NATIONAL INSTITUTE OF APPLIED SCIENCE (INSA) OF STRASBOURG

ENGINEERS + ARCHITECTS

Researching Future

methodology for long-term technological forecast

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outline

1. Why do we need a reliable forecast?
2. Why is it difficult to forecast?
3. What are the existing approaches?
4. What is suggested?
5. How to improve reliability of forecast?

*…The **righter** we do the wrong thing,*

*the **wronger** we become…*

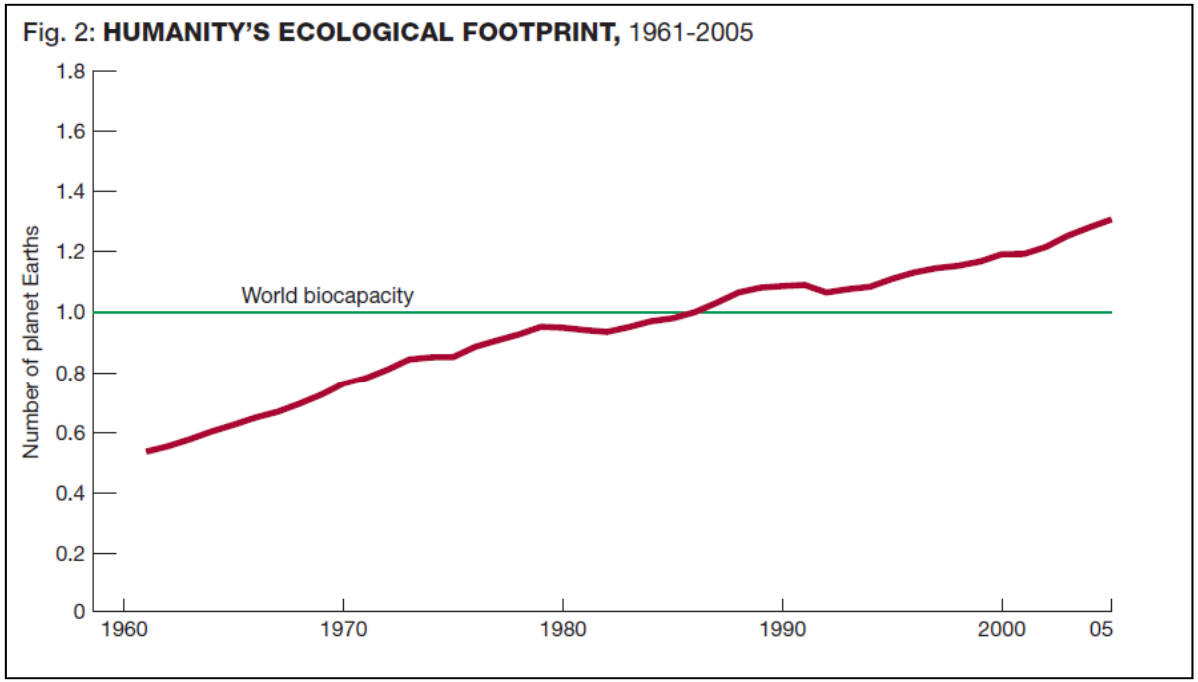
Russel Ackoff (2003)

Why do we need a reliable forecast?

Why do we need forecast?

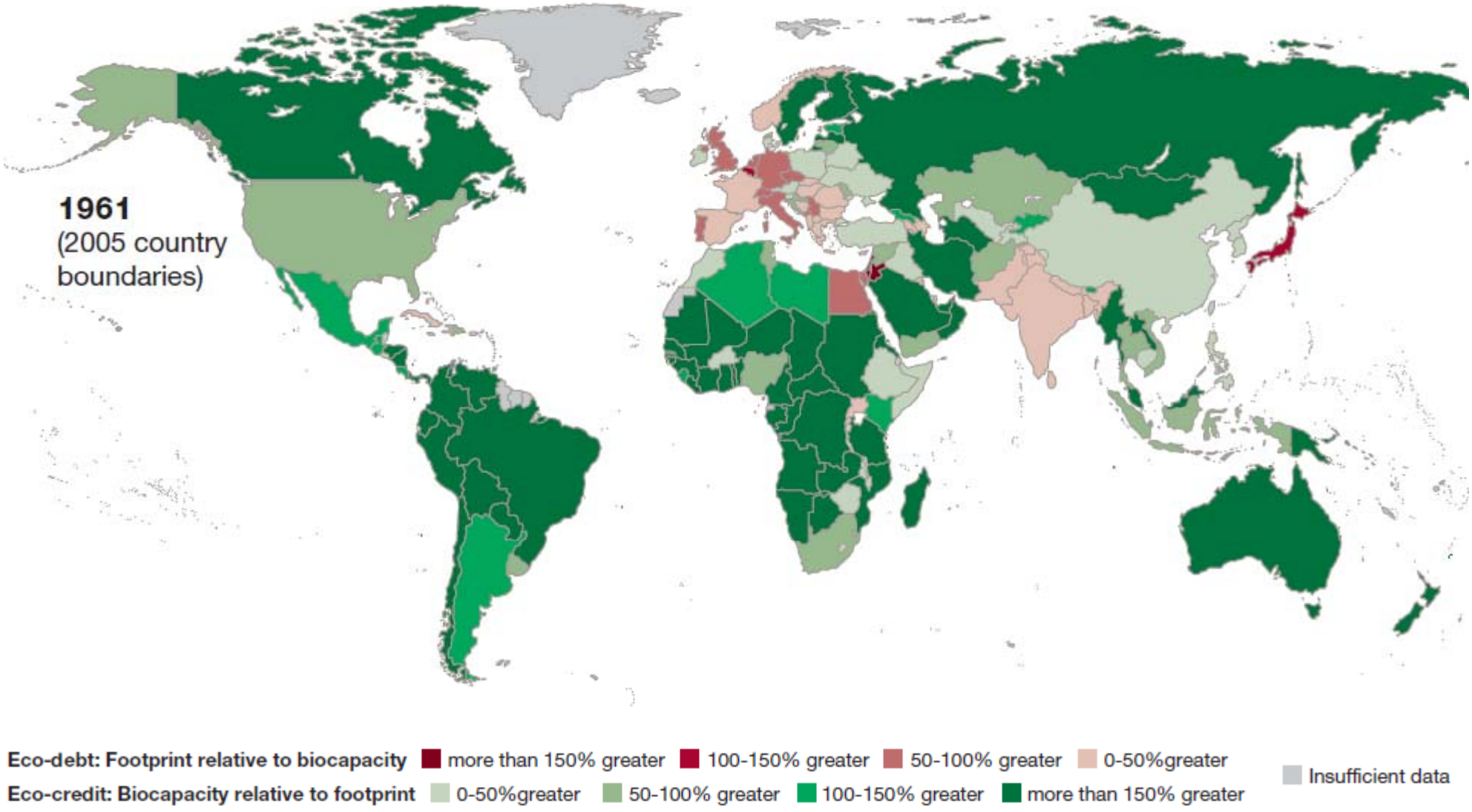
- We delay to recognize and to be agree about problems and threats.
- We delay to solve problems and to be agree about solutions.
- We delay to implement a potential solution and recognize its limitations.

earth and human (socio-technical systems and environment)



source: LIVING PLANET REPORT 2008 (http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/)

ecological debtor and creditor countries (1961)



