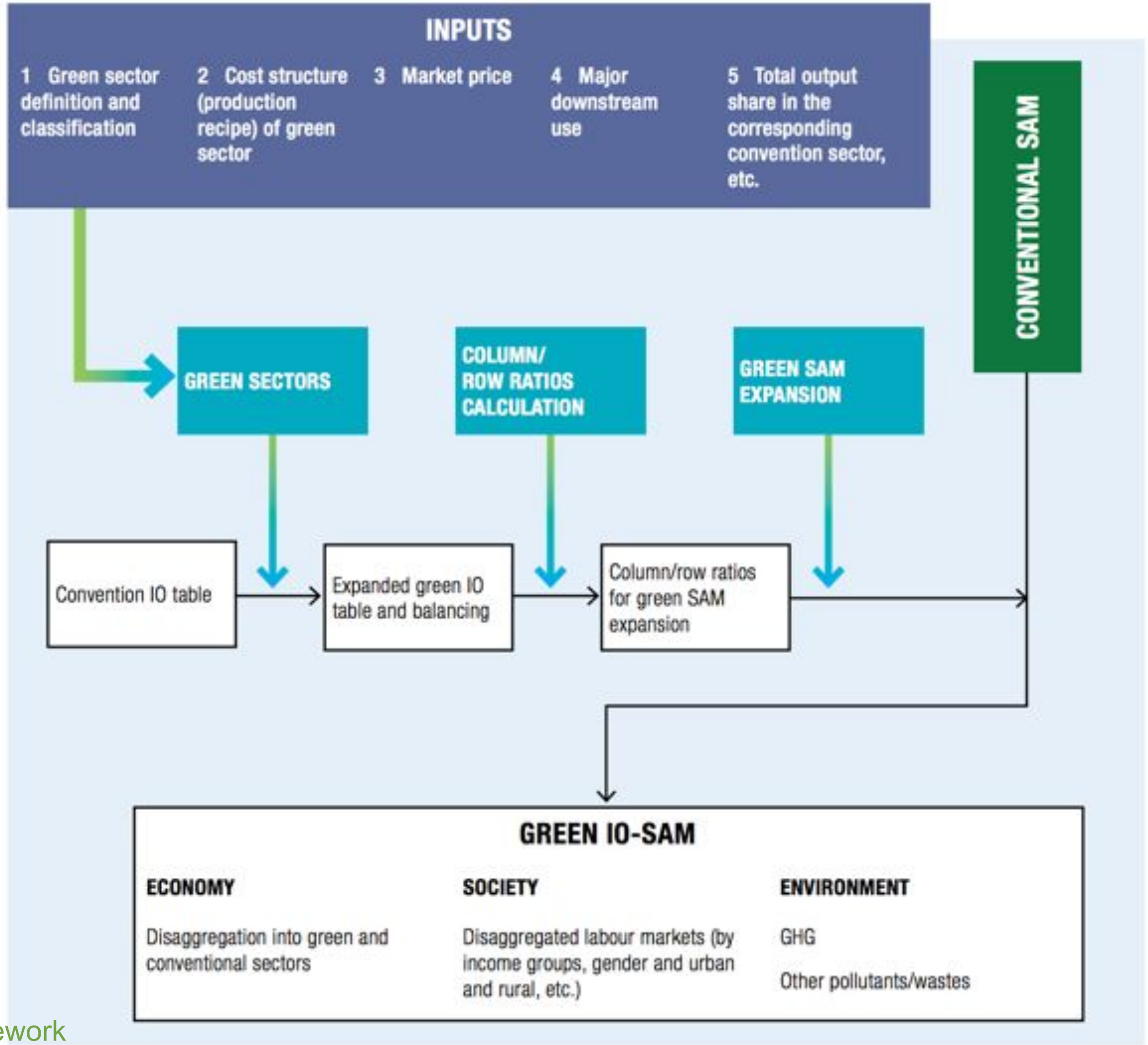
		PURCHASING SECTORS						FINAL DEMAND				TOTAL OUTPUTS (X)
		1	...	j	...	n	$n+1$					
PRODUCING SECTORS	1	x_{11}	...	x_{1j}	...	x'_{1n}	$x'_{1,n+1}$	c_1	i_1	g_1	e_1	X_1
	⋮	⋮		⋮		⋮	⋮	⋮	⋮	⋮	⋮	⋮
	i	x_{i1}	...	x_{ij}	...	x'_{in}	$x'_{i,n+1}$	c_i	i_i	g_i	e_i	X_i
	⋮	⋮		⋮		⋮	⋮	⋮	⋮	⋮	⋮	⋮
	n	$x'_{n,1}$	...	x'_{nj}	...	$x'_{n,n}$	$x'_{n,n+1}$	c'_n	i'_n	g'_n	e'_n	X'_n
	$n+1$	$x'_{n+1,1}$	...	$x'_{n+1,j}$	...	$x'_{n+1,n}$	$x'_{n+1,n+1}$	c'_{n+1}	i'_{n+1}	g'_{n+1}	e'_{n+1}	X'_{n+1}
VALUE-ADDED (v')		v_1	...	v_j	...	v'_n	v'_{n+1}	v_c	v_i	v_g	v_e	V
IMPORTS (m)		m_1	...	m_j	...	m'_n	m'_{n+1}	m_c	m_i	m_g		M
TOTAL INPUTS (X)		X_1	...	X_i	...	X'_n	X'_{n+1}	C	I	G	E	

Source: PAGE, 2017

STEP 2: CREATE AN EXPANDED (OR GREEN) SAM

Diagram on how to prepare a green SAM based on a green I-O

Source: PAGE, 2017



GREEN CGE AND GREEN I-O SAM

Diagram of the linkages between the CGE model and the I-O SAM model

Source: PAGE, 2017

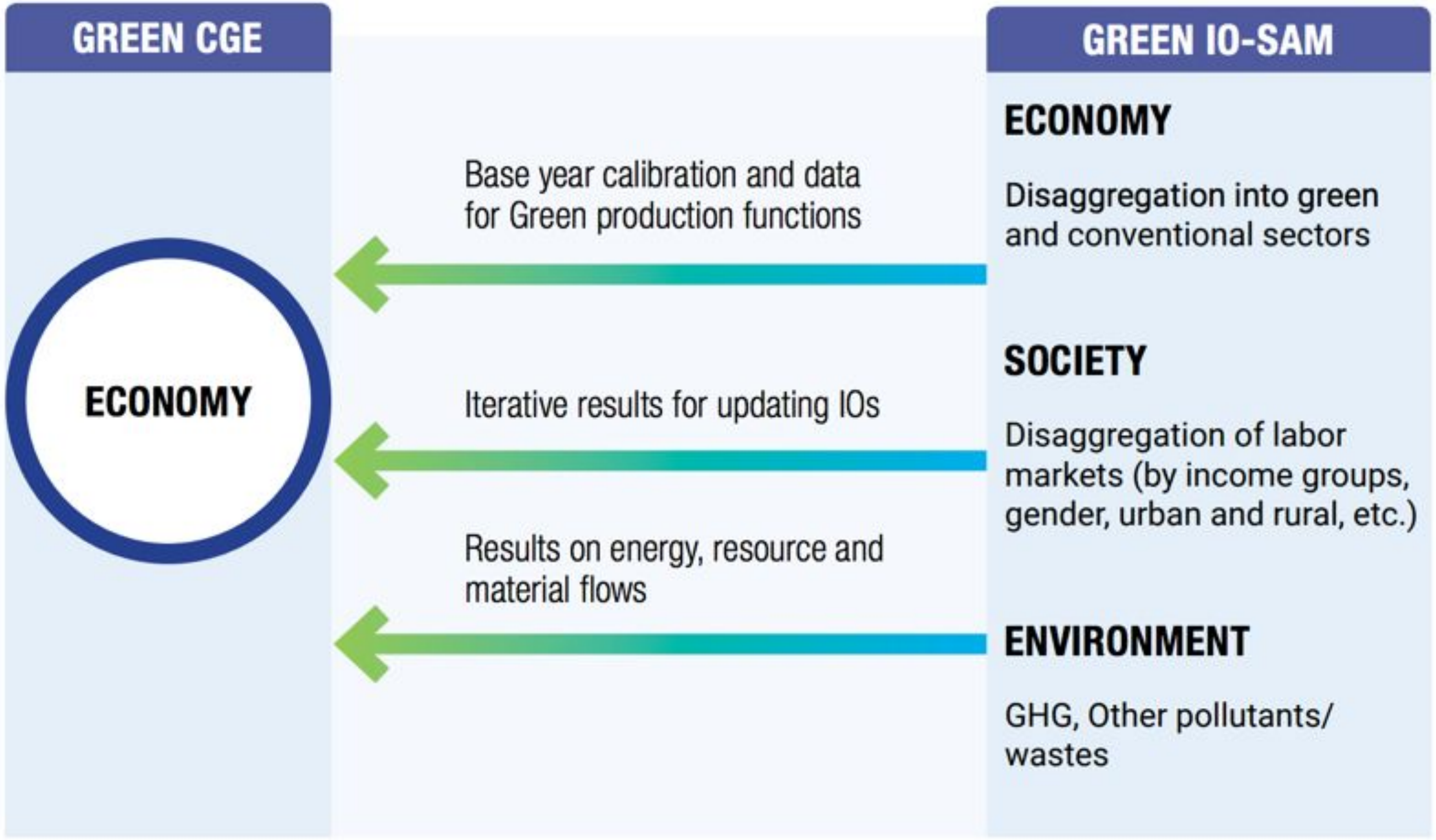
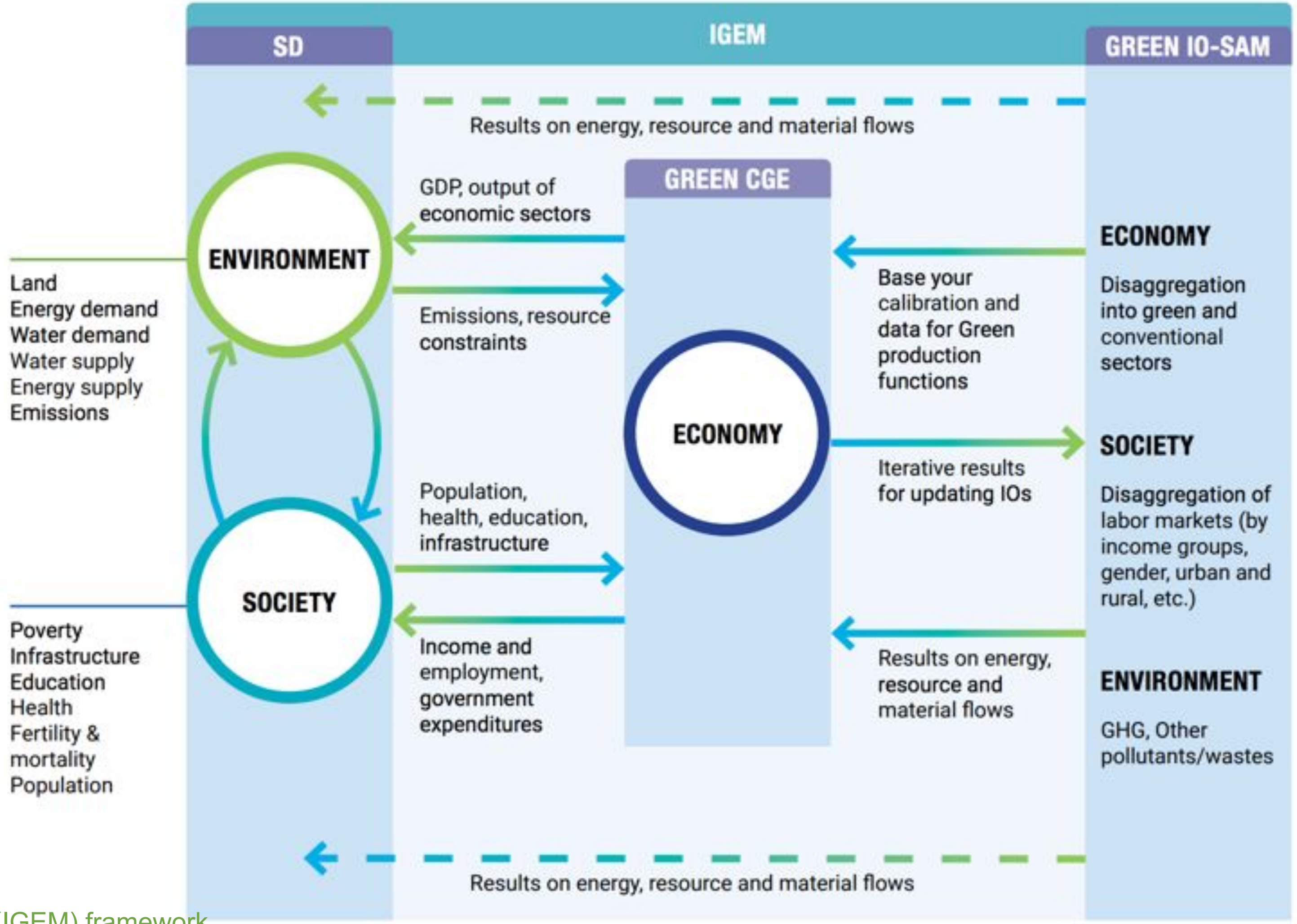


