Session 3

NEXUS and Metabolic Analysis: Basic Concepts

Mario Giampietro and Ansel Renner Institute of Environmental Science and Technology (ICTA) Autonomous University of Barcelona (UAB)



Please use this QR code or link for the session's quiz questions: https://app.sli.do/event/ip5om0dj

10.00–11.15	Epistemological challenges when trying to quantify the nexus
11.15–11.30	Intermission
11.30–12.00	Governance Challenges the implications of complexity on the usefulness of quantitative information
12.00–12.30	How to carry out an integrated NEXUS analysis across levels: STATE-PRESSURE quantification
12.30–13.00	How to carry out an integrated NEXUS analysis across levels: PRESSURE-IMPACT quantification



WEFE Nexus in the Mediterranean: From Research to Practice >>> 7 December 2021

Technical incommensurability
 Social incommensurability
 Metabolic patterning
 Social-economic holism

Technical incommensurability Social incommensurability Metabolic patterning Social-economic holism

The challenge of complexity (= multiple scales) for sustainability science . . . In quantitative analysis: *Non-equivalent descriptive domains* = *Non-reducible models*

Dietary intake in the USA relevant for nutritional analysis

Dietary intake in the world (average) relevant for comparison (equity issue)





Different levels of analysis same observation method



grain consumption per capita per year in the USA







Gross biophysical production needed by the US food system relevant for sustainability analysis

Gross biophysical production needed to keep economically viable the US agricultural sector relevant for economic analysis

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Another example of the risk of underestimating the challenge presented by complexity . . .

assessing the consumption of food energy per capita per day

... an indicator of nutritional status measured in kcal per day per capita?

Giampietro & Ansel Renner. Al

The standard narrative used to introduce the issue of world injustice in relation to food supply

PNAS Vol. 96, Issue 11, 5908-5914, May 25, 1999 :

World food and agriculture: Outlook for the medium and longer term

Nikos Alexandratos Head Global Perspective Studies Unit, Food and Agriculture Organization

* * * the part of world population living in countries where per person food supplies are still very low . . . under 2,200 kcal/person/day * * *

* * * the very high levels of food availability generally found in the statistics of many high-income countries . . . often over **3,500** kcal/person/day * * *

CLAIM MADE: "2,200 kcal/day is a diet showing a shortage of calories for the poor . . . "

100 people = $(40 \times 15) + (30 \times 30) + (20 \times 55) + (10 \times 50) = 3,100 \text{ kg}$ Average weight of 1 person = 31 kg 2,200 kcal/day = 71 kcal/kg/day



Limits defining age classes

CLAIM MADE: "3,500 kcal/day! A diet showing an excess of calories for the rich . . ."

100 people = $(10 \times 17) + (20 \times 40) + (40 \times 70) + (30 \times 60) = 5,570 \text{ kg}$ Average weight of 1 person = 55.7 kg 3,500 kcal/day = 62 kcal/kg/day



Limits defining age classes

In developed countries an "average person" weighs 50 kg . . . In developing countries an "average person" weighs 30 kg . . .

3,500 kcal/day! excess of the rich

2,200 kcal/day! shortage of the poor

62 kcal/kg/day < 73 kcal/kg/day

1,000 kg grain p.c./year >> 250 kg grain p.c./year USA Developing Countries

At the level of the whole food system

THE COMPERTS Car CONNERS TTER!

Challenges for Scientific Advice

TECHNICAL INCOMMENSURABILITY

There are always different explanations and representations of a given issue—dependent on the chosen explanation narrative.

The truth of the representation of a "fact" depends on the usefulness of the chosen perception of the external world, for a given purpose.

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https://magic-nexus.eu/documents/quality_stdentific-advice-policy-insights-complexity



The "measured length" of a coastline is NOT a "fact"!

Benoit Mandelbrot

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The epistemological challenges of complexity . . .



dx = 100 km, length = 2,800 km

The measure (fact) used by a captain of a large oil tanker reading a nautical chart (functional identity)





dx = 50 km, length = 3,400 km

The measure (fact) used by a bus driver reading a road map (functional identity)





Mont Saint Michel (France)

dx = 10 m, length = not measurable

The experience (fact) of a person walking around the coastline







CONCLUSION: We should abandon the Cartesian dream of prediction and control

Despite the recognized importance given to the term . . .