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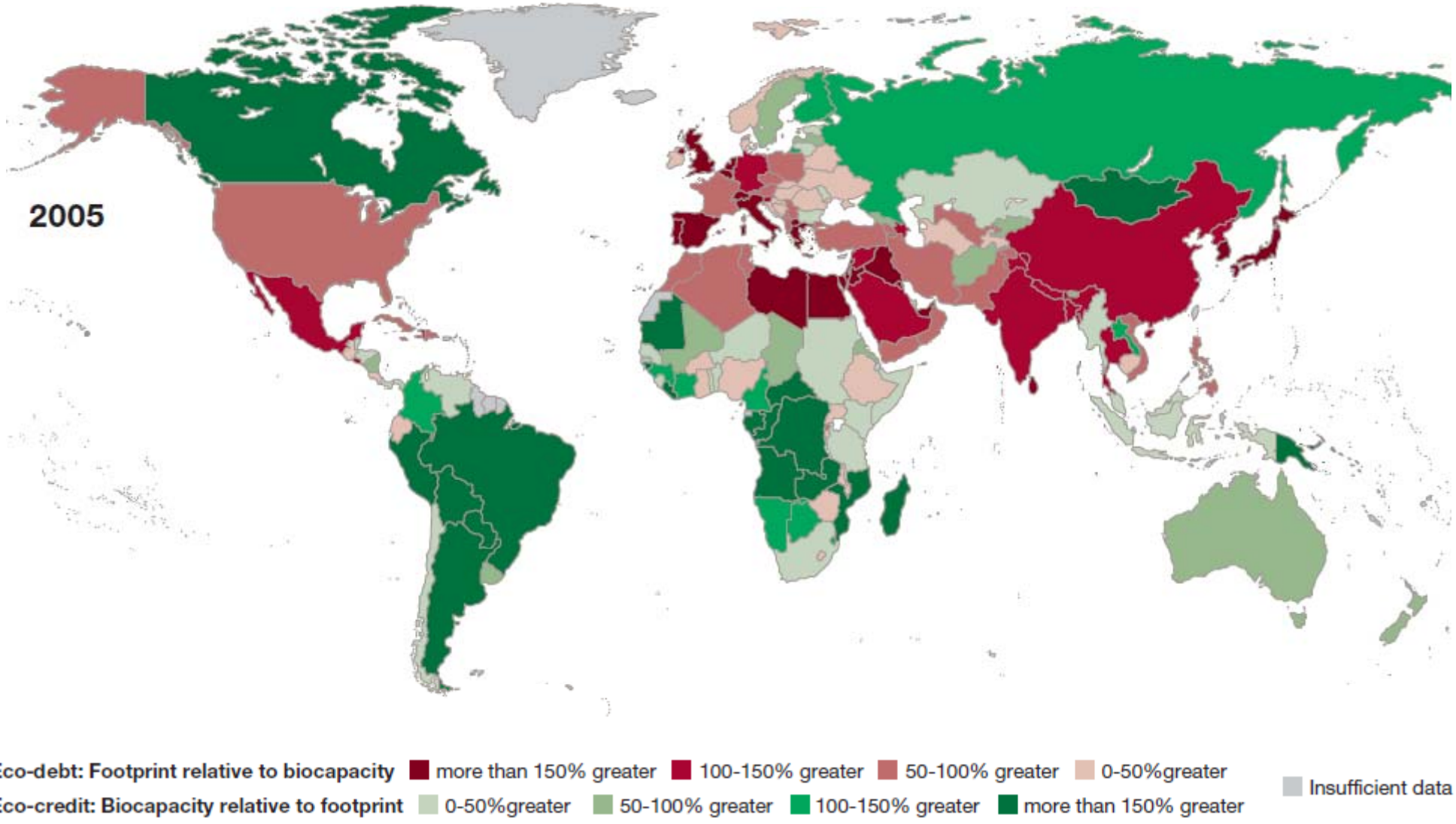
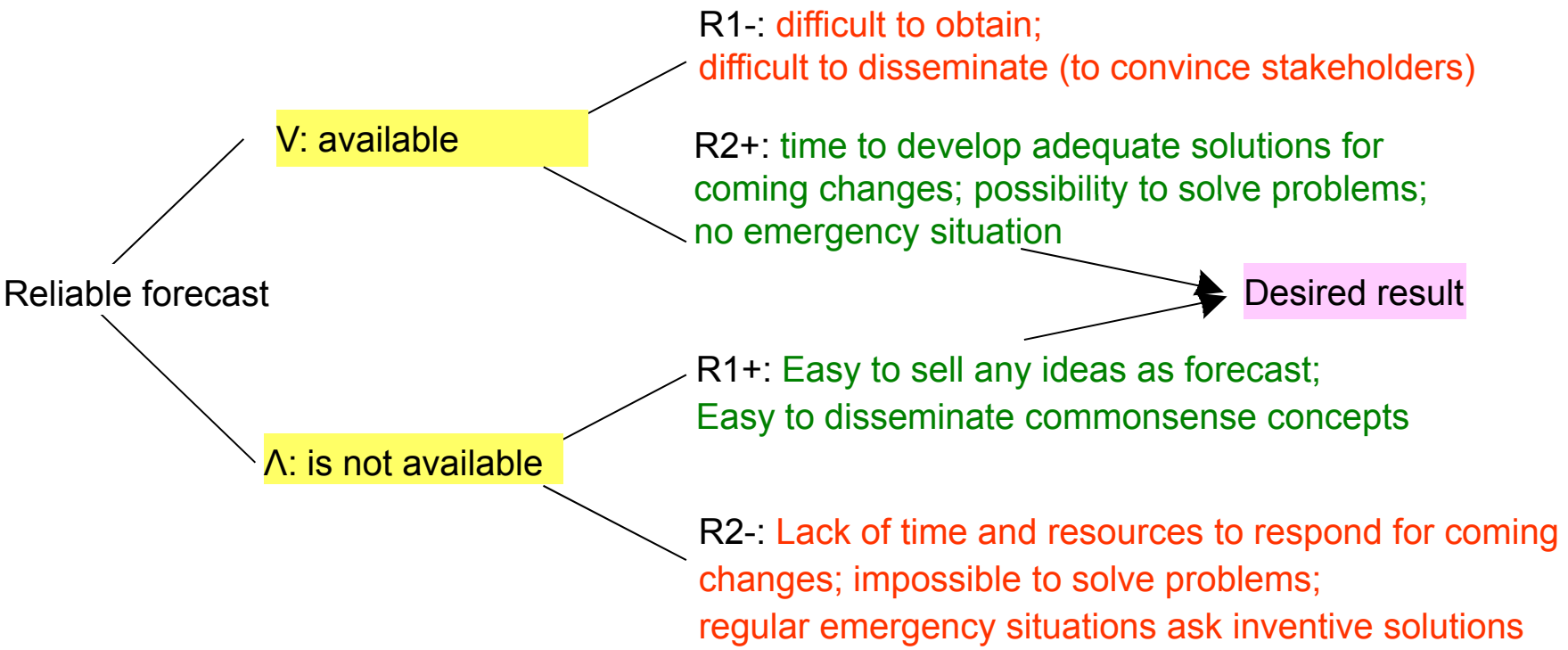
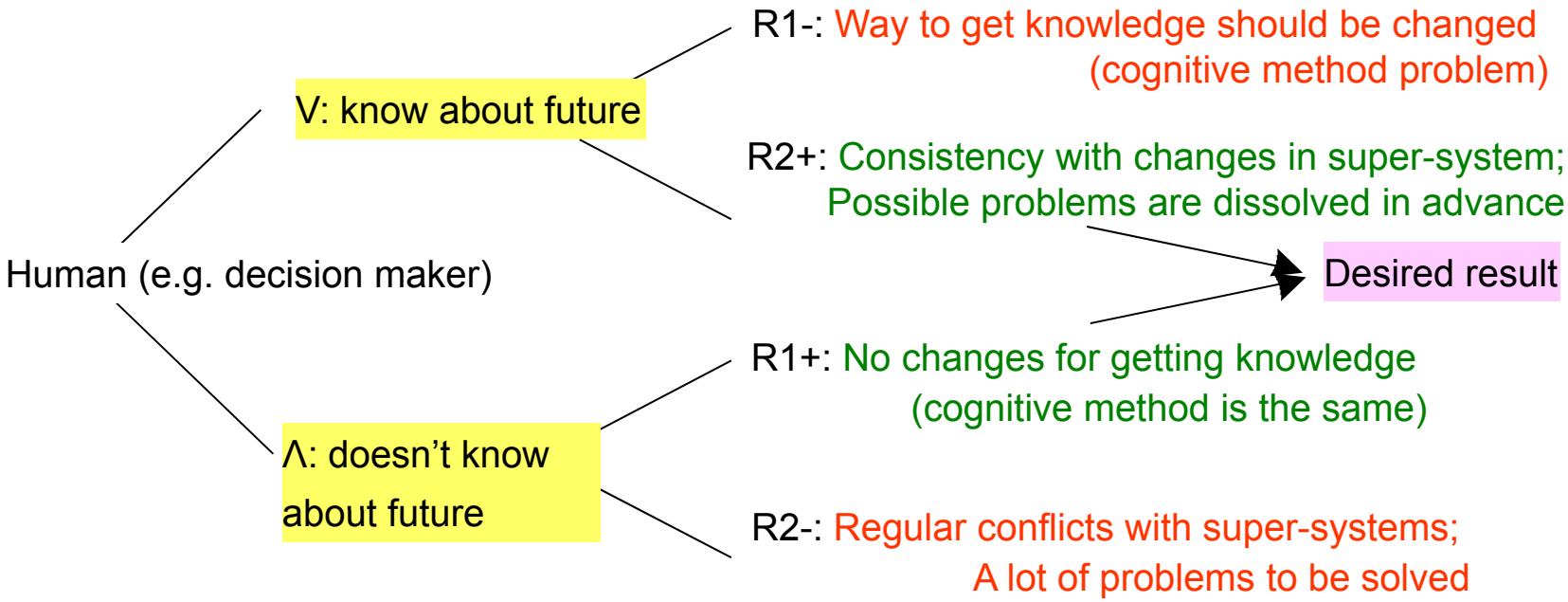