DIAGRAM OF IGEM FRAMEWORK INFORMATION STRUCTURE

Diagram of the IGEM framework information structure

Source: PAGE, 2017



TARGETS VERSUS INVESTMENT DRIVEN

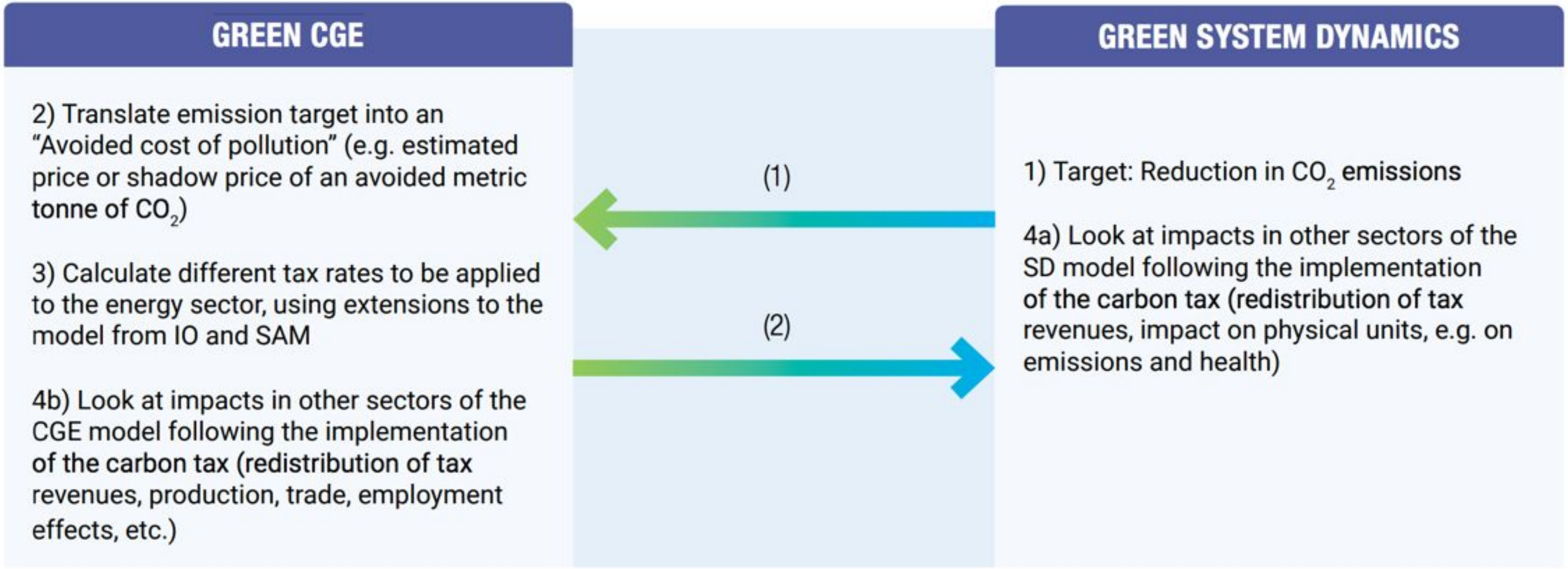
The IGEM can be applied in two ways to analyse green economy policies:

following a **target-driven** approach;

x

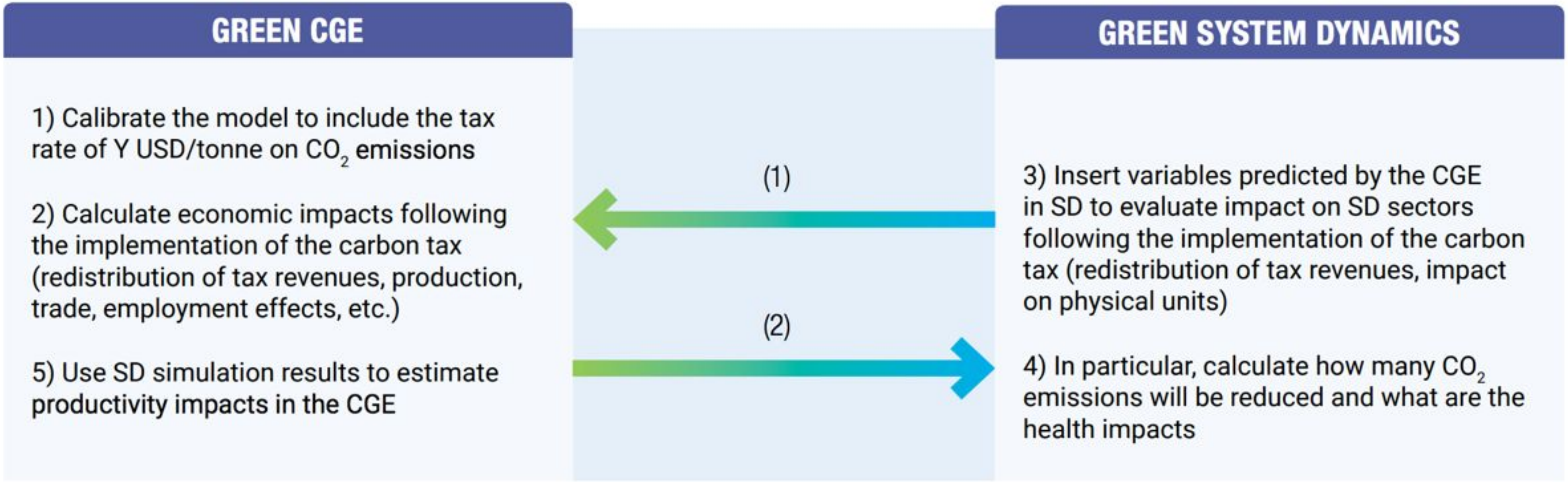
following an **investment-driven** approach.

TARGET-DRIVEN APPROACH



Source: PAGE, 2017

INVESTMENT- (OR PRICE-) DRIVEN APPROACH



Source: PAGE, 2017

CARBON TAX SCENARIOS TESTED BY THE IGEM FRAMEWORK

<table>
<tr><th>SCENARIO</th><th>TAX RATE</th><th>CGE</th><th>SYSTEM DYNAMICS</th></tr>
<tr><td>Scenario 1 - Feebate scenario with low tax rate (FBL)</td><td>3.5 USD/tCO_2eq (current carbon tax rate in Mexico)</td><td rowspan="5">1) Estimate the economic effects of feebate scenarios compared to a revenue neutral carbon tax (lump-sum) and a business-as-usual scenario

3) Use results from the SD to estimate effects of increased longevity on productivity</td><td rowspan="5">2) Estimate the social and environmental impacts resulting from the CGE simulation (health and emissions)</td></tr>
<tr><td>Scenario 2 - Feebate scenario with high tax rate (FBH)</td><td>25 USD/tCO_2eq[40]</td></tr>
<tr><td colspan="2">The two feebate scenarios will be compared to:</td></tr>
<tr><td>Rebate scenario (lump sum) with high (RH) and low (RL) tax rates</td><td>3.5 and 25 USD/tCO_2eq</td></tr>
<tr><td>Business-as-usual scenario (BAU)</td><td>No carbon tax[41]</td></tr>
</table>

Source: PAGE, 2017

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

CONCLUSIONS – on Greening

The **IGEM framework** shows:

- The CGE can be greened through the inclusion of additional sectors and/or by using a green I-O SAM as input;
- The SD model can be greened by disaggregating a particular sector to address environmental and social questions of interest to policymakers.

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

CONCLUSIONS – on Coupling

- The IGEM framework identifies the main entry points between the models and how this linkage can be reinforced following different rounds of integration.

- In Mexico, GDP growth is enhanced when the effect of lower emissions on longevity and, later, on labor productivity is taken into account. Linkages go in both directions (CGE ⟷ SD)

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

End of Module 3.

Thank you for your attention!

Annex A
Additional Information About Different Models

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

DELPHI ANALYSIS

Resources required

- Approximately 45 days; each round of questionnaires (four in total) has to be carefully prepared and analysed.

Potential for integration with other methods and tools

- Can be used in combination with other methods (receiving and providing inputs).
- Provides inputs to the formulation of scenarios and identification of suitable methods.
- Supports the validation of model results.

DELPHI ANALYSIS

Strengths

- Supports the identification of adequate quantitative methods..
- Data needs are fairly low.
- Complementary with many different analysis methods.

Weaknesses

- The emergence of new knowledge might be hampered by the process itself.
- Delphi investigators need to be cognisant and exercise caution.
- Narrow focus on experts with knowledge about technologies/policies.
- The quality of results is ultimately dependent on the participation of experts in the process of knowledge elicitation.

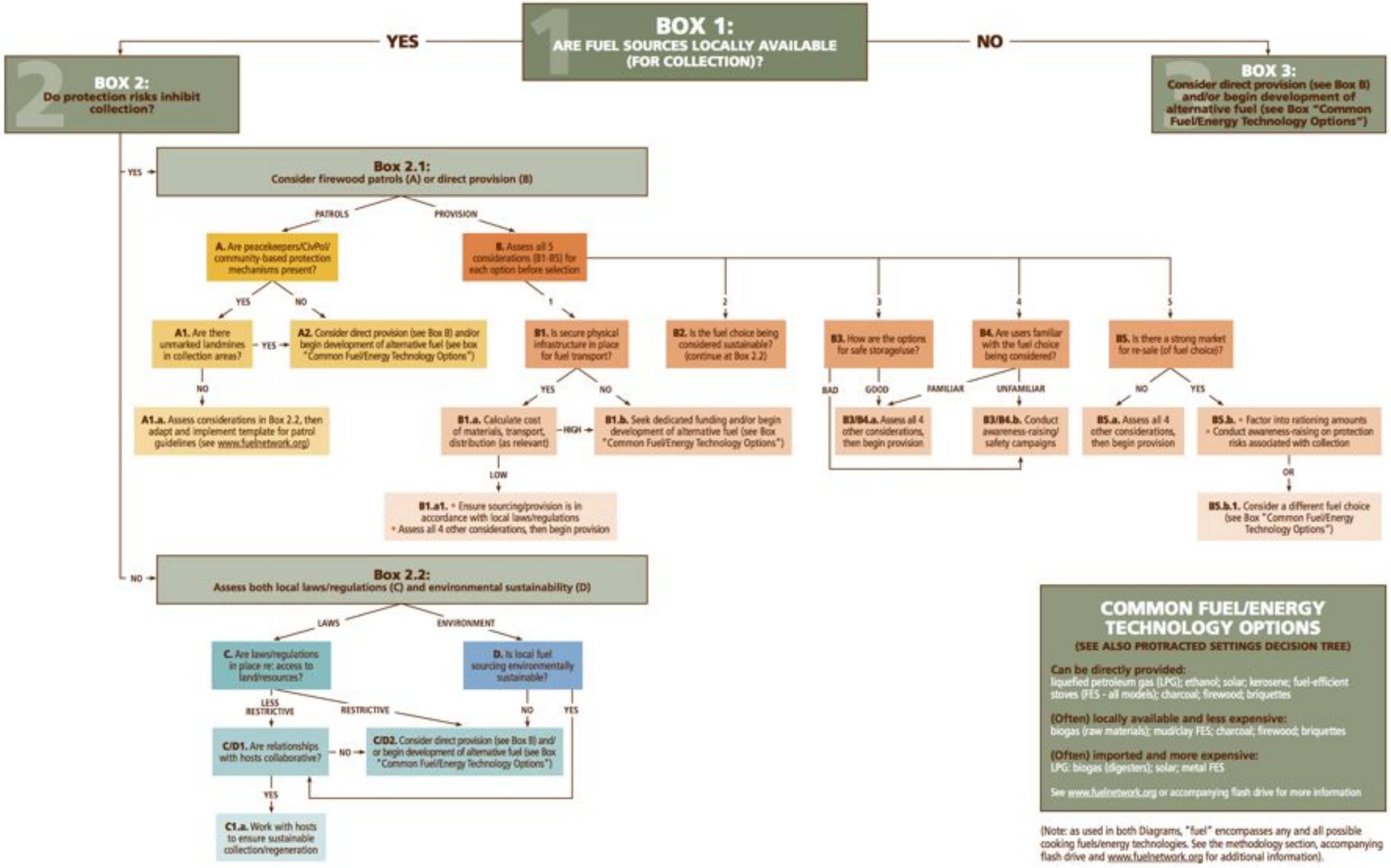
QUALITATIVE MODEL: Decision Tree (DT)

- A decision support tool that uses a binary tree-like graph or model to identify and map the relationship between inputs and outputs.
- DT explicitly maps the structure of a system and related intervention options.
- Starting from the indicator that is affected by the policy to be analysed, each branch corresponds to a possible outcome.
- DT diagrams can be qualitative and quantitative.

DECISION TREE (EXAMPLE)

Decision tree diagram for choosing a cooking fuel strategy in acute emergencies

Source: IASC, 2009



DECISION TREE

Data source(s)

- Expert elicitation or case study review.

Data Availability

- Data is generally available from other studies or historical databases.
- Depending on the size of the DT, additional research may be required to carry out validation.

Accessibility and Typical Users

- Qualitative DT are easily accessible by a wide range of audiences.
- They concern key questions or trade-offs, and typical users are policy makers and stakeholders that are involved in the decision-making process.

DECISION TREE

Resources required

- Simple decision trees are usually created within days through a multi-stakeholder workshop.
- The validation of the DT takes, depending on its size, approximately one month. Most of the work can be done in-house.

Potential for integration with other methods and tools

- Can be used in combination with various other methods, using inputs from other modelling exercises and providing inputs for the identification of suitable methods and models.