- (i) quantitative "analysis of the nexus" is still done using *reductionism*—studying issues one scale and dimension at the time;
- (ii) "governance of the nexus" remains an example of *silo governance*—trying to solve the different problems/issues of water, energy, food and the environment independently from each other.

Strategies adopted to deal with the nexus treat Copyright © 2021 Mnexus systems as if they were simple.

Technical incommensurability Social incommensurability Metabolic patterning Social-economic holism

Challenges for Scientific Advice

SOCIAL INCOMMENSURABILITY

There are always different framings of policy problems depending on the chosen justification narrative—the concern to be addressed . . .

The priority given to the chosen concern to be addressed depends on the identity of the story-teller . . .

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EXPERT ADVICE at the SAGUF World Food Conference, Zurich, October 9–10, 1996

Different Story-tellers! Story-telling about National Policy

I.F.P.R.I. - U.S. scientist Keep prices of food commodities LOW

Protecting the urban poor

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	advice depends on the priority given by							
Wupper "the story-teller" to legitimate but contrasting								
Ag. Dev.	perce	perceptions, aspirations and purposes.						
Story-telling about Social Policy								
NGO - Swiss Feminist		PRESERVING local cultural heritag	e Protecting cultural diversit	t y				
Sociologist - Prof. from India		FIGHTING local cultural heritage	Protecting wives burned a together with dead husba	live nds				
		Copyright © 2021 Mario Giampietro reserved.	& Ansel Renner. All rights					

Challenges for Scientific Advice

THERE ARE MULTIPLE VALID COMBINATIONS OF JUSTIFICATION AND EXPLANATION NARRATIVES RELATED TO THE SAME EVENT

Different valid combinations of **justification narratives** and **explanation narratives** can generate the coexistence of contrasting **normative narratives** . . .

The choice of just a normative narrative depends on the chosen identity of the **story-teller** . . .

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https://magic-nexus.eu/documents/quality_sclentific-advice-policy-insights-complexity

"All models are wrong, but some are useful."



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"Models are opinions embedded in mathematics."

Weapons of Math Destruction: How Big Data Jack as Inequality and Ansel Renner. All rights Threatens Democracy (2016, PENGUIN)

WEAPONS OF Math Destruction



HOW BIG DATA INCREASES INEQUALITY

AND THREATENS DEMOCRACY

CATHY O'NEIL Cathy O'Neil

A diversity of information sources and data is NEEDED to handle complex operations.

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What's the problem?

In sustainabilty science, quantitative analyses are still carried out using the analytical methods developed by Newton . . .

... reductionism ... one scale and one dimension at a time!

"Make everything as simple as possible, **but not simpler.**"

Nobody wants to fly on this plane . . .

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Clarifying the Concept

HOW CAN WE DEAL WITH THE NEXUS?

In order to deal with the NEXUS we have to reach an agreement on 3 coexisting problems . . .

1. WHAT is generating the nexus—what is the biophysical mechanism that generate an **entanglement** over the flows of water, energy, food and environmental services?

2. HOW to represent the nexus—the analytical representation has to be based on observable attributes (data) that are referring to different levels and dimensions of analysis.

3. WHY we want to represent the nexus—the governance dimension.

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- Technical incommensurability
 Social incommensurability
 Motabolic patterning
- 3. Metabolic patterning
- 4. Social-economic holism

How is this possible?!



The consequences of HYPOCOGNITION - or -HOW TO MISS THE ELEPHANT IN THE ROOM



Would you believe someone who told you that next year Messi will eat 75% less what he eats now while still playing the same quality of football?



Nobody seems to object to the claim that it would be possible to cut the emission of developed countries by 75% in two decades?