source: LIVING PLANET REPORT 2008 (http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/)

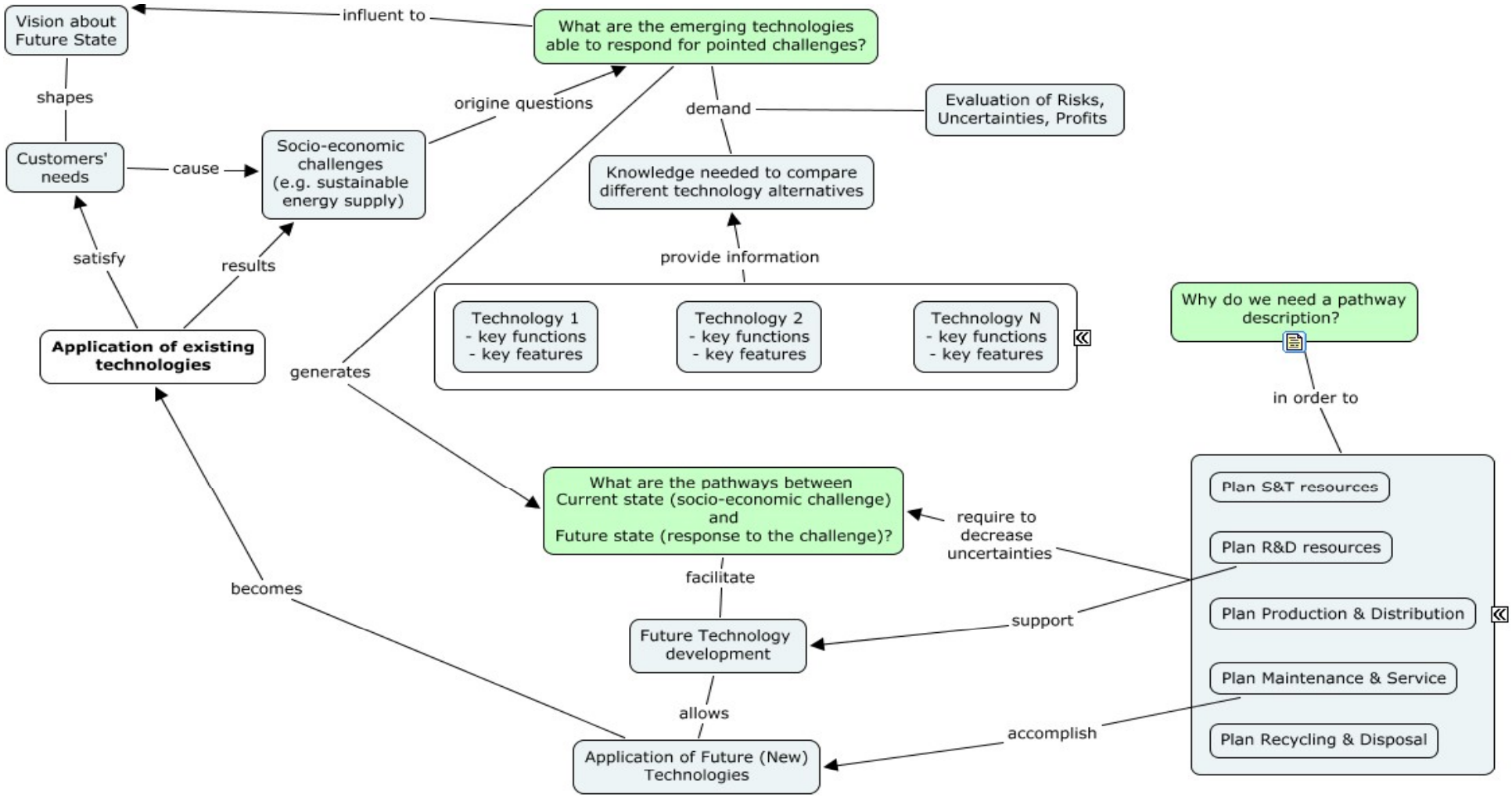
reliable forecast vs. foretelling



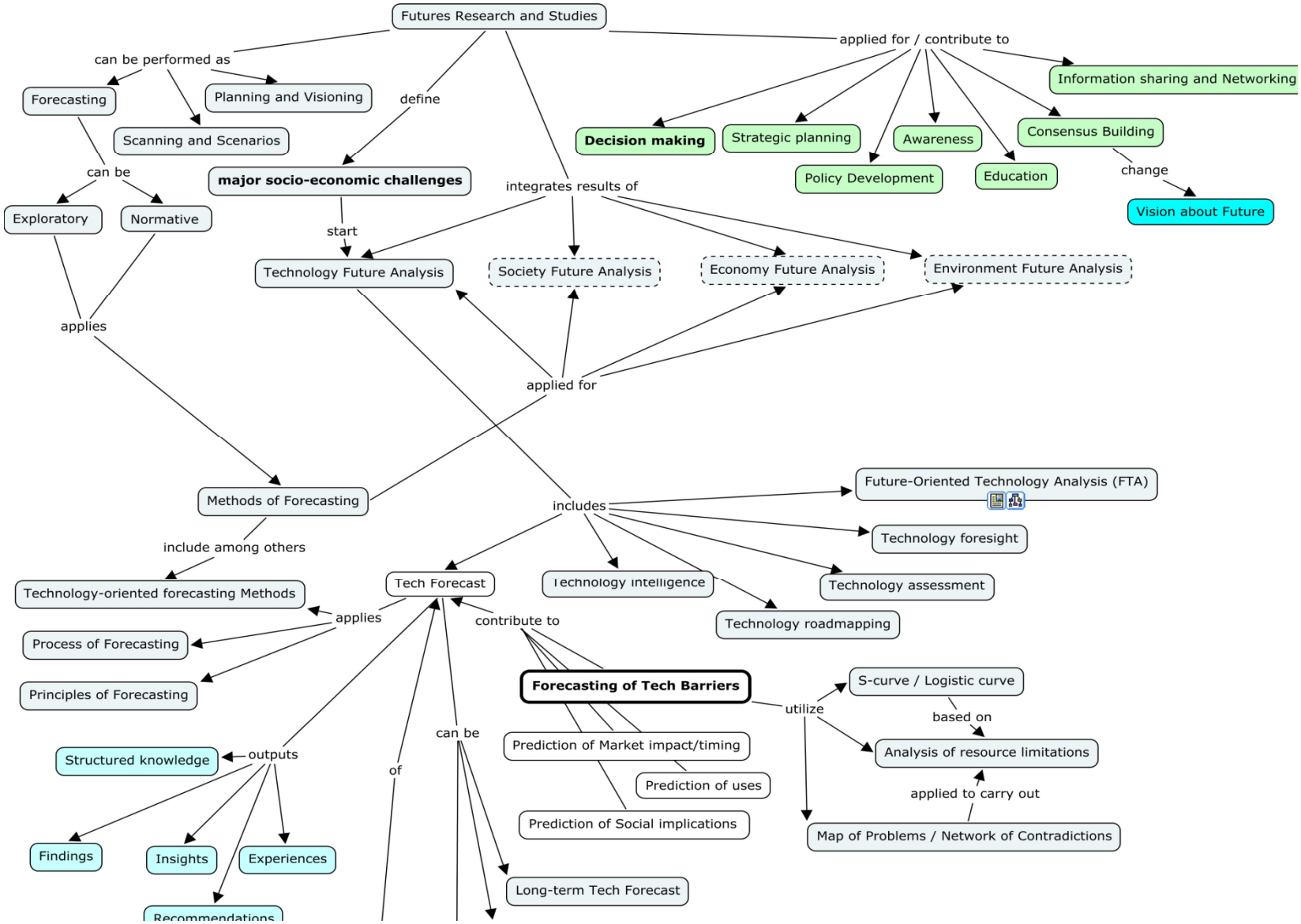
why do we need to know about future?



what are the objectives of a TF?



scope of a TF


Futures Research and Studies
can be performed as
Forecasting
Planning and Visioning
Scanning and Scenarios
can be
Exploratory
Normative
applies
define
major socio-economic challenges
start
Technology Future Analysis
integrates results of
Society Future Analysis
Economy Future Analysis
Environment Future Analysis
applied for
applied for / contribute to
Information sharing and Networking
Decision making
Strategic planning
Awareness
Consensus Building
Policy Development
Education
change
Vision about Future
Methods of Forecasting
include among others
Technology-oriented forecasting Methods
applies
Process of Forecasting
Principles of Forecasting
outputs
Structured knowledge
Findings
Insights
Experiences
Recommendations
includes
Future-Oriented Technology Analysis (FTA)
Technology foresight
Technology assessment
Technology roadmapping
Tech Forecast
Technology intelligence