DECISION TREE

Strengths

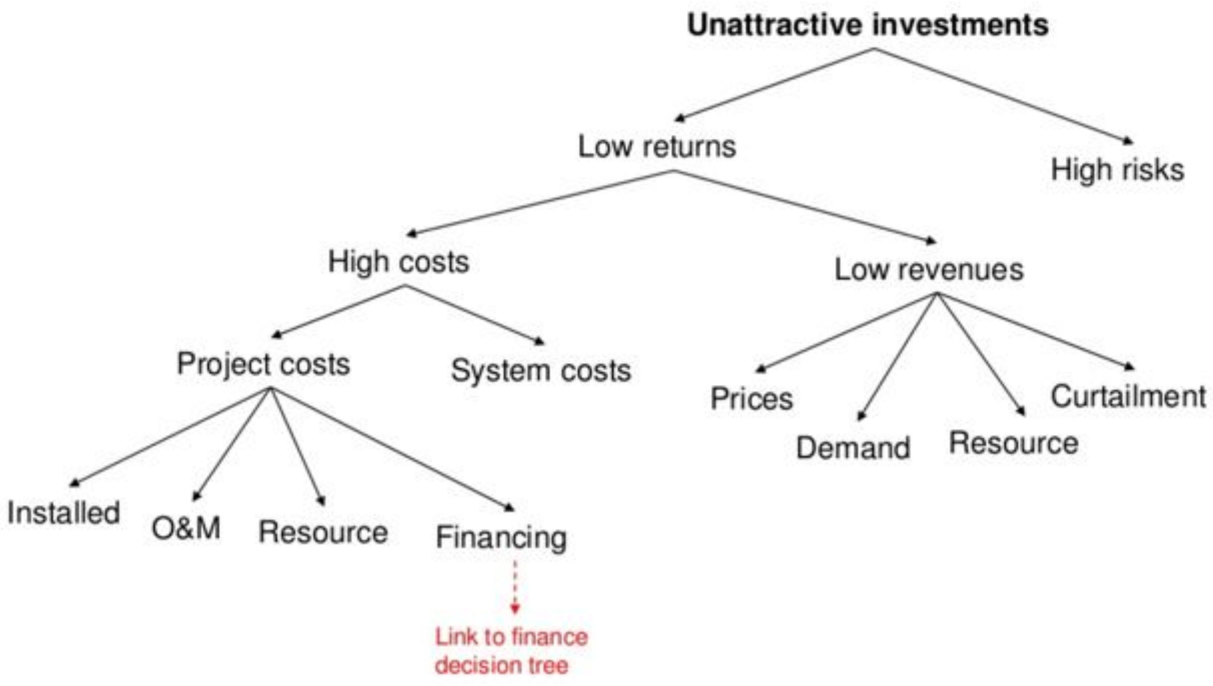
- Identifies and maps the relationship among key indicators of performance.
- Data needs for small DT are typically low, only increasing as the tree grows.
- Time requirement to develop a DT and conduct a (light) validation in a workshop setting can be as low as 1-2 days.

Weaknesses

- It often results in the creation of very complex diagrams.
- The number of nodes and output indicators grows exponentially.
- The DT diagram does not capture (feedback) loops.

EXAMPLE

- The Inter-Agency Standing Committee (IASC) developed a decision tree diagram for fuel strategies in humanitarian settings.
- The goal is to identify and map a range of fuel-related issues, and to illustrate that different local contexts require different (socio-) technological solutions.
- The tree provides guidance on strategic approaches (long- and short-term) that can be deployed to tackle the issues at hand.



Source: Pueyo, 2017

CAUSAL LOOP DIAGRAMS (CLD)

Data source(s)

- Data for causal loop diagrams can be obtained from literature and from experts, or during group model building exercises.

Data Availability

- Data for model development, such as information on the local context, is generally available.
- Both qualitative and quantitative data can be used for developing a CLD.

Accessibility and Typical Users

- Highly accessible; results consist of a system map and underlying feedback loops.
- Typical users range from researchers to decision makers.

CAUSAL LOOP DIAGRAMS

Resources required

- Very low time requirement.
- A CLD can be created in three hours (or up to 2 days) with a group of 20 – 30 stakeholders.
- Depending on the context, a whiteboard and markers, or a laptop with projector and modelling software are sufficient.

Potential for integration with other methods and tools

- Can directly support several other methods (formulate scenarios, identify policy impacts, explore the dynamics of the system and select appropriate quantitative methods).

CAUSAL LOOP DIAGRAMS

Strengths

- Identifies and represents the interconnections between indicators in the sector.
- Supports the identification of policy packages using a systemic approach.
- Highly compatible and complementary with other methods.

Weaknesses

- Quality related to the knowledge used to develop the diagram.
- The selection of experts for creating the CLD is critical.
- To avoid biased policy assessments, both systemic boundaries and relationships between variables must be captured correctly.
- The estimation of causal relations cannot be performed as the causal diagram is qualitative.

QUANTITATIVE MODEL: Household Income & Expenditure Survey (HIES)

- A statistical survey to study the economic behaviour of households.
- This survey is the primary data source for the creation of Input-Output tables and the Social Accounting Matrix.
- It is carried out with a frequency of between one and five years, and includes the following information:
    - Household characteristics, income, consumption and saving, wealth in terms of real estate, financial assets and liabilities.

HOUSEHOLD INCOME AND EXPENDITURE SURVEY

Data source(s)

- Primary survey

Data Availability

- Data is generally available through respondents.
- Quality and accuracy depends on the clarity of the survey and the participants targeted.

Accessibility and Typical Users

- HIES are generally accessible, and typically developed and maintained by national government departments, such as the ministry of finance and the ministry of social development.

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

HOUSEHOLD INCOME AND EXPENDITURE SURVEY

Resources required

- Creating a new survey, its dissemination and collection of results takes, on average, between six and 12 months.

Potential for integration with other methods and tools

- It is the primary data source for household assessments, to estimate impacts on consumption, expenditure and income.
- Outcomes can be used to customize and calibrate several models.

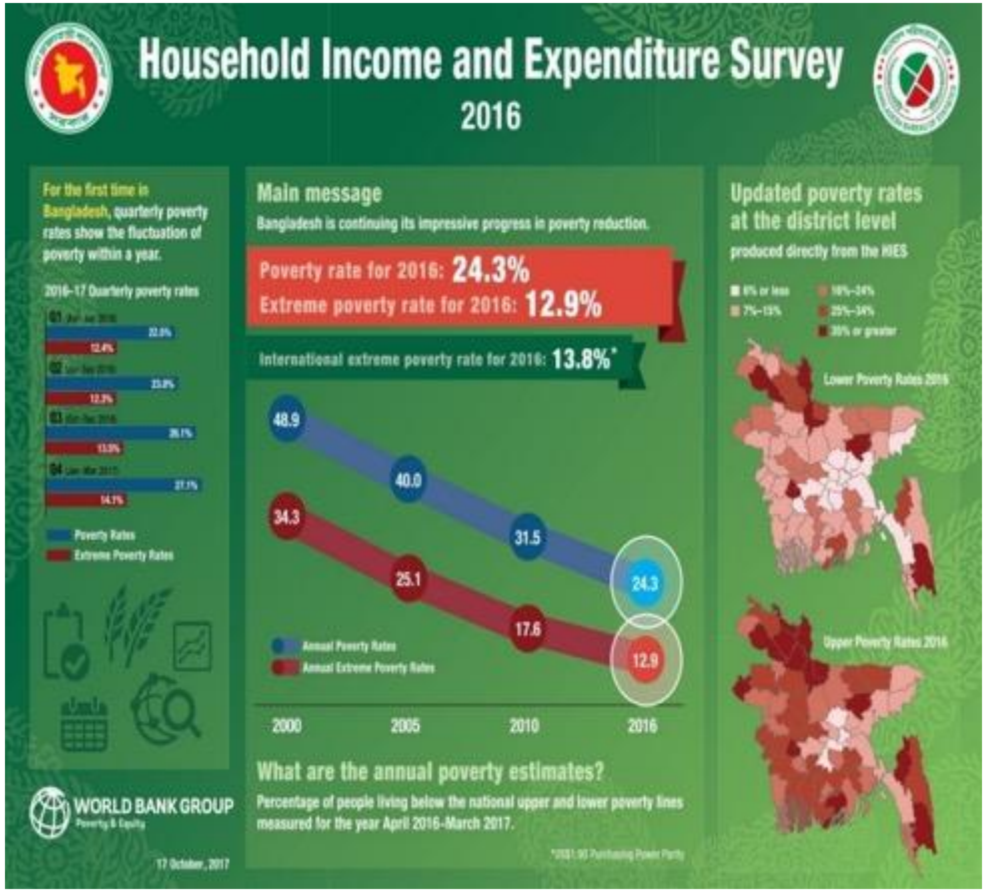
HOUSEHOLD INCOME AND EXPENDITURE SURVEY

Strengths

- Primary data source for studies assessing policy impacts on consumption, income and expenditure.
- Time required: between six and 12 months.

Weaknesses

- The design stage is crucial, regarding the quality of the survey and the pool for respondents.
- Requires a large number of households surveyed and comprehensive geographical coverage, along with a good representation across income classes.
- Not possible to customize an existing HIES database; any customization requires preparing a new survey.



Source: World Bank, 2017

SECTORAL INPUT-OUTPUT (I-O) TABLES

Data source(s)

- National and sectoral statistics.

Data Availability

- Data from national statistics (at the country level) is generally available.
- Sectoral data on material and energy flows may be lacking.

Accessibility and Typical Users

- I-O tables are accessible, and developed and maintained by the Ministry of Finance, the Central Bank or the National Statistical Office (for economic I-O tables), sectoral ministries (for biophysical I-O tables) and universities (for integrated and multi-country I-O tables).

SECTORAL INPUT-OUTPUT (I-O) TABLES

Resources required

- Building a new I-O table is a labour- and resource- intensive process.
- The time required to develop a new model depends on the number of sectors considered and can take between two months and a year.

Potential for integration with other methods and tools

- Can be used to parameterise and initialise other quantitative models.
- Provides an indication of ripple effects across sectors for possible short-term policy impacts.

SECTORAL INPUT-OUTPUT (I-O) TABLES

Strengths

- I-O models capture ripple effects (upstream and downstream) across the value chain.
- Used as input for more complex and sophisticated national and/or sectoral models.

Weaknesses

- The effort required to create an I-O table can be regarded as a limitation.
- Strong focus on the interdependence between industries but lack of other interdependences.
- Generally assumes fixed prices and fixed I-O multipliers (or ratios).

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

QUANTITATIVE MODEL: Social Accounting Matrix (SAM)

- A comprehensive, economy-wide input-output table with details of all transactions that have taken place between economic agents in an economy.
- A SAM displays the macro- and meso-economic accounts of a socio-economic system in a square matrix, ensuring that all inflows equal the sum of the outflows.
- The SAM can be regarded as an extension of an I-O table.

EXAMPLE

- SAM analysis for evaluating renewable energy initiatives in Egypt.
- The analysis aimed at examining what initiatives would yield the highest benefits for Egypt, for GDP and household income.

Type of Multiplier	Multiplier of base scenario (current level of investment)	Multipliers of 1st scenario (DESERTEC plan)	Multipliers of 2nd scenario (secure local demand of electricity from CSP)	Multipliers of 3rd scenario (government plan till 2020)
GDP multiplier	1.62	2.12	1.67	1.72
Income multiplier	2.15	2.19	2.04	2.16
Output Multiplier	4.04	4.32	4.46	4.21

Source: Farag and Komendantova, 2014

SOCIAL ACCOUNTING MATRIX (SAM)

Data source(s)

- Input-output tables, System of National Accounts (SNA), industrial statistics, consumption expenditure surveys and foreign trade statistics.

Data Availability

- High data requirements but data is generally available (e.g. GTAP database).
- Multipliers need to be derived ad hoc.

Accessibility and Typical Users

- Access is generally constrained to trained personnel but most SAMs are developed in Excel, which reduces barriers.
- Commonly used for analysing how policy impacts are distributed over economic actors.

SOCIAL ACCOUNTING MATRIX (SAM)

Resources required

- Creating a simple SAM from the SNA may take a month, a detailed SAM up to a year.
- Modifications can be performed in the range of two to four months.

Potential for integration with other methods and tools

- Can be used to parameterise and initialise other quantitative models.
- Provides an indication of ripple effects across sectors for possible short-term policy impacts.

Social accounting matrix structure in symbols

	1. Good and services	2. Production	3. Generation of income	4.a House holds	4.b Other institutions	5. Capital	6. Gross fixed capital formation	7. Finance	8. RoW current	9. RoW capital	Total receipts
1. Good and Services		$B\hat{x}$		$C\hat{y}$			f				q
2. Production	$D\hat{q}$										x
3. Generation of income		$W\hat{x}$									v
4.a Households			$Y\hat{v}$				h				y
4.b Other institutions	Net taxes on products		Other income	Transfers	Transfers				Transfers		
5. Capital				Savings	Savings			Borrowing		Capital Transfers	
6. Gross fixed capital formation						Gross fixed capital formation					
7. Finance						Lending				Net lending to RoW	
8. RoW current	Imports of products			Transfers	Transfers						
9. RoW Capital									Current external balance		
Total expenditure	q'	x'	v'	y'							

Source: ILO, 2017

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

SOCIAL ACCOUNTING MATRIX (SAM)

Strengths

- Extension of an I-O table, with an emphasis on private households and their socioeconomic relations.
- Large degree of flexibility regarding the disaggregation of the displayed information.