Humankind seems to believe that it is easier to re-adjust the metabolic rate of a complex socio-economic system than the metabolic rate of a human organism (Messi)! We don't believe we can cut food to Messi. Why? Because we have a multi-level knowledge of human metabolism!

reserved



WHOLE MESSI level *n* Total mass = 73 kg Metabolic Rate = 1.6 W/kg Endosomatic Flow = 10.4 MJ/day

PARTS OF MESSI basal metabolism level *n-1*

Component	kg	W∙kg⁻¹	W	MJ/day
Liver	1.4	9.6	13	1.1
Brain	1.3	12	15	1.3
Heart & Kidneys	0.3	21	6.3	0.5
Skeletal Muscle	26	0.62	16	1.4
Adipose Tissue	19	0.22	4.2	0.4
Residual Mass	25	0.58	14	1.2
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For human societies you can find the expression of a metabolic pattern associated with a set of expected benchmarks for the internal "organs"

- * **Household** *Reproducing humans* . . .
- * **Service and Government** *Reproducing institutions / social practices* . . .
- * **Manufacturing and Construction** *Supplying goods / infrastructures* . . .
- * Agriculture Supplying food and fiber / feedstocks . . .
- * **Energy and Mining** *Supplying energy carriers and minerals* . . .

Total Human Activity 60.8 Gh (year)

Total Energy Throughput 1,120 PJ (year)

Exosomatic Metabolic Rate 18.4 MJ/h



Relative size of the compartments expressed in hours/year

CATALONIA 2005



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h/year



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The METABOLIC PATTERN of socialecological systems

Relational analysis enables you to solve the conundrum of multi-level accounting while keeping the possibility of defining quantitative impredicative relations . . .

What is the external referent of the metabolic pattern?

Is there a **biophysical** mechanism generating a set of constraints determining the stability of this metabolic pattern?

Is there a way to study the emergent property of the pattern, i.e. when a metabolic system is "old" or "young"?
The internal view of the metabolic pattern looking at the different end uses

* The ENJOYMENT of life!



H.A. Human activity Veg. Vegetal products P.C. Power capacity Elec. Electricityopyright © MML Animal products RenB.L.A. Buildings & infrastruct. reserved.

The internal view of the metabolic pattern looking at the different end uses

* The ENJOYMENT of life!



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Clarifying the Concept

WHAT IS THE NEXUS?

Three different definitions. . .

1. A biophysical pattern of interest operating in the external world generating an entanglement between different forms of water, energy, food, ecosystems processes.

2. A useful scientific representation of the entanglement over WEFE flows.

3. A procedure for helping the governance of the NEXUS.



Reflection

Biophysical processes and external circumstances do not determine WHAT HAPPENS in social-ecological systems, but they determine WHAT CANNOT HAPPEN—the option space . . .

The analysis of biophysical processes cannot predict future events nor define optimal solutions ("what we should do"), but it can be very useful to reduce "hypocognition" and avoid stupid mistakes . . .







Webinars

Although we prefer to speak face-to-face, we also do webinars on a wide gamut of sustainability topics.



Consultancies

We have extensive experience consulting for institutions from local governments to large international organizations.



Research

Our research is markedly heterodox. We appreciate the need to pass on key knowledge through graduate directorships.



Summer Schools

We've designed and run about a dozen summer schools across six different countries. We are educators at heart.

Our Mission

Our aim is to guarantee the quality of narratives used to frame and discuss sustainability predicaments. To achieve this, we focus our research efforts on the development and application of novel accounting methods and methodologies grounded in the complexity frame of reference and the conceptual approach of post-normal science. We further invest substantial effort in educational activities related to sustainability science and science for governance. Copyright © 2021 Mario Giampietro & Ansel Renner. All rights





What is Uncomfortable Knowledge? ()

Farm to Fork: Updating Narratives About Agriculture

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Science-policy interface Assessment versus analysis

Flows

Science-policy interface Assessment versus analysis

Flows

Who decides the validity of knowledge claims and how?