contribute to
of
can be
Forecasting of Tech Barriers
Prediction of Market impact/timing
Prediction of uses
Prediction of Social implications
Long-term Tech Forecast
utilize
S-curve / Logistic curve
based on
Analysis of resource limitations
applied to carry out
Map of Problems / Network of Contradictions

We fail more often because we solve the wrong problem than because we get the wrong solution to the right problem.

Russell Ackoff

Why is it difficult to forecast?

why is it difficult to forecast reliably?

Please, discuss and arrange a list of causes.

Place the most important causes high on the list:

1. _____
2. _____
3. _____
4. _____

.....

.....

.....

why is it difficult to forecast reliably?

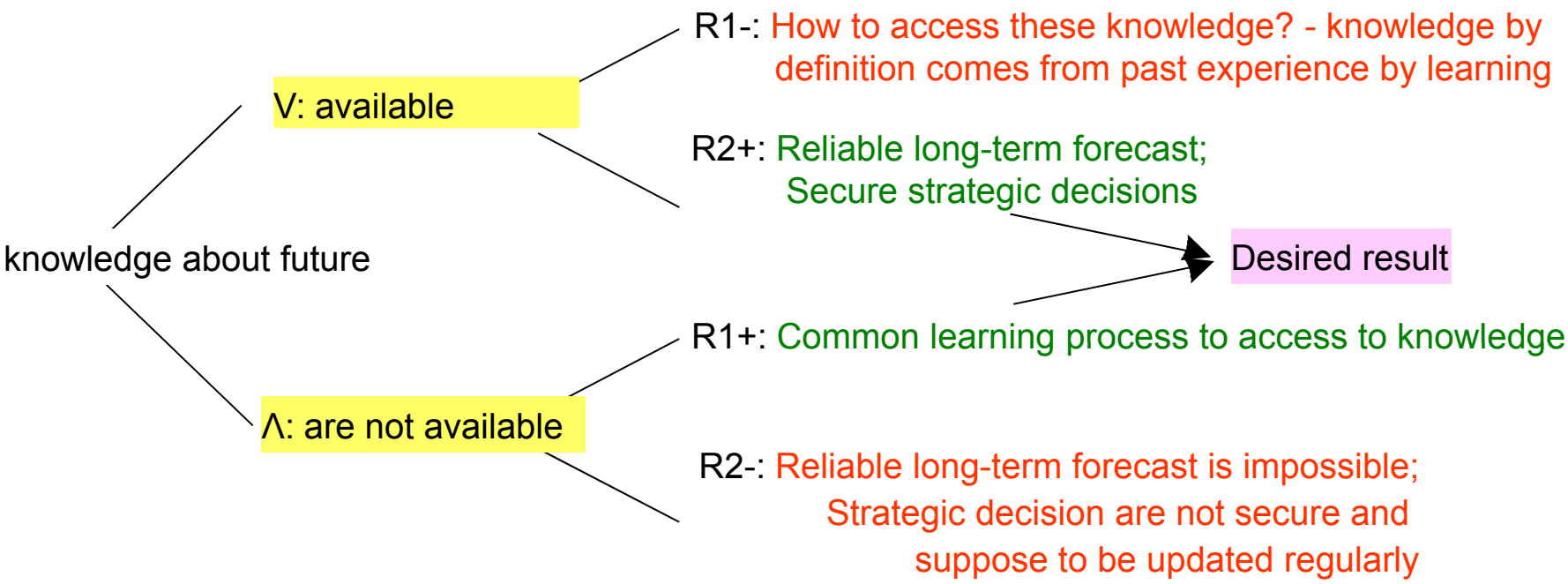
- lack of information for time being & past;
- impossible to validate;
- variable socioeconomic and political factors;
- possibility of unexpected changes at related sectors;
- future trends may not follow the regular path (past behaviour)

- lack of knowledge;
- subjective approach;
- other technological development (replacement of function);
- dynamic environment (e.g. wars, economic crises, regulations, etc.)