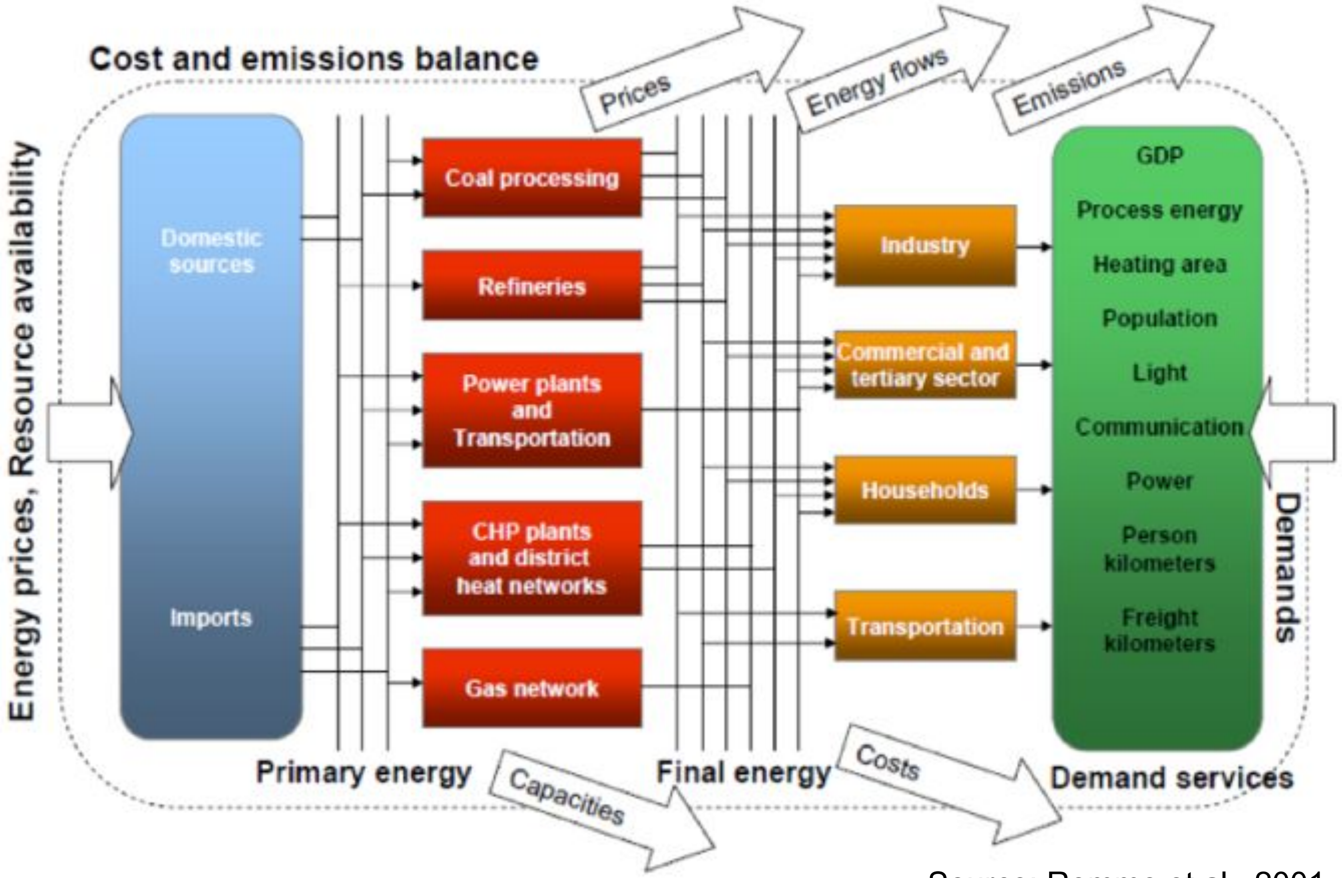
Weaknesses

- Might miss important policy outcomes due to a lack of data for the base year.
- Not suitable for investigating the medium- and long-term impacts of policy implementation.
- SAMs typically do not include physical flows.

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

QUANTITATIVE MODEL: Partial Equilibrium models

- A family of models that covers a single sector, generally at a high-level of detail.
- PE models typically use a “bottom-up” approach, placing emphasis on individual technologies.
- PE models primarily use optimization and simulation.



Source: Remme et al., 2001

PARTIAL EQUILIBRIUM MODELS

Data source(s)

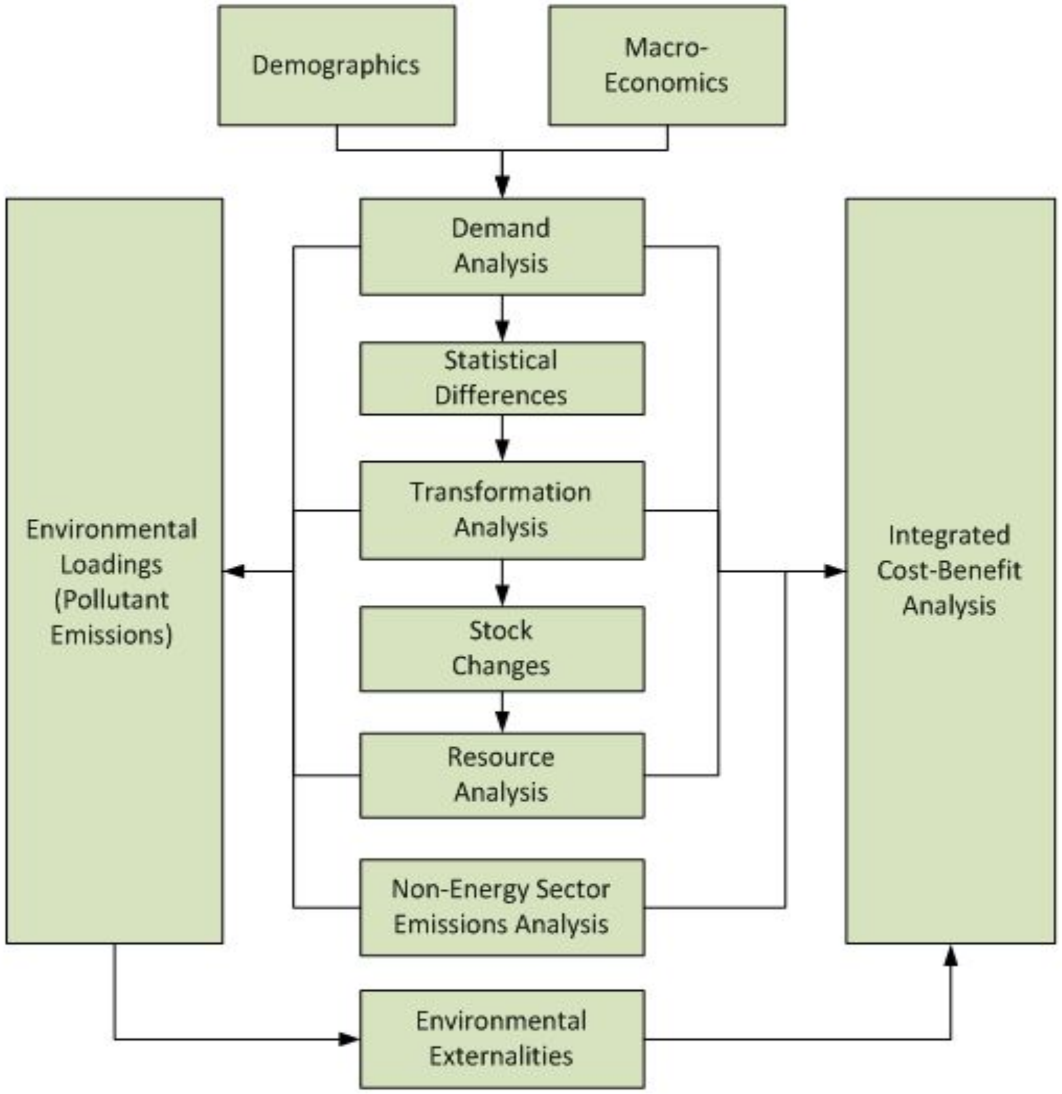
- Sectoral data, databases with technology parameters, such as cost, lifetime and efficiency, and potential adoption rates.

Data Availability

- Available from national and international databases.

Accessibility and Typical Users

- Specialised users, with depth of knowledge of the sector.
- Commonly used in sectoral analysis (country and regional).
- Typically developed and maintained by line ministries and academia.



Source: SEI, 2019

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

PARTIAL EQUILIBRIUM MODELS

Resources required

- Building and calibrating a new PE model requires two to six months, depending on the level of detail represented.

Potential for integration with other methods and tools

- Can be used in combination with macroeconomic models, to provide more realism using a bottom-up approach.

PARTIAL EQUILIBRIUM MODELS

Strengths

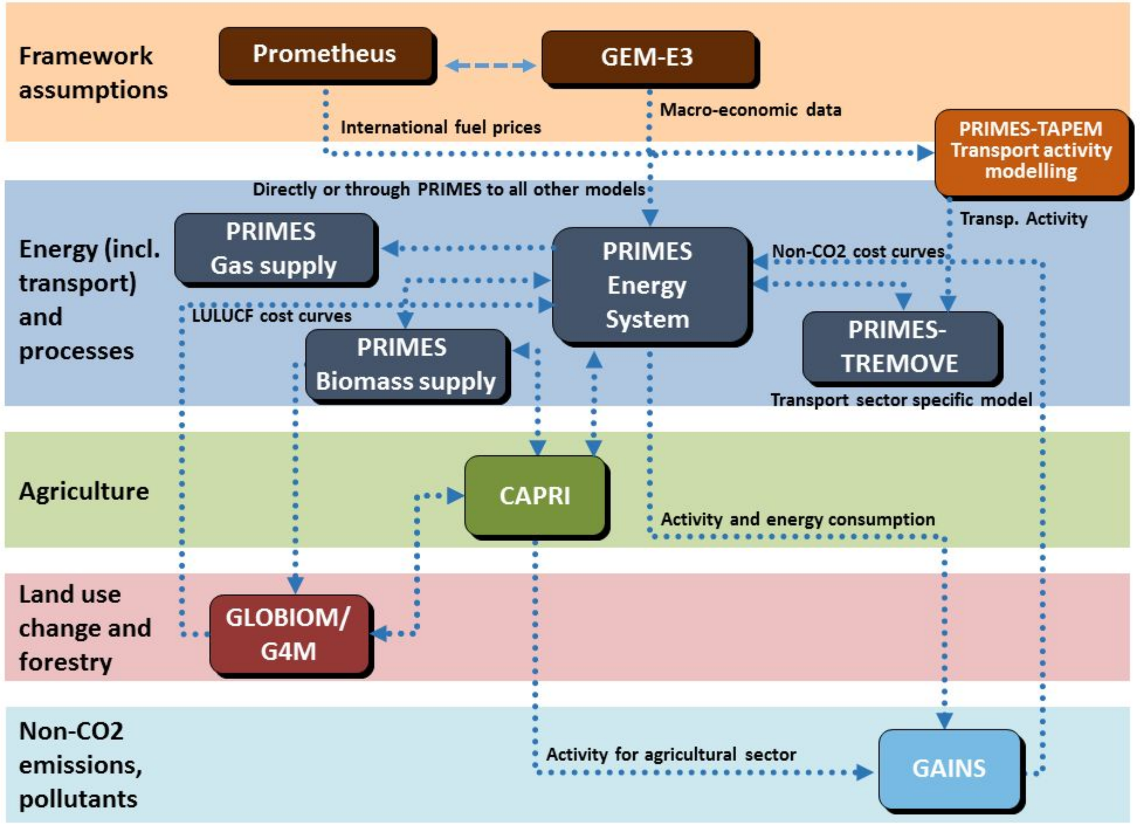
- Typically uses a “bottom-up” approach, placing emphasis on individual technologies.
- Provides a realistic representation of the impact of adopting various technologies.

Weaknesses

- Reliance on sectoral boundaries leads to lack of dynamics (and feedback loops).
- Limited coverage of social, economic and environmental indicators.
- Focus on short-term impacts, given that longer term impacts are reflected in general equilibrium effects.

EXAMPLE

- PRIMES is a partial equilibrium model of the energy market (E3MLab/ICCS, 2014).
- It finds a price at which consumer and producer surplus are maximized, and at which supply equals demand.
- Policy instruments examined include: emission and/or renewables targets, price-based policies, regulations, infrastructure policies and Emissions Trading Schemes.



Source: European Commission, 2020

COMPUTABLE GENERAL EQUILIBRIUM (CGE)

Data source(s)

- Input-output table and/or Social Accounting Matrix.

Data Availability

- Use data from SAMs and/or input-output tables, so data is often dated.
- Additional data disaggregation may be required.

Accessibility and Typical Users

- Highly specialised.
- Generally very limited number of operational CGEs in a country.
- Developed and maintained by Ministry of Finance, Central Bank, academia, Multilateral Development Banks.

COMPUTABLE GENERAL EQUILIBRIUM (CGE)

Resources required

- Building and calibrating a new CGE takes about 12 months.
- Using an existing model is likely to require some changes. An experienced user would need, on average, three to four months.

Potential for integration with other methods and tools

- Uses a SAM as input.
- Can be coupled with sectoral models, such as energy, for the addition of a bottom-up analysis, such as on technology.