PLAUSIBILITY

of data, models and scenarios (*Descriptive Quality*)

RELEVANCE

of the chosen issue definition, policy options, goals, taboos (*Normative Quality*)

LEGITIMACY

of the process of production and consumption of scientific information (*Procedural Quality*)



Who decides the **RELEVANCE** of narratives, **USEFULNESS** of perceptions and **PERTINENCE** of representations and how? right 200 Mario Gampletro & Ansel Renner. All rights You have a set of non-equivalent *observations* of a natural system, made by non-equivalent *perceivers*, resulting in non-equivalent *representations*.

Is there an emergent *shared perception*? Is there an emergent *shared representation*?

Validating a *knowledge claim* implies deciding that the chosen models and indicators are *relevant* and *useful* for a given purpose . . .

Validating a knowledge claim requires *reflexivity*—a check on the quality of the process used to combine *normative* and *descriptive* inputs . . .

Science-policy interface Assessment versus analysis

Flows

Why is it so difficult to get the right "**issue definition**" when dealing with "issues" of sustainability and the resource nexus? Sustainability has to do with learning how to meet the challenges associated with understanding, deciding and acting, within an adequate time frame, to change.

Sustainability implies facing the **"tragedy of change"** you have to accept to lose something in order to be able to keep something else.

Being able to understand and to decide what we want to retain while becoming something else, and how much we want to "pay" for it—this is at the core of sustainability science. However, this implies challenging the "status quo" . . .

... dealing with the **TRAGEDY OF CHANGE** means putting in discussion

* The actual **STRUCTURE OF POWER**

* The given identity of the "STORY-TELLER"

* The existing perception and implementation of ETHICAL NORMS

* ASKING POLITICALLY INCORRECT QUESTIONS (e.g., what happened to the "population bomb"?)

* ACKNOWLEDGING THE **EXISTENCE OF DEATH** for both individuals, institutions, civilizations . . .

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An assessment:

must go through three distinct checks related to its: (1) scientific credibility; (2) political legitimacy; and (3) practical usefulness for guiding action, i.e. in a process of decision making. *(Millennium Ecosystem Assessment, 2005)*

An analysis refers only to:

- (1) quantification of a set of parameters (after selecting an adequate source of data, e.g., secondhand data or through a measurement scheme); and
- (2) generation of a model that characterizes the performance of a system using a selected set of attributes and options, leading to the SELECTED NARRATIVE.

An assessment is associated with an evaluation of both:
(i) the pertinence and rigor of the analysis; and
(ii) the relevance and validity of the narrative within which the analysis has been performed.

A narrative is associated with the pre-analytical choice of a given shared perception (problem structuring/issue definition):
(i) the identity assigned to the investigated system;
(ii) relevant causal mechanisms to be studied;
(iii) the resulting scale used to represent relevant events;
(iv) a linearization in a given sequence of relevant events.

A narrative is the storyline within which the model makes sense.

Let's illustrate the relevance of this distinction using a familiar example . . .

... choosing a car to buy.

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Economic Safety Criteria Criteria Fuel Road consumption handling Maintenance Reliability costs Safety Price devices Speed / acceleration Design Comfort Status Symbol Colour Noise Cultural **Driving Quality** Criteria Criteria Copyright © 2021 Mario Giampietro & Ansel Renner-All rights reserved.

Different buyers, according to their personal characteristics, specific history, contingent situations, will perceive the **performance** of the car they want to buy using different sets of: (i) **attributes**; (ii) **targets and benchmarks**; (iii) **data**.

14



Industrial milk production





Household milk production

Therefore, concerning assessments on the science-policy interface, it is crucial to keep separated:

what is about the STORY-TELLER semantic; normative

NARRATIVES, VALUES, GOALS, HISTORY, POWER RELATIONS

from

what is about the OBSERVED (and the observation process) syntax; descriptive

MODELS, INDICATORS, DATA, TECHNOLOGY, STORAGE MEMORY Copyright © 2021 Mario Giampietro & Ansel Renner. All rights Integrated assessment requires the ability to tailor both the issue definition and the problem structuring used to perform an **integrated analysis** on what is relevant, credible and acceptable for the social actors

> This is about learning how to negotiate an IDENTITY FOR THE STORY-TELLER (this will affect the NORMATIVE task) . . . WHAT IS A USEFUL PERCEPTION?