- uncertainty of super-system (social, economic, industrial, natural factors);
- since forecast itself based on subjective opinion;
- lack of knowledge about sub-systems for present

why is it difficult to forecast?

Assumption: For strategic decision-making it is necessary to have reliable knowledge about distant future



why is it difficult to predict?

[numerous relationships… over long time horizon]

The forecasting models should

<capture and simulate numerous relationships >, in order

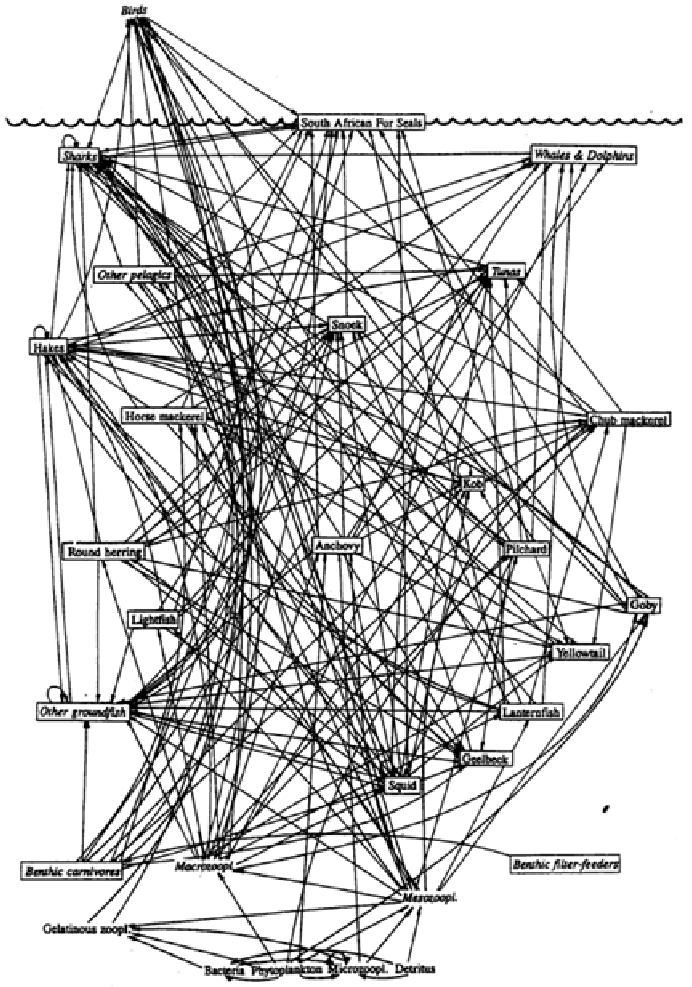
- to represent changes in product market, in product use, and in product production;
- to characterize the activity of an economic system;
- to imitate the feedback characteristics.

However, **the forecasting model** should

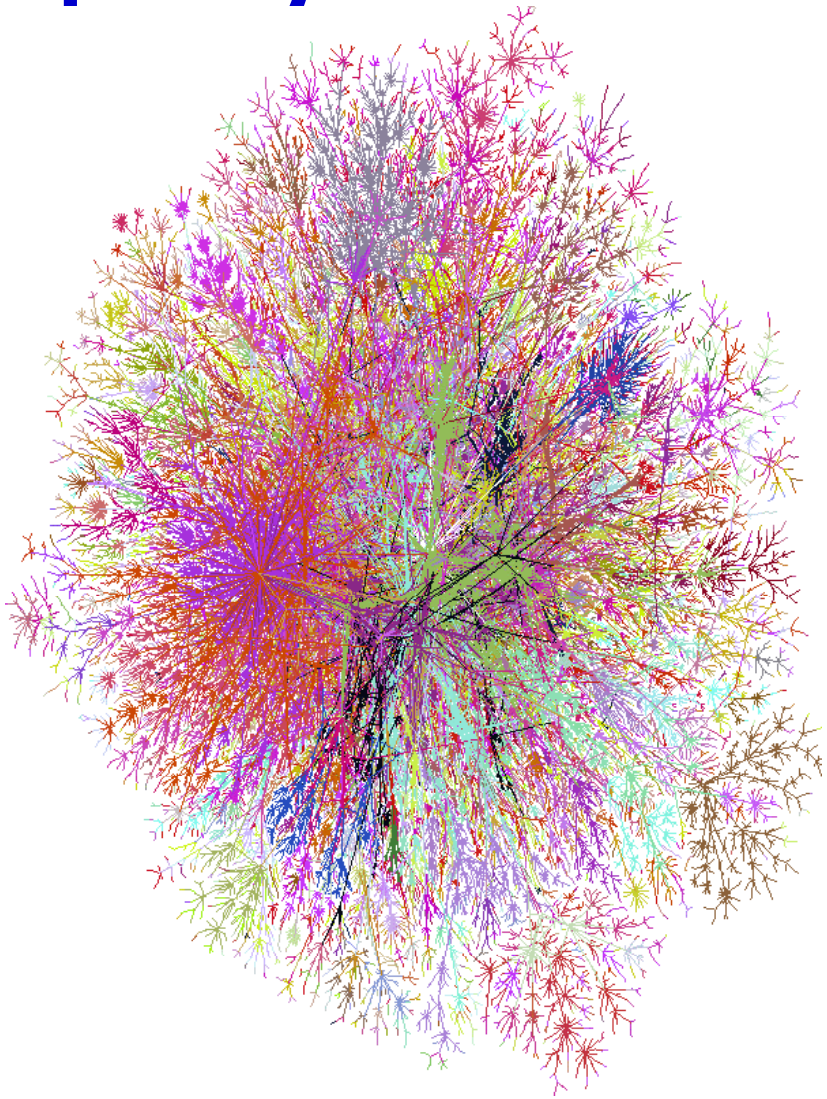
<apply minimum characteristics>, in order

- to minimize errors owing by data (e.g. synergy effect);
- to minimize inaccuracy of results due to model complexity;
- to provide a clear unambiguous interpretation of results.

complexity vs. design capacity



'a portion of the food web for the Benguela ecosystem (Buchanan, 2002)



This map appeared in the December 1998 Wired (Internet Mapping Project, http://www.cheswick.com/ches/map/index.html)