COMPUTABLE GENERAL EQUILIBRIUM (CGE)

Strengths

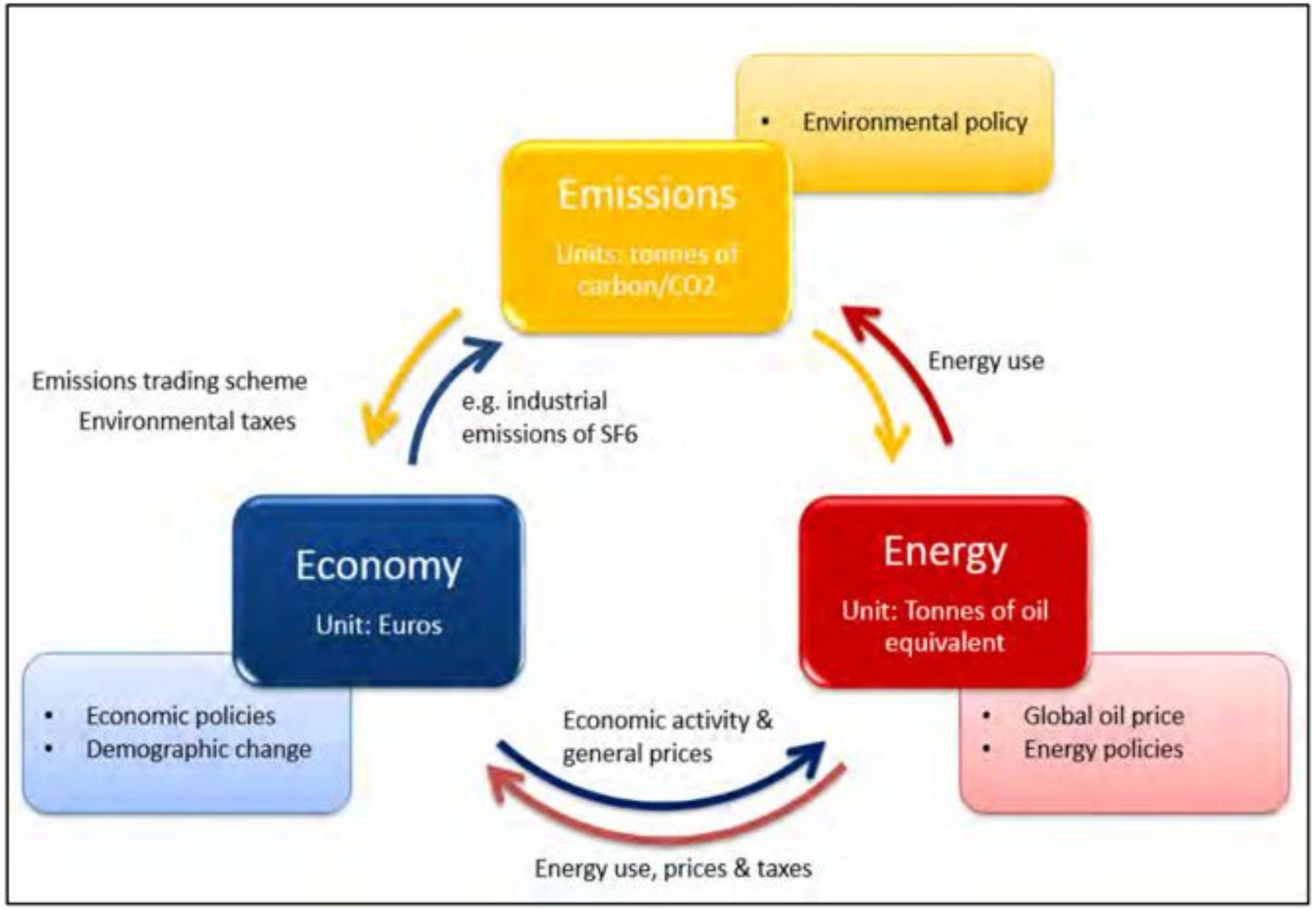
- Widely used to analyse aggregate welfare and distributional impacts of policies.
- Estimates first-, second- and third-order effects.
- Allows for indicators on a full set of impacts across an economy.

Weaknesses

- Assumption that optimisation is possible.
- Normally works under the assumption of full employment.
- Typical versions of the model do not incorporate social and human capital as a key factor of production.

QUANTITATIVE MODEL: Macroeconometrics

- Uses economic theory and statistical techniques to determine how a change in one variable is correlated with changes in others.
- Top-down models used to analyse policy outcomes primarily on economic variables.
- Used to assess similar questions to those evaluated by CGE models.



Source: Cambridge Econometrics, 2019.

MACROECONOMETRICS

Data source(s)

- Historical time series from the System of National Accounts, input-output table and/or Social Accounting Matrix.

Data Availability

- National data available from various sources.
- SAMs and/or input-output tables can also be used for model relationships.

Accessibility and Typical Users

- Highly specialised.
- Limited number of operational macroeconometric models in a country.
- Often developed by international organisations, universities and the Ministry of Finance.

MACROECONOMETRICS

Resources required

- Building a new macroeconometric model requires at least four to six months.
- Using an existing model is likely to require some changes, which an experienced user could complete in one to two months.

Potential for integration with other methods and tools

- Can be used in combination with a SAM, especially for short-term assessments and for adding detail, such as disaggregation by income classes.
- Can also be coupled with sectoral models, such as energy, for the addition of a bottom-up analysis, such as on technology.

MACROECONOMETRICS

Strengths

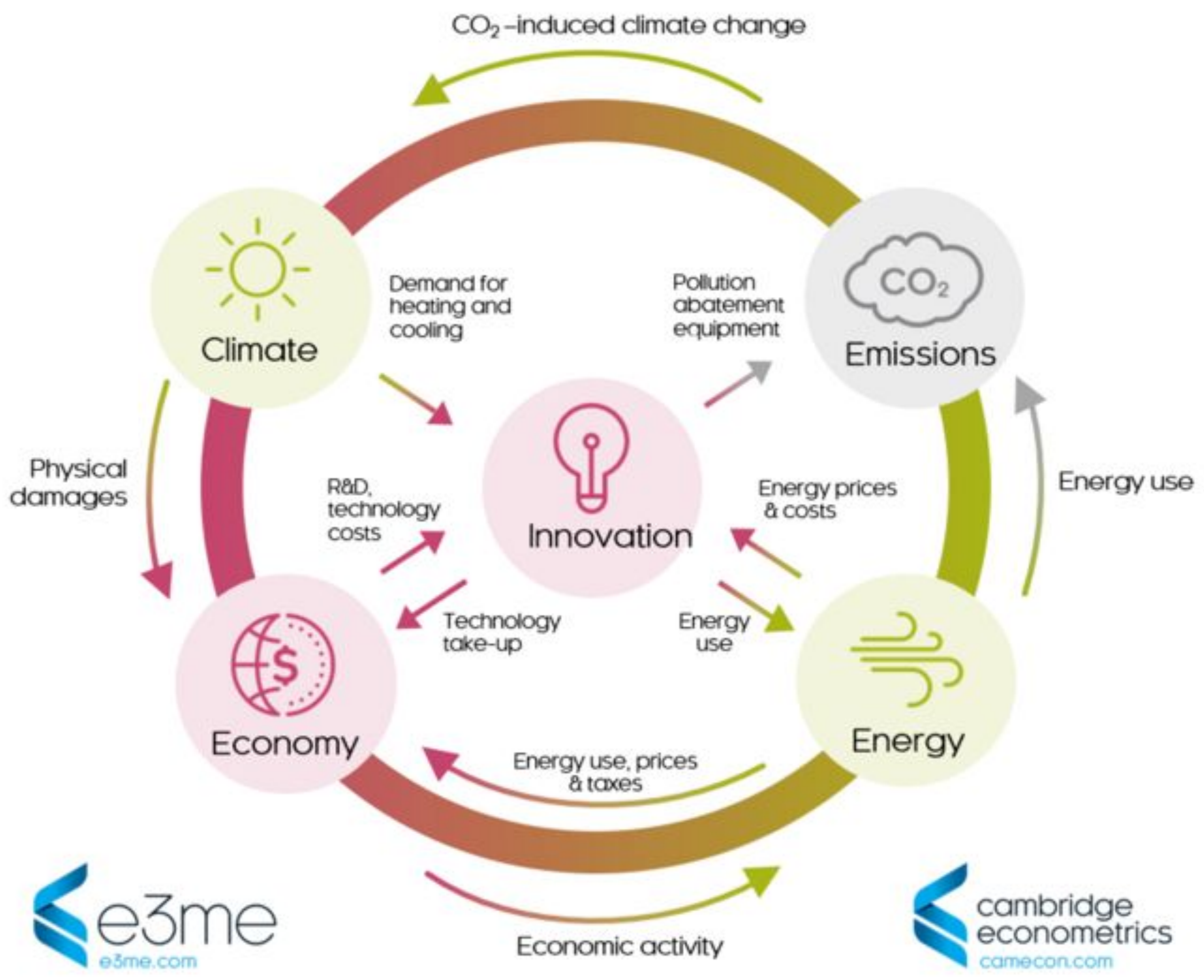
- Measures how an economy has evolved based on actual (historical) data.
- Well-defined links between economic sectors.
- Assessment of impacts of response measures.

Weaknesses

- Top-down modelling with heavy reliance on historical data.
- Assumes that future behavior will be similar to past behaviour.
- Quality of outputs related to quality of data.
- Typical macroeconometric models do not link well to microeconomic theories.

EXAMPLE

- The E3ME is a model of the economy, energy systems and environmental emissions developed by Cambridge Econometrics.
- The E3ME consists of 22 estimated sets of equations, each disaggregated by sector and by country.
- The economic module contains 42 economic sectors, all linked by input-output relationships.



Source: Cambridge Econometrics, 2020.

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

SYSTEM DYNAMICS

Data source(s)

- Historical data obtained from national and international databases, or parameters that can be obtained through econometrics or from other models.

Data Availability

- National level generally available.
- Can also use qualitative information.

Accessibility and Typical Users

- Developed to analyse a specific problem or policy.
- Generally defined “white boxes”.

SYSTEM DYNAMICS

Resources required

- Building and validating a new System Dynamics simulation model takes, on average, between one and six months.
- Depends on the size of the model and the extent to which stakeholders are actively involved in model development.

Potential for integration with other methods and tools

- It complements other approaches with a more systemic analysis.
- Can be used in combination with I-O, macroeconometric and CGE models.
- In a multi-method approach, it is suited for providing strategic directions and identifying the emergence of possible side effects.

SYSTEM DYNAMICS

Strengths

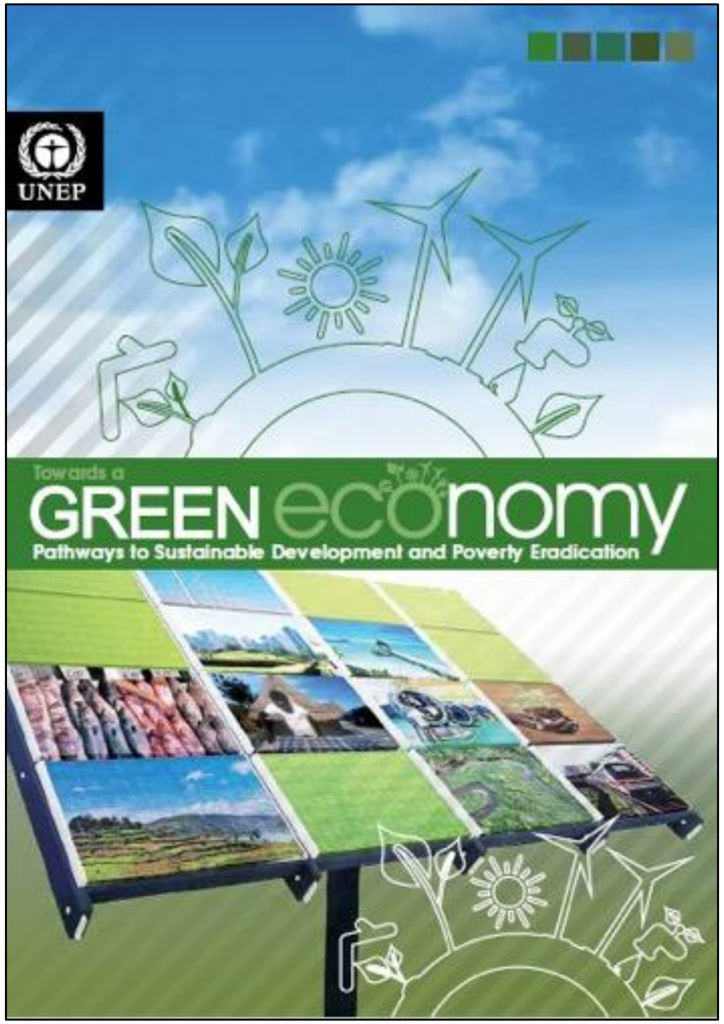
- Flexible methodology that allows the integration of social, economic and environmental indicators.
- High customisation potential.
- Captures impacts of feedbacks, delays and non-linearities over time.
- Supports policy formulation with “what if” scenarios.

Weaknesses

- Requires experience and practice to correctly estimate the underlying feedback structure of the system.
- Requires a substantial amount of interdisciplinary knowledge.
- Typical model tends to oversimplify economic behavioural relationships and resources constraints.

GLOBAL GREEN ECONOMY MODELLING

- Integrated, cross-sectoral global model.
- Simulates from 1970 to 2050.
- Based on three pillars: **causal loops** (feedbacks), **non-linearity** and **delays.**
- Integrates state of the art sectoral models.
- Replicates existing scenarios within one framework.



Source: UNEP, 2012

COMPARISON OF SCENARIOS FOR SELECTED SECTORS AND ACTIONS

Sector	BAU Scenarios[a]	Green Scenarios
Agriculture: Yield increase	Higher utilization of chemical fertilizers	Expansion of conservation agriculture, using organic fertilizers, among others
Energy: Expansion of power generating capacity	Thermal generation (fossil fuels)	Renewable energy power generation
Fisheries: Increase production	Expansion of the vessel fleet, pushing catch in the short term	Reduction of the vessel fleet, investing in stock management to increase catch in the medium and longer term
Forestry: Increase production	Increase deforestation	Curb deforestation and invest in reforestation (expanding planted forests)
Water: Manage supply and demand	Increase water supply through higher withdrawal	Invest in water efficiency measures, water management (including ecosystem services) and desalination
[a] Refers to BAU1 and BAU2 with additional investments allocated to match existing patterns.		