Before wisely choosing an IDENTITY FOR THE OBSERVATION SPACE (this will affect the DESCRIPTIVE task) . . . WHAT IS A USEFUL REPRESENTATION?

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But if we admit that in quantitative integrated analysis the name of the game is deciding how to characterize the investigated system— ... the IDENTITY of the observation space.

> Who and how will the identity of the story-teller be decided?

The wisdom of Humpty Dumpty

Copy



It is the master that decides about meaning and semantic . . .

EXPERT ADVICE at the SAGUF World Food Conference, Zurich, October 9–10, 1996

Different story-tellers! Story-telling about National Policy

I.F.P.R.I. - U.S. scientist Keep prices of food commodities LOW

Protecting the urban poor

Ag. Econ. -The usefulness (and fairness) of scientific advice depends on the priority given by "the story-teller" to legitimate but contrasting Wupper Ag. Dev. sector perceptions, aspirations and purposes. **Story-telling about Social Policy** NGO - Swiss Feminist **Protecting cultural diversity PRESERVING** local cultural heritage **Protecting wives burned alive FIGHTING** local cultural heritage Sociologist - Prof. from India together with dead husbands Copyright © 2021 Mario Giampietro & Ansel Renner. All rights 19 reserved.

'A war against poverty may have the effect of eliminating the poor . . .'

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Assumptions typical of NORMAL SCIENCE looking for OPTIMAL SOLUTIONS

- #1 It is possible to obtain a sound and reliable "issue definition, problem structuring, and pre-analytical choice of narratives"...
- #2 The given "issue definition, problem structuring and pre-analytical choice of narratives" is agreed upon by those that will use the scientific analysis . . .
- #3 The role of the scientist is only that _______ iven "issue definition, problem structuring, and pre-analytical choice _______ for generating models, analyses, data, and indicators leading to the "optimal" solution . . .
- #4 An acceptable quality of the narratives and acceptable levels of ignorance can be guaranteed by using more complicated models, bigger computers, and so forth . . .

SCIENTISTS MUST CRUNCH NUMBERS TO PRODUCE BETTER ANALYSES Quantitative analyses are used to individuate the **best** course of action

Reflection

Science and scientists should accept to return to be considered as another category of social actors rather than pretending to be referees above partisan interests.

Science and scientists should help the rest of society to understand and learn the issues associated with sustainability, especially when facing the existence of knowledge gaps. In this case, pushing one opinion against another is acceptable where scientists do not claim to be also the referee.

Scientists giving advice should be less arrogant—they should always keep in mind the definition of "scientist" given by Socrates: "scientists are those that know about their own ignorance"





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The MAGIC-NEXUS Project

Finding new ways to tackle complex policy issues at the nexus between water,

energy and food resources

Deliverable 4.4

http://magic-nexus.eu/documents/deliverable-44-report-nexus-structuring-space

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THE STABILITY OF PRIMARY FLOWS!

Feasibility

"the view from outside"



reserved.

THE STABILITY OF SECONDARY FLOWS!

Assuming that the supply of needed inflows is available



Viability

"the view from inside"

Studying processes under human control END-USE MATRIX

Assuming that the needed sink capacity (for outflows) is available

Compatibility with internal constraints

THE STABILITY OF SOCIAL FABRIC!

Please answer "true" or "false"-

If I were a chicken, I would gladly

suffer and die to become a "nugget".

D

Desirability

"the view from our identity"

COMPATIBILITY WITH NORMATIVE VALUES KEEPING TOGETHER SOCIAL INSTITUTIONS



Whose concerns matter?