Efficiency *is doing things right;*

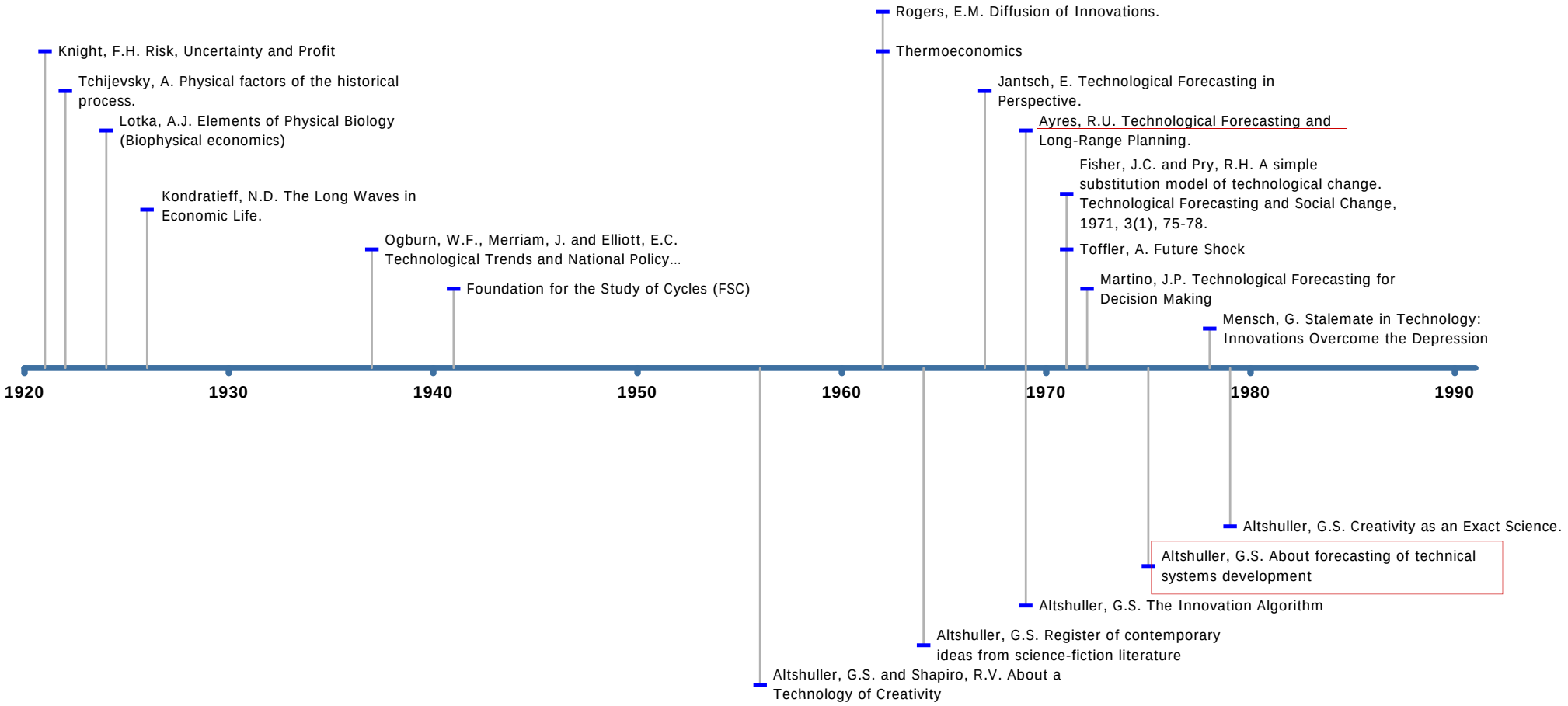
effectiveness *is doing the right things…*

Peter Drucker

What are
the existing approaches?

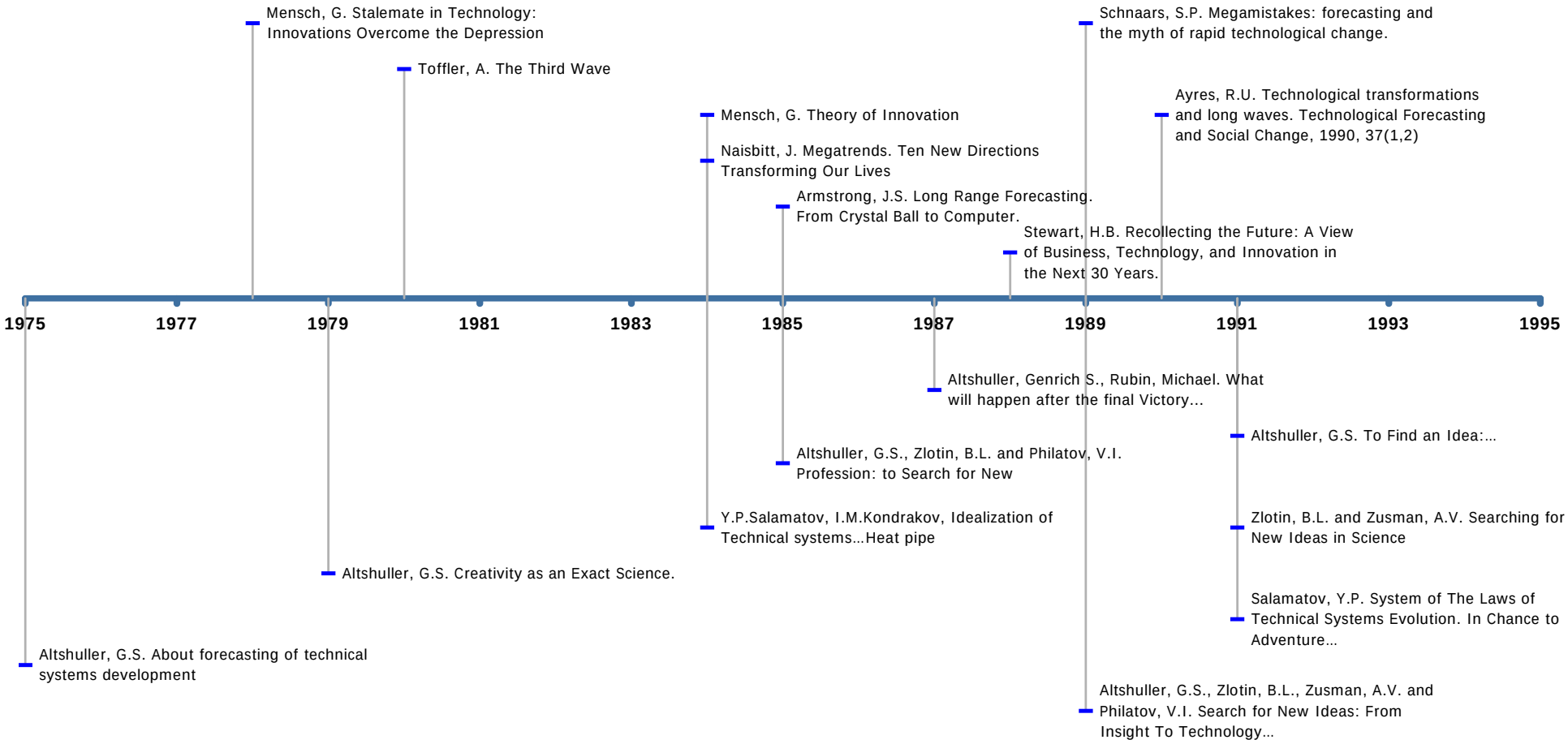
Forecasting and TRIZ

[timeline fragment #1]