RESULTS: Growth and Sustainability

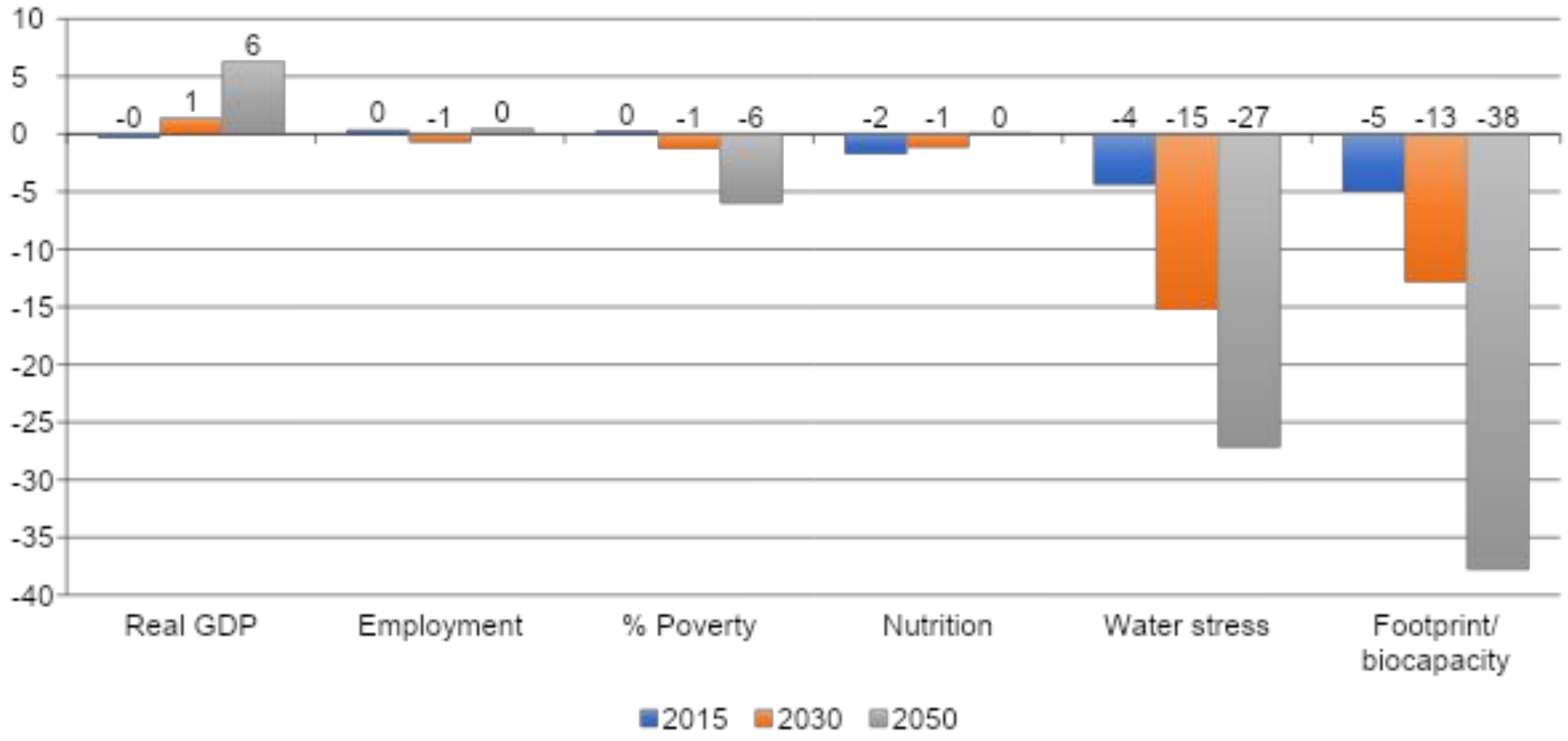
Outcomes over time

- **Short-term:** Brown scenarios perform best, then Green and BAU.
- **Medium-/long-term:** Green scenarios perform best, then Brown and BAU.

Overall

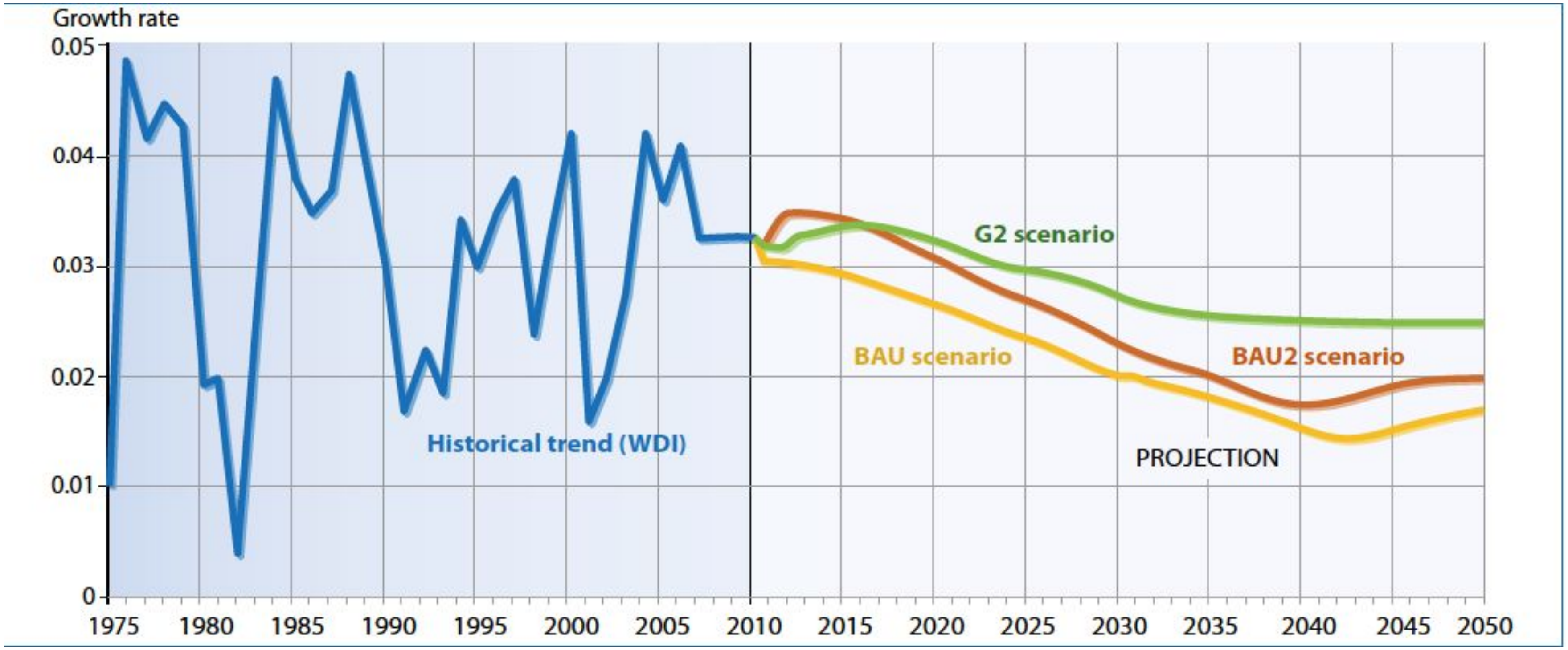
- **Higher longer-term resilience in Green scenarios.**
- **Clear cross sector synergies** allow a positive ROI for Green cases (3:1) to be reached, higher than Brown in the medium- and long-term.

RESULTS: IN A NUTSHELL (GREEN VS. BROWN) – VARIOUS INDICATORS



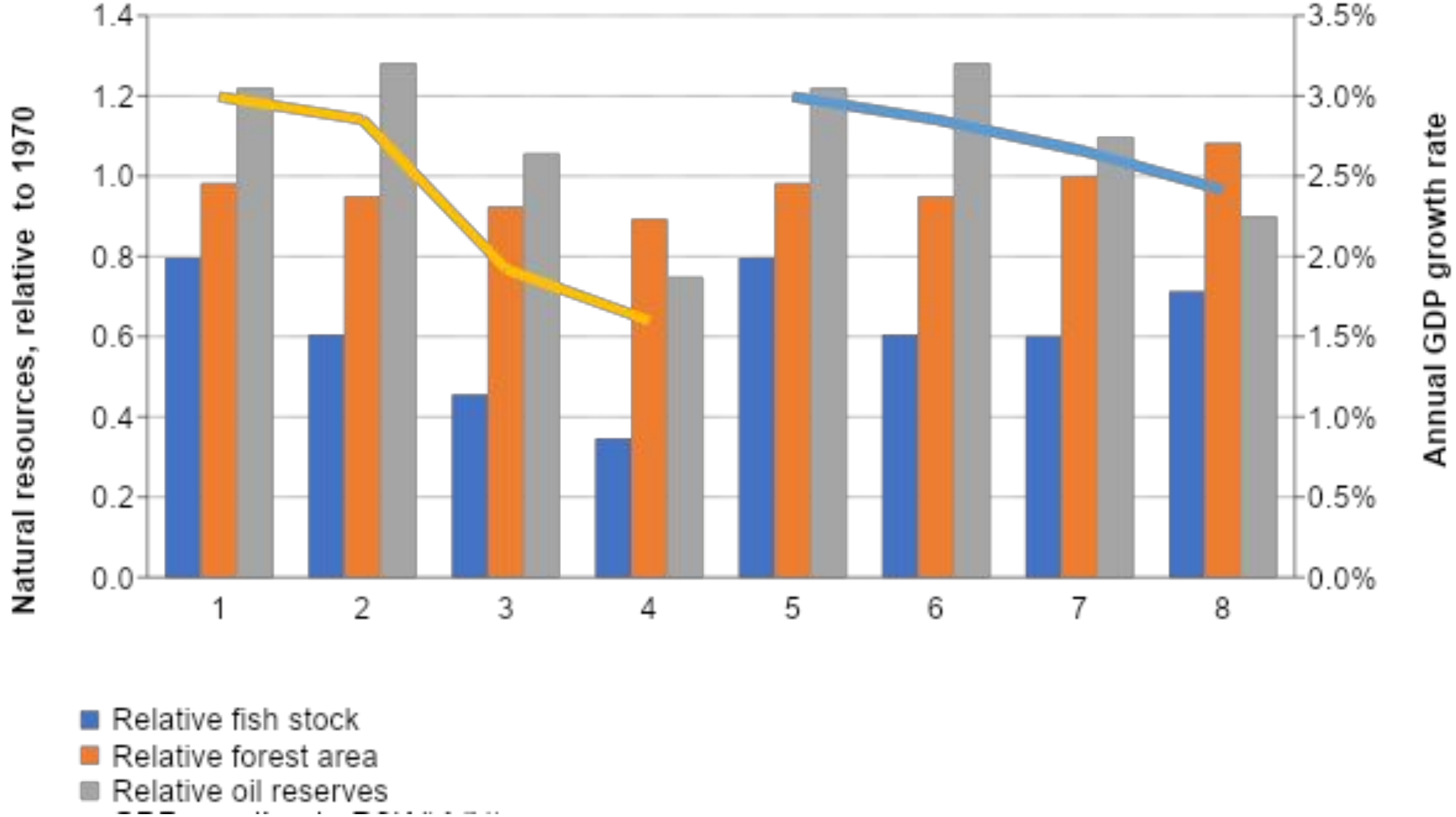
Source: UNEP, 2011

RESULTS: IN A NUTSHELL (GREEN VS. BROWN) - GDP GROWTH



Source: UNEP, 2011

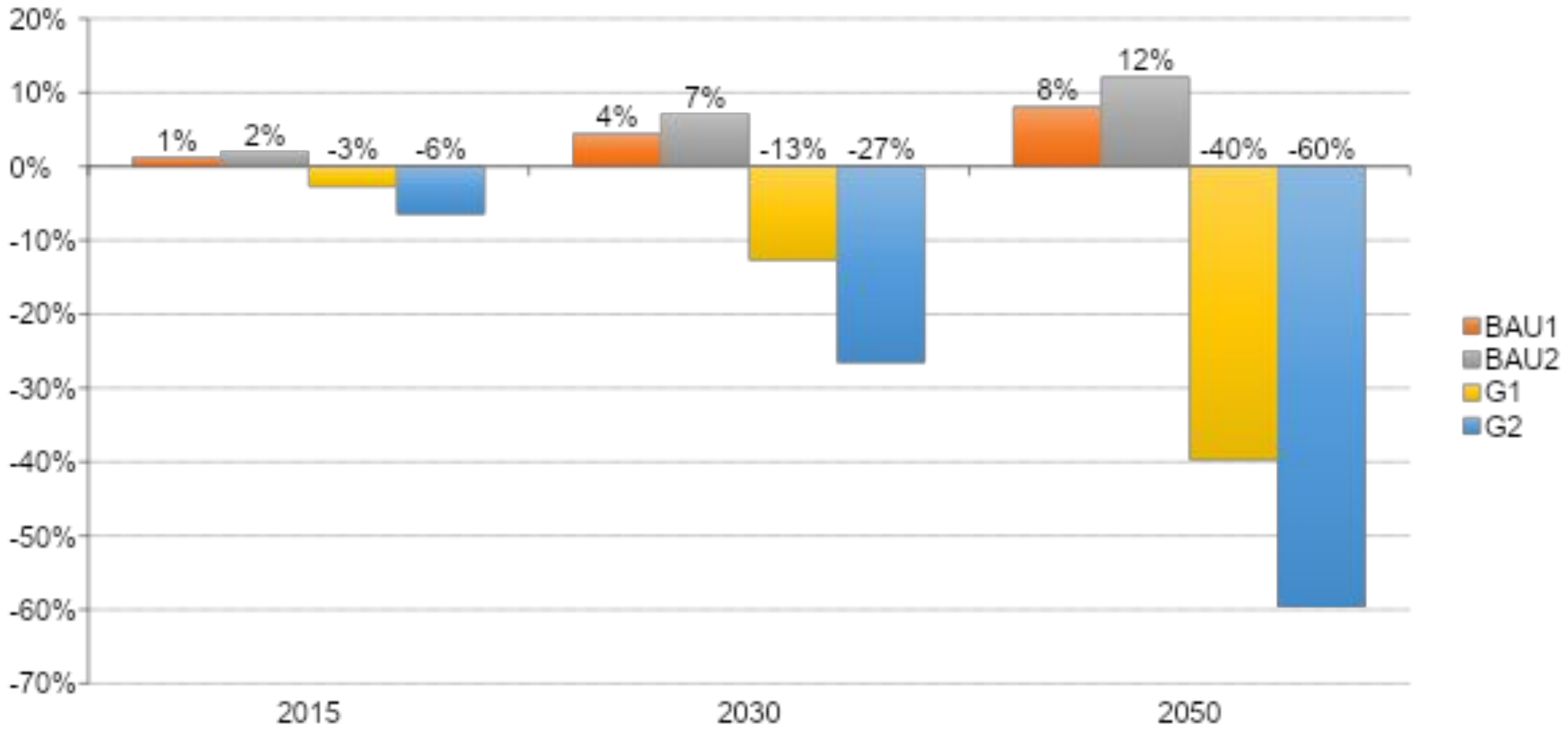
RESULTS: IN A NUTSHELL (GREEN VS. BROWN) – NATURAL RESOURCE STOCKS AND THE ECONOMY