Dependency on imported goods: Is it "good" or "bad"? *"the level of openness of the economy"*



EXTERNALIZATION

"the game changer . . . "

The conceptual innovations of the MAGIC tool-kit for the analysis of the metabolic pattern of social-ecological systems using principles of non-equilibrium thermodynamics

1. The **STATE-PRESSURE** relation is analyzed adopting the narrative of **non-equilibrium thermodynamics** in terms of a *metabolic pattern of social-ecological systems.*

2. The **STATE-PRESSURE** relation is analyzed within the narrative of the **NEXUS**—there is a entanglement across *different types of metabolic flows* across *different levels of analysis and scales.*

The conceptual innovations of the MAGIC tool-kit for the analysis of the metabolic pattern of social-ecological systems using principles of non-equilibrium thermodynamics

- 3. The **STATE-PRESSURE** relation is analyzed by considering the implications of the **openness of globalized economies**: *trade makes it possible to externalize* both the requirement of production factors inside the system (needed to express the STATE) and the requirement of primary sources and primary sinks (needed to cope with the ENVIRONMENTAL PRESSURE).
- 4. The **STATE-PRESSURE** relation is analyzed in relation to the *desirability* of the STATE of the society by considering the resulting **social practices**, that should match the *expectations about the quality of life found among the various social actors*.

Summarizing formal representations of the organs and sectors.

The END-USE MATRIX



Í	EU27+N	HA (10 ⁵ h/vear)	x	EMR_elec (MJ/h)	EMR_heat (MJ/h)	EMR_fuel (MU/h)	EJP (€/h)	=	ET_elec (PJ/year)	ET_heat (PJ/year)	ET_fuel (PJ/year)	GVA (10 ⁹ €)	%HA_i/ HA_AS	%VA_i/ VA_AS	EEI (MJ/€)
ן	Whole Society	4.422		2,6	4,3	3,9	2,6		11.415	19.110	(17.243)	11.631	100%	100%	6,4
	EU27+N	ĤA (10 ⁹ h/vear)		EMR_elec (MJ/h)	EMR_heat (MJ/h)	EMR_fuel (MJ/h)	EJP (€/h)		ET_elec (PJ/year)	ET_heat (PJ/year)	ET_fuel (PJ/year)	GVA (10 ⁹ €)	%HA_i/ HA_AS	%VA_i/ VA_AS	EEI (MJ/€)
	Household	4.167	×	0,74	1,7	1,9	0	=	3.098	7.078	7.889	0	94%	0%	-
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	Agriculture, Forestry & Fishing	21		8,0	15	26	9,3		171	326	556	198	8,4%	1,7%	7,9
	Energy & Mining	3,9	×	280	612	17	122	=	1.092	2.386	68	475	1,5%	4,1%	12
	Manufacturing & Construction	65		57	103	7,1	36		3.706	6.664	459	2.347	25%	20%	7,5
	Service & Government	172		19	15	48	50		3.348	2.657	8.271	6.611	68%	74%	2,7
		_									—				
	EU27+N	HA (10 ⁹ h/year)		EMR_elec (MJ/h)	EMR_heat (MJ/h)	EMR_fuel (MJ/h)	EJP (€/h)		ET_elec (PJ/year)	ET_heat (PJ/year)	ET_fuel (PJ/rear)	GVA (10 ⁹ €)	%HA_i/ HA_SG	%VA_i/ VA_SG	EEI (MJ/€)
	Services & Government (without Transport)	166	x	19	14	3,7	41	=	3.116	2.255	607	6.827	96%	79%	1,7
Convrig	Transport Services	6,3	0	37 & Ansel R	64 enner Al	1.224	17		232	401	7.663	109	3,6%	1,3%	107
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From the **METABOLIC NETWORK** to the **END-USE MATRIX**









		Iron & Steel			397	1.484	33	34
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	(Construction			58	103	122	406
K								
_{Lev} မြဲစုµ፮ehold	4.167 hours/y	EM3R098 MJ/h	E t r/	1 07-8 t ⁄IJ/h	E M R SB MJ/h	^{EJ} ð €/h		
Manufacturing &	65	3.706 6		.664	459	2.347		
Service &	470	0.040	~	057	0.074	0.014		

172

3.348

Level n-2

Government

	Services & Government	166	3.115,6	2.255	607	6.827,1
Level n-3	Transport Services	6,3	232,0	401	7.663	109

8.271

8.611

2.657







Moving from an analysis of PRESSURE to an analysis of IMPACT requires indicator contextualization The implications of **purposive** quantitative analysis: **quantitative indicators** must be handled with care . . .