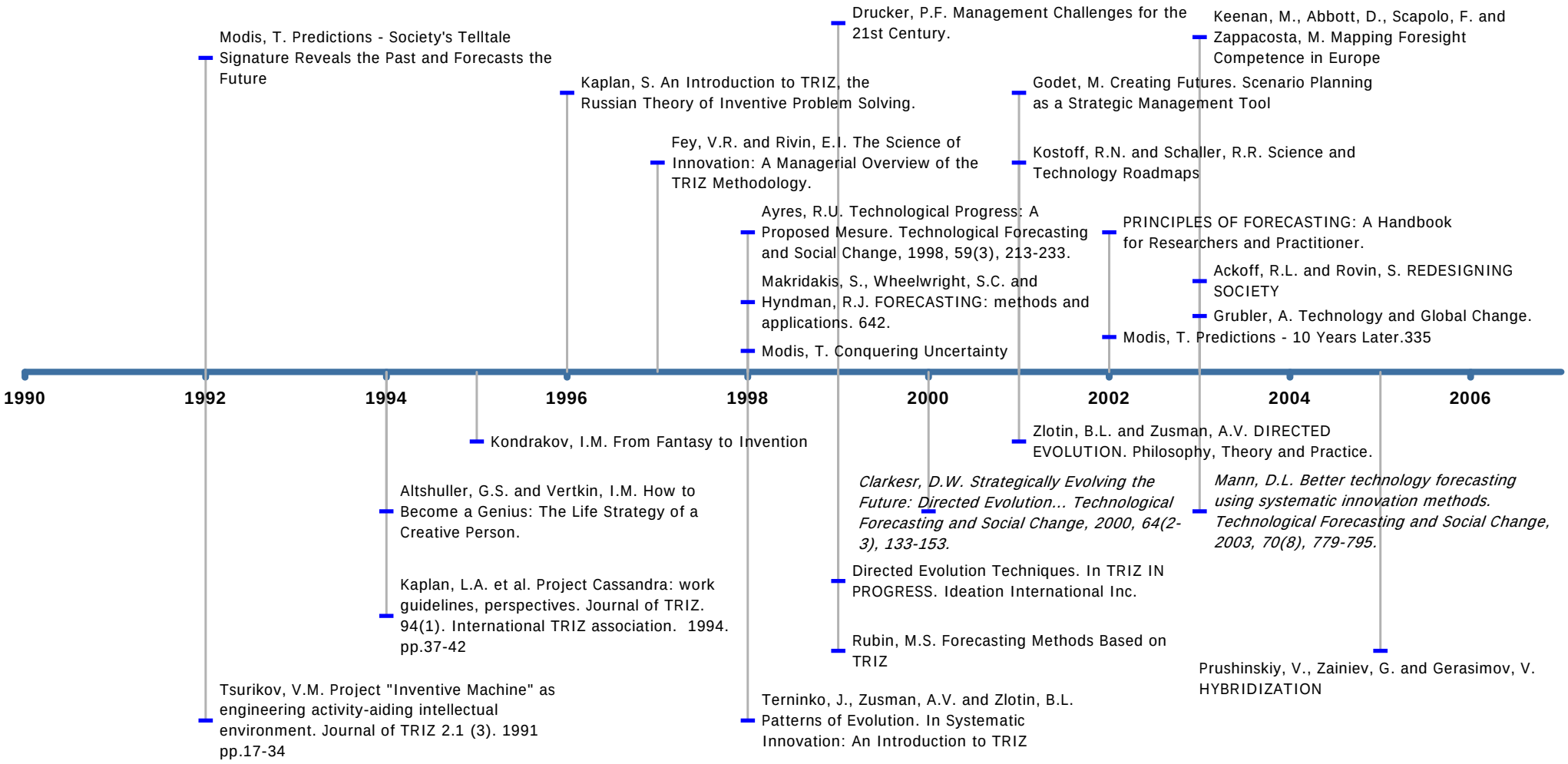
TRIZ and Forecasting

[timeline fragment #2]

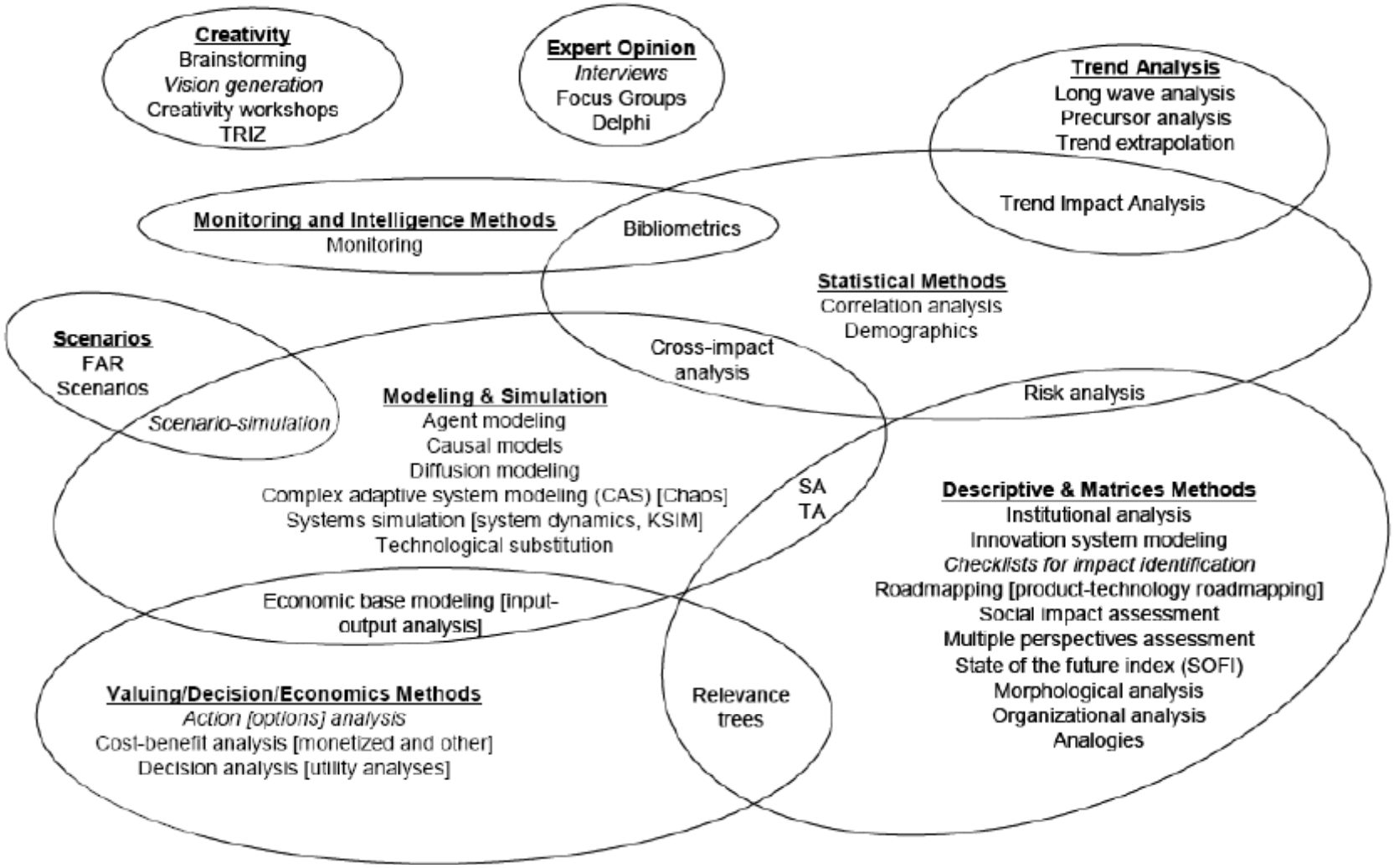


Technological forecasting & TRIZ

[timeline fragment #3]