Source: UNEP, 2011

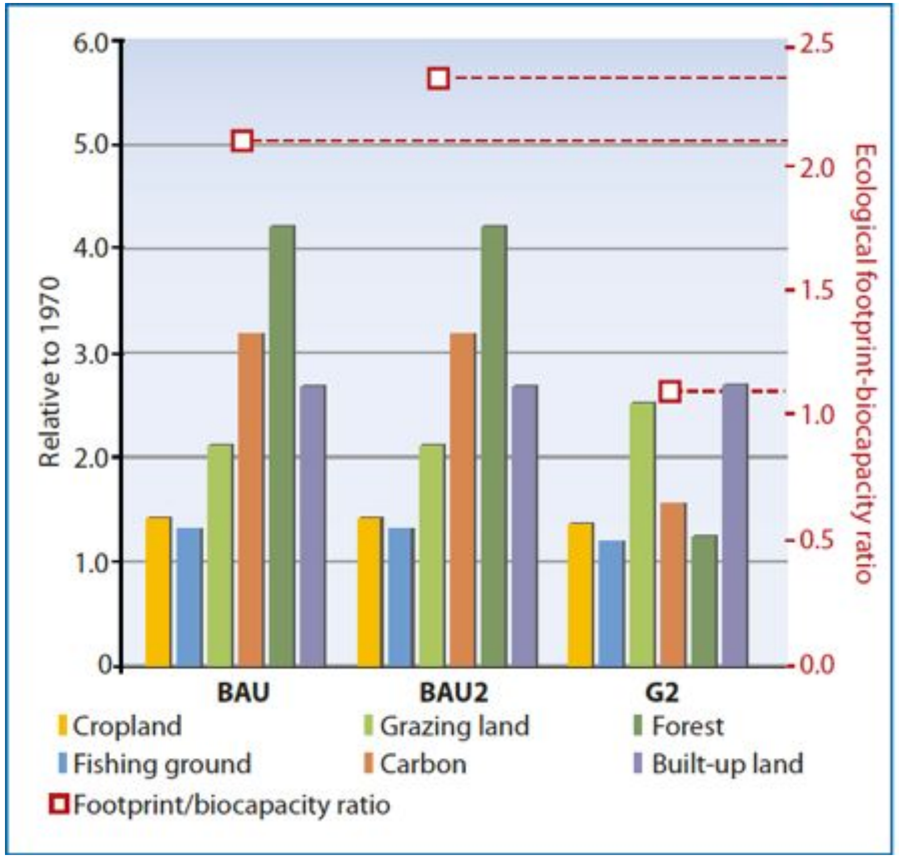
PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

RESULTS: IN A NUTSHELL (GREEN VS. BROWN) – CO_2 EMISSIONS



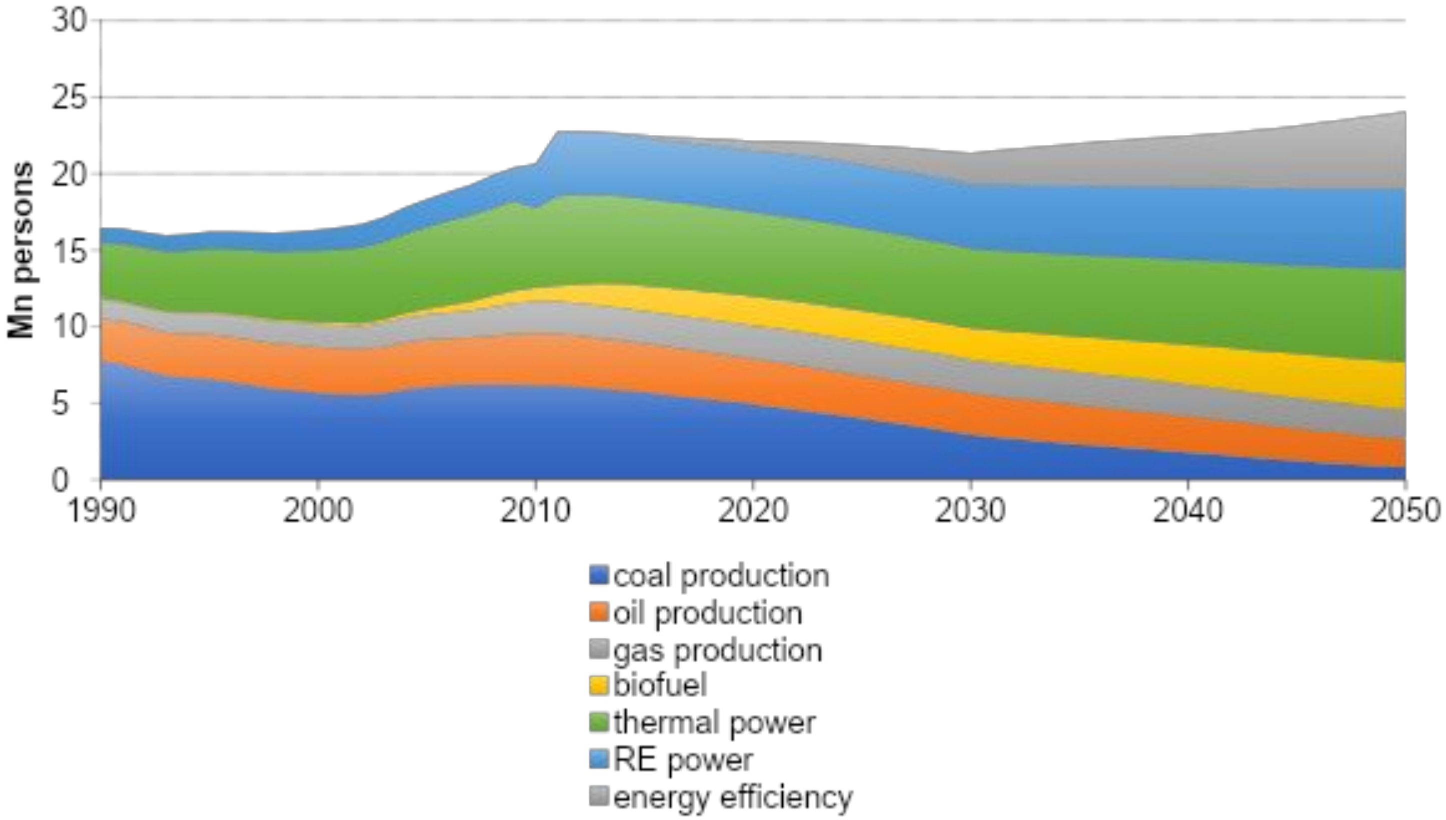
Source: UNEP, 2011

RESULTS: IN A NUTSHELL (GREEN VS. BROWN) – ECOLOGICAL FOOTPRINT (INDEX: 2010 =1)



Source: UNEP, 2011

RESULTS: IN A NUTSHELL (GREEN VS. BROWN) – ENERGY EMPLOYMENT



Source: UNEP, 2011

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

Annex B:
Additional information about IGEM

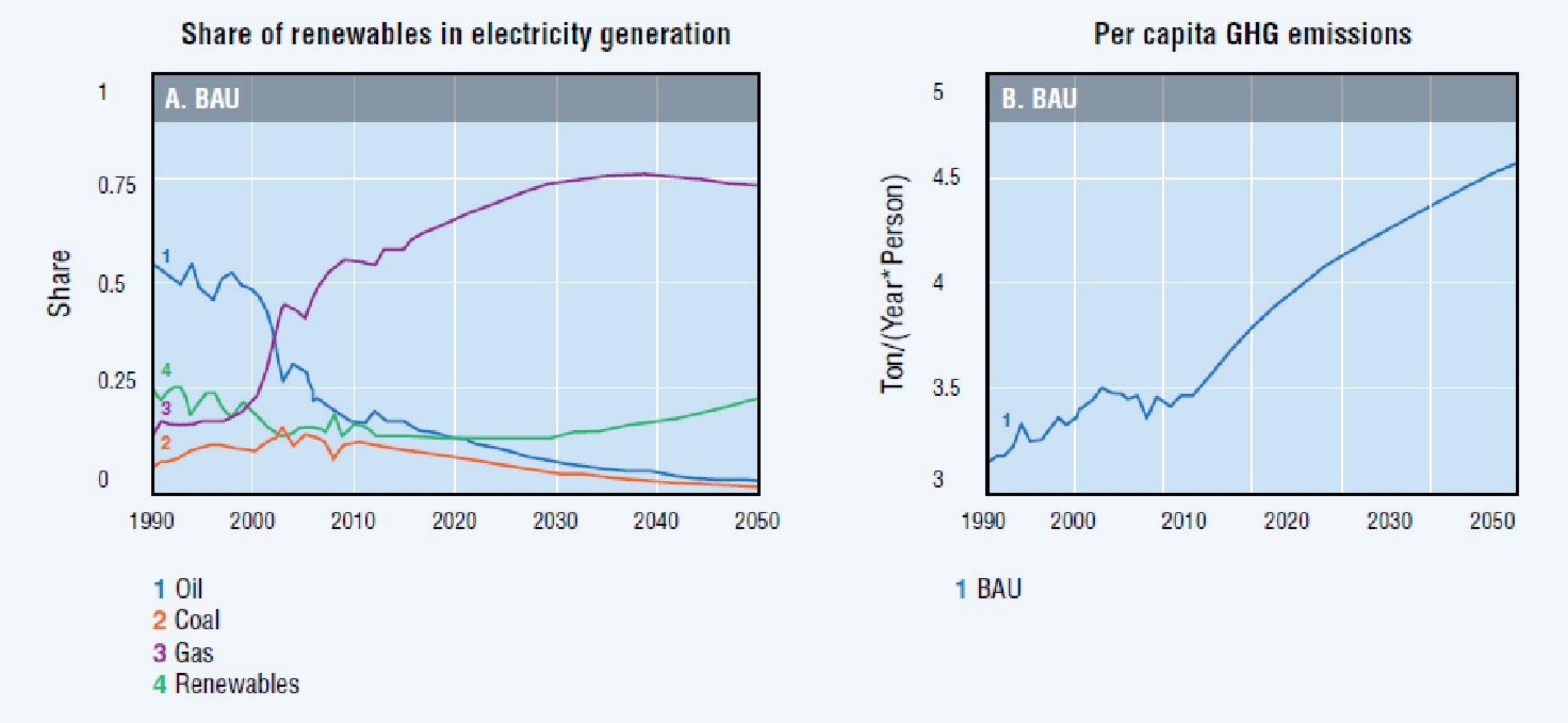
RESULTS FROM THE CGE – SCENARIO 1 (LEFT) AND 2 (RIGHT)

Aggregate and sectoral effects of a revenue-neutral carbon tax, in 2036.