Understanding the difference between INTENSIVE and EXTENSIVE variables



INTENSIVE VARIABLES they characterize in qualitative terms the society, but they need scaling

China

CO₂ emission p.c. 5.5 tons per year

CO₂ emissions in the USA are 3.3 times larger than In China

USA

CO₂ emission p.c. 18 tons per year

EXTENSIVE VARIABLES they make the scaling possible, after having characterized the society ("how much society")

Population 1,400 million

Quantitative characteristics of human society

Population 320 million

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EXTENSIVE

In order to answer these questions, we have to include in the analysis also the functioning and the state of the atmosphere . . .

N₂

Load of CO₂? 7.7 billion tons

How much is too much?

How large is this flow in relation to the sink capacity of the atmosphere?

> Load of CO₂? 5.8 billion tons

Does 100 kg of salt generate more environmental impact than 50 kg of salt?



What is the meaning of these numbers? How do we know how much is too much?

Dumped in a 500 liter tank of drinking water

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MAGIC tool-kit Metabolic processors Case study

ENNG

Flows

Generating formal representations of the organs and sectors

What society offers for it...

What society wants...



H.A. Human activity Veg. Vegetal products P.C. Power capacity Elec. Electricity Copyright MAL Animal productssel RB. Buildings & infrastruct. reserved.





leakage

flows

profile of outputs (extensive values)

Crop CORN

Produced

Crop



NOTIONAL: profile of expected inputs per unit of supply (unitary)



Biosphere

Technosphere

	work			
funds	machinery			
	land use			
CI.	fertilizer	INPUTS		
flows	pesticide			
	bluewater			
flows	wheat kg	Ουτρυτ		
110 113	commodity \$			
funda	greenwater	INPUTS		
tunas	soil			
_	Abstraction BW			
flows	GHG emissions	OUTPUTS		
	leakage			

Biosphere

Metabolic profile of a crop type

Greenwater Sreenwater

Abstraction BW-

Fertilizers Besticides Bluewater Work Vork Canoler

MAGIC tool-kit Metabolic processors Case study

NNG

Flows

Example of application of a multi-level, multi-dimensional grammar—the METABOLISM of the MAURITIUS ISLANDS.



90% of the land is in sugarcane production, but the EU is no longer guaranteeing acceptable prices . . . What to do?





Diagnostic-Simulator Tool



GROSS FOOD REQUIREMENT					ENERGY [CARB ;	CARRIERS PRO ; FATJ		END USES [HA ; CARB ; PRO ; FAT]			
IMPORTS							Flow elen	nents	Fund elements		
		Food (PJ)	Flow ele Energy (FJ-			Food (PJ)	Energy (PJ- GER)	Water (hm3 extraction)	HA (Mhr)	PC (GW)	Land (k ha)
			GER)	$\overline{\ }$	НН	5.9	16	100	10,000	4.5	
	HH	5.9	16	ис	PW*	0.8	37	44	606	1.4	28
uo	PW* LOSS	ES 0.8	37	npti	AG	1.3	negl	190	39	negl	21
mpti	AG	1.3	neg	insu	EM	n/a	2.2	260	8	0.03	negl
nsuo	EM	n/a	2.2	3	exp _{PW*}	n/a	n/a	3	590	n/a	n/a
ŭ	exp _{PW*}	n/a	n/a		exp _{AG}	negl	0.4	1,100	33	0.02	54
	exp _{AG}	negl	0.4		Whole	8	56	1,700	11,300	6.0	103
	Whole	8	56	Ń	Imports	6.7	49	n/a	n/a	n/a	n/a
γlo	Imports	6.7	49	Supp	Domestic	1.3	7	1,700	11,300	6.0	103
Supp	Domestic Supply	1.3	7		Supply	,		urs	host	aroac of	
tonnes of animal products tonnes of cereals		nes of xals	HU Gi	MAN ACTIVITY ga hours (Gh)	Proteins (PRO) Fats (FAT)		ot human activity	land use			

1. Challenges

2. Grammar 3. Society

4. Environment




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