Source: PAGE, 2017

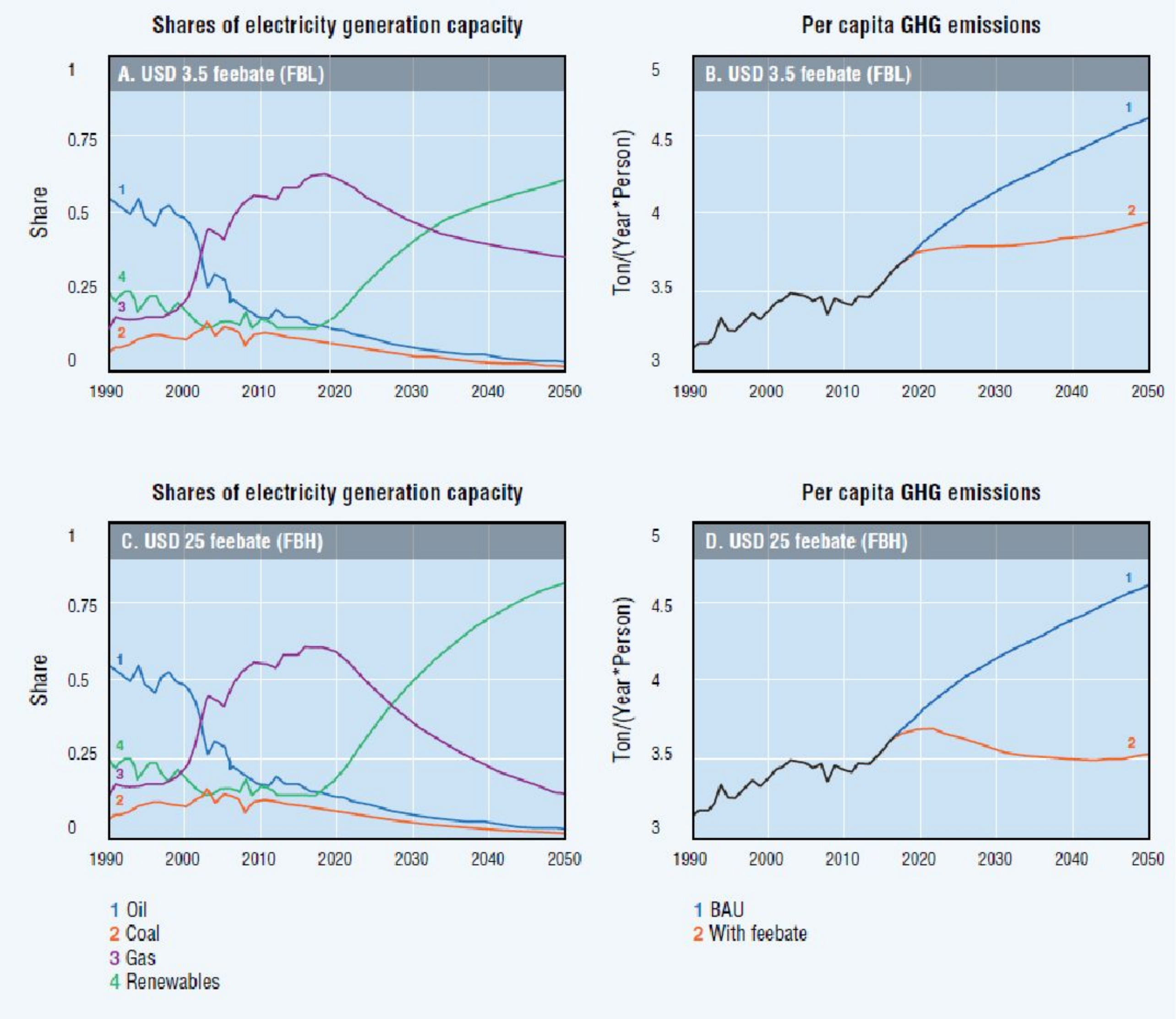
	COLUMN 1	COLUMN 2
Aggregate results	FBL vs. BAU (%)	FBL vs. RL (%)
GDP	-0.1670	0.2652[43]
Investment	0.4514	1.0984
Government[44]	-0.2072	-0.0125
Capital Stock	-0.3253[45]	0.0078
Welfare		
Agent 1 (20% poorest)	-0.1174	-0.0364
Agent 2 (3-5 deciles)	-0.1119	0.0097
Agent 3 (6-8 deciles)	-0.1192	0.0167
Agent 4 (20% richest)	-0.1407	0.0321
Aggregate welfare agents 1-4	-0.1279	0.0078[46]
Government welfare	0.0000	0.0000
Selected sectors		
Agriculture	-0.7599	-0.3504
Manufacturing	-1.0087	-0.3915
Oil	-5.1713	-1.5797
Natural gas	-4.7644	-1.3594
Mining	-6.2312	0.2144
Refining	-4.1215	-1.1295
Electricity	5.6699	6.2579

RESULTS FROM THE SD – BAU SIMULATION



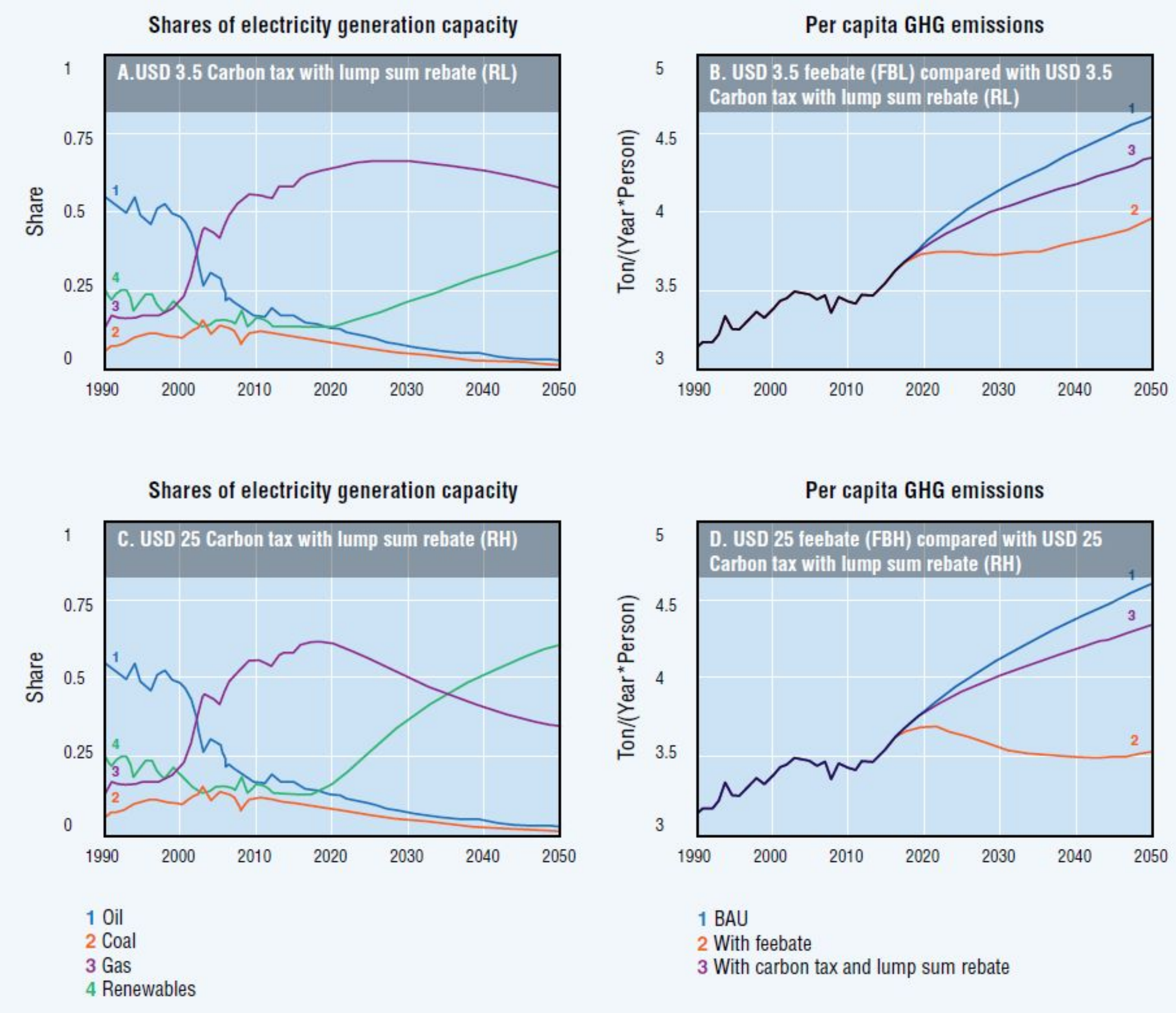
Source: PAGE, 2017

RESULTS FROM THE SD – FEEBATE SCENARIO



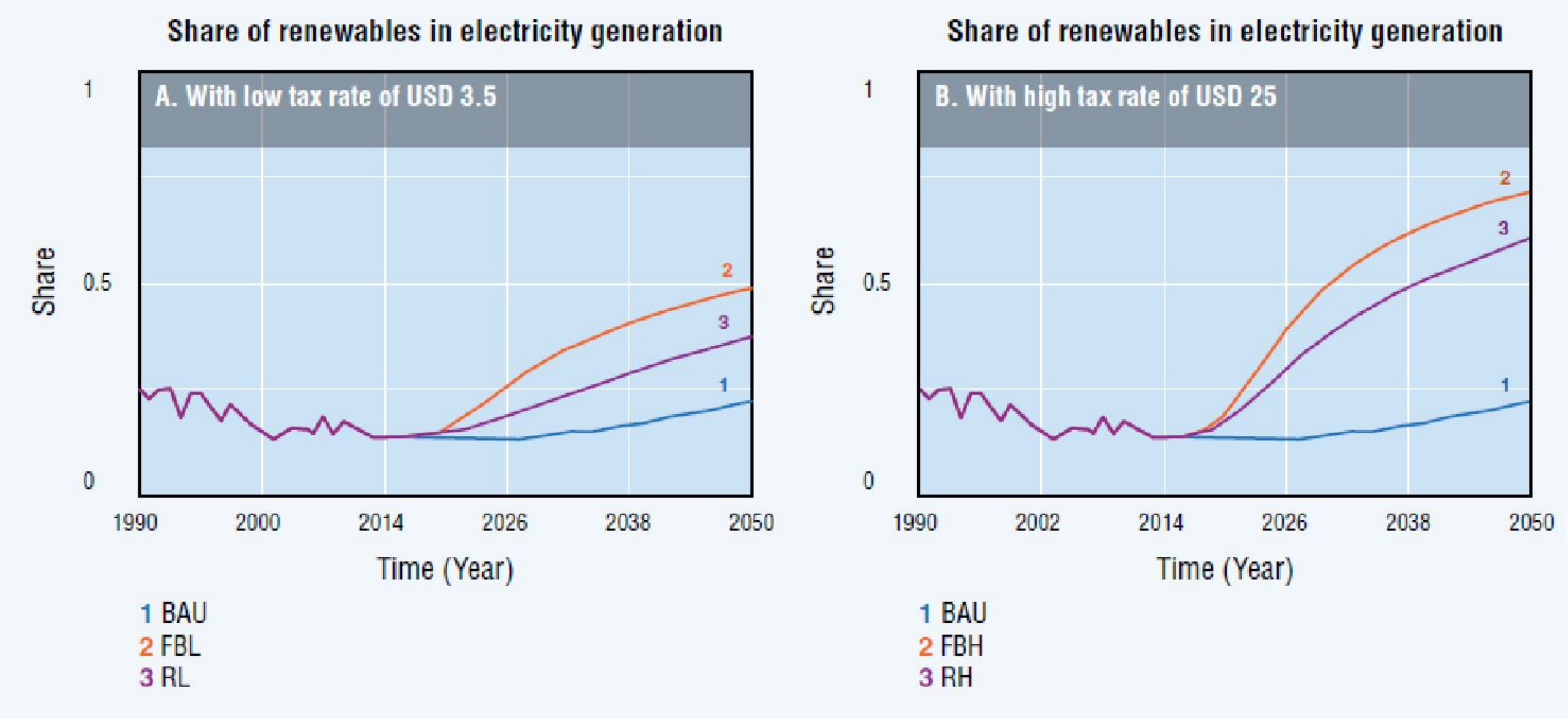
Source: PAGE, 2017

RESULTS FROM THE SD – REBATE SCENARIO



Source: PAGE, 2017

EVOLUTION OF THE SHARE OF RENEWABLE ENERGY CAPACITY FOLLOWING BAU, FBL, RL, FBH AND RH SCENARIOS



Source: PAGE, 2017

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

EXAMPLE OF RESULTS FROM THE IGEM

- The IGEM simulated the dynamic CGE model in conjunction with the SD model, and used output gathered from the SD model to supplement and adjust the CGE input parameters.
- It is estimated that a carbon tax would have positive impacts on the health of the population and labor productivity.
- As a result, IGEM considers **any increase in longevity equal to an increase in productivity.**

RESULTS FROM THE IGEM

Aggregate and sectoral effects of a revenue-neutral carbon tax and a feebate scenarios, in 2036.

Source: PAGE, 2017

	COLUMN 1	COLUMN 2	COLUMN 3
	RH with longevity vs BAU (%)	RH with longevity vs RH no longevity (%)	RH with longevity vs RH with no longevity (%)
GDP	-2.5608	0.3332	1.2949
Investment	-2.7583	0.7796	3.8981
Government[57]	-1.3718	0.1916	0.3705
Capital Stock	-2.0615	0.2945	1.7113
Welfare			
Agent 1 (20% poorest)	-0.5612	0.0614	0.0709
Agent 2 (3-5 deciles)	-0.8088	0.0585	0.0938
Agent 3 (6-8 deciles)	0.0525	0.0525	0.1438
Agent 4 (20% richest)	-1.1663	0.0533	0.2468
Aggregate welfare agents 1-4	-0.9912	0.0545	0.1786
Government welfare	0.0583	0.0542	0.0471
Selected sectors			
Agriculture	-2.2540	0.5032	0.4238
Manufacturing	-3.3250	0.7797	0.5180
Oil	-19.4086	0.3080	-1.4591
Natural gas	-18.6950	0.3195	-1.2141
Mining	-48.2412	0.2921	0.0974
Refining	-16.7771	0.3899	-0.1950
Electricity	-5.8425	0.4676	23.7461

SUMMARY OF RESULTS FROM THE IGEM

SCENARIO	MAIN RESULTS FROM CGE SIMULATION	MAIN RESULTS FROM SD SIMULATION	MAIN RESULTS FROM IGEM SIMULATION (SD-CGE)
— Scenario 1 – Feebate scenario with low tax rate (FBL) — Scenario 2 – Feebate scenario with high tax rate (FBH) The two feebate scenarios will be compared to: — Rebate scenario (lump sum) with high (RH) and low (RL) tax rates — Business-as-usual scenario (BAU) = no carbon tax	Scenario 1: FBL-BAU — Introducing a carbon tax on emissions of fossil fuels will entail small losses with regards to consumer welfare, GDP, and the size of the capital stock. Scenario 2: FBH-RH — Feebate scenario will result in higher values for aggregate indicators (e.g. GDP, Investment, etc.) up to 2036 than rebate scenario. Both scenarios — A carbon tax paired with "green" investment will have positive environmental impacts, while improving the energy mix by increasing the share of renewables with minimal impact on overall production (GDP).	Scenario 1: FBL-BAU/RL — Low tax levels are of limited capacity in inducing a transformation of the electricity generation mix. Scenario 2: FBH-BAU/RH — Feebate policy, with the high carbon tax on full emissions, achieves the greatest carbon emission reduction.	— GDP grows up to 1.3 percentage points (0.33 percentage points) when the effect of lower emissions on longevity and later on labour productivity is taken into account in the feebate (rebate) scenario. — The gains are more or less evenly distributed over all consumers, with a slight bias towards the richest agents in the economy. — Government revenues also increase.

Source: PAGE, 2017