many technology forecasting methods…

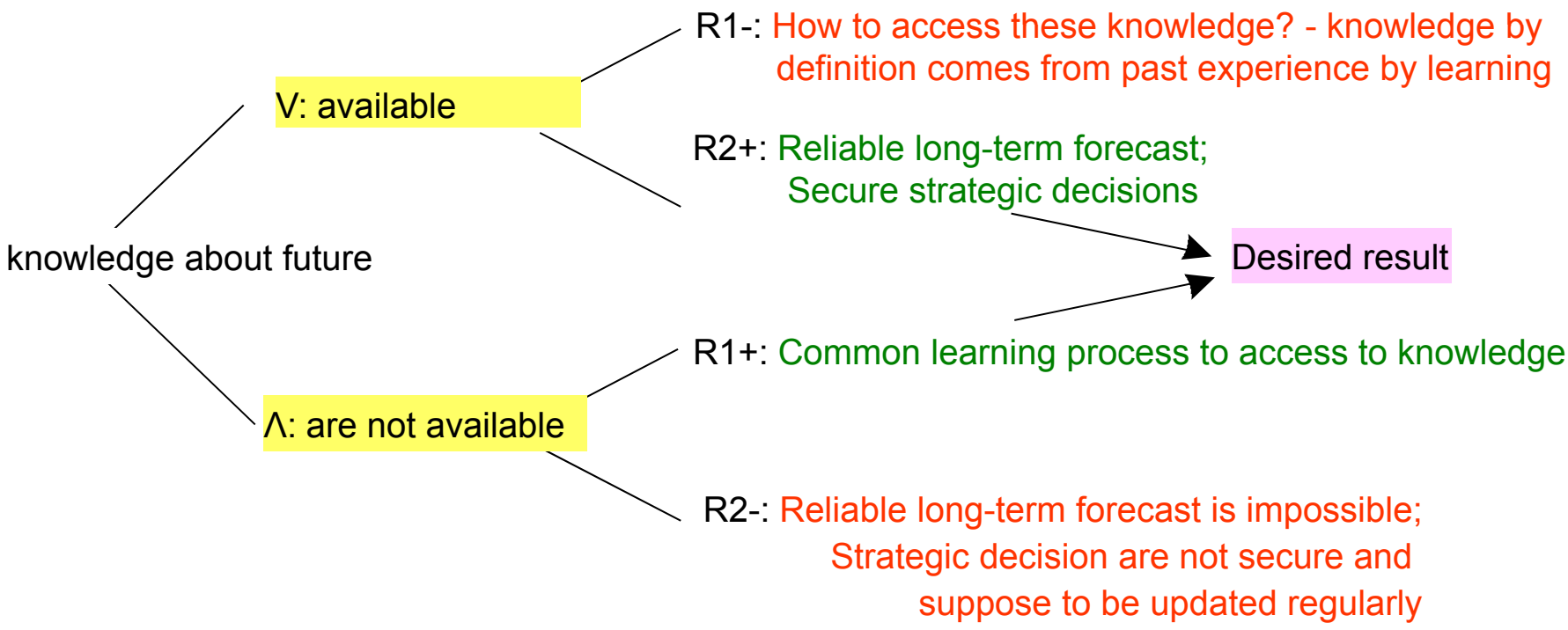


Source: Cascini G. 2012

What is suggested

why is it difficult to forecast?

a basic assumption: For strategic decision-making it is necessary to have reliable knowledge about distant future

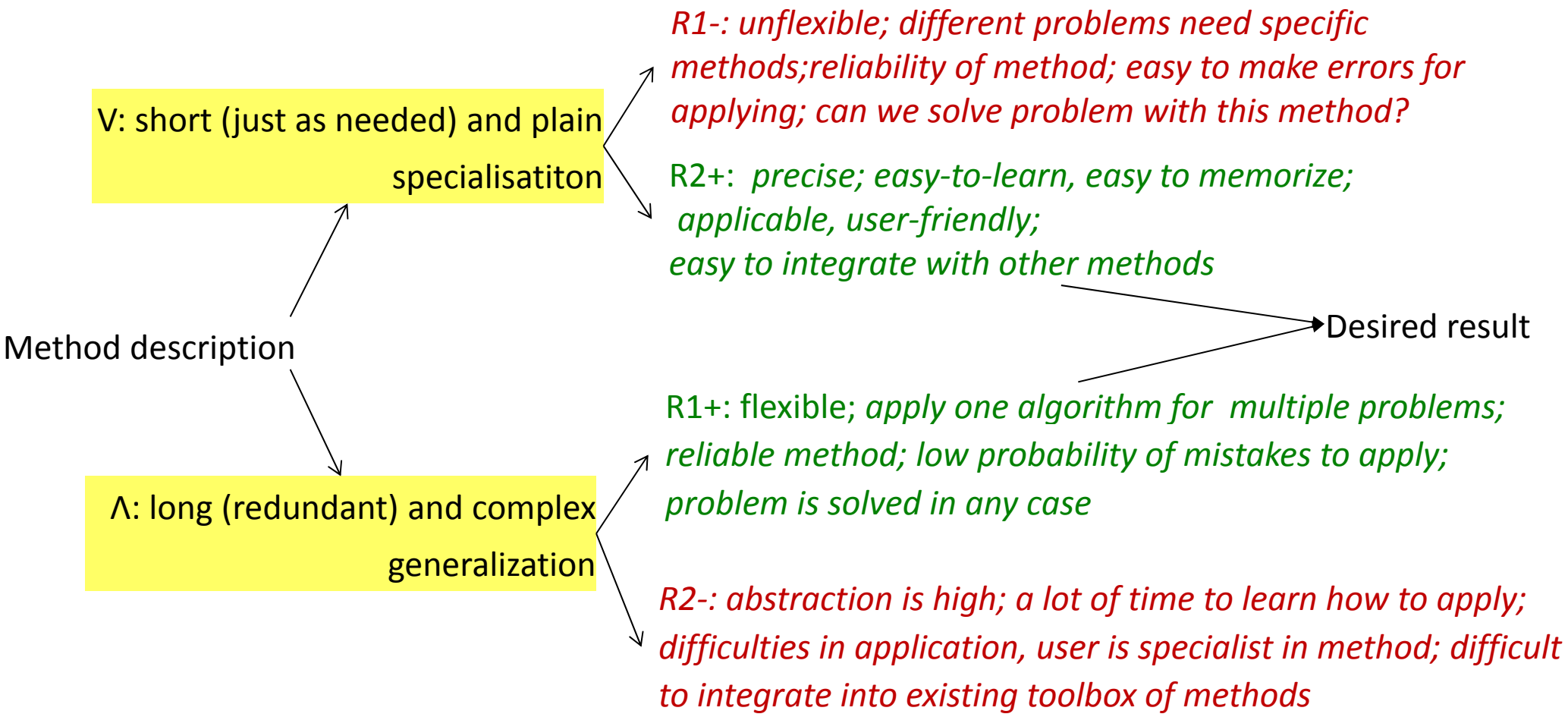


Problems are more important than solutions. Solutions can become obsolete when problems remain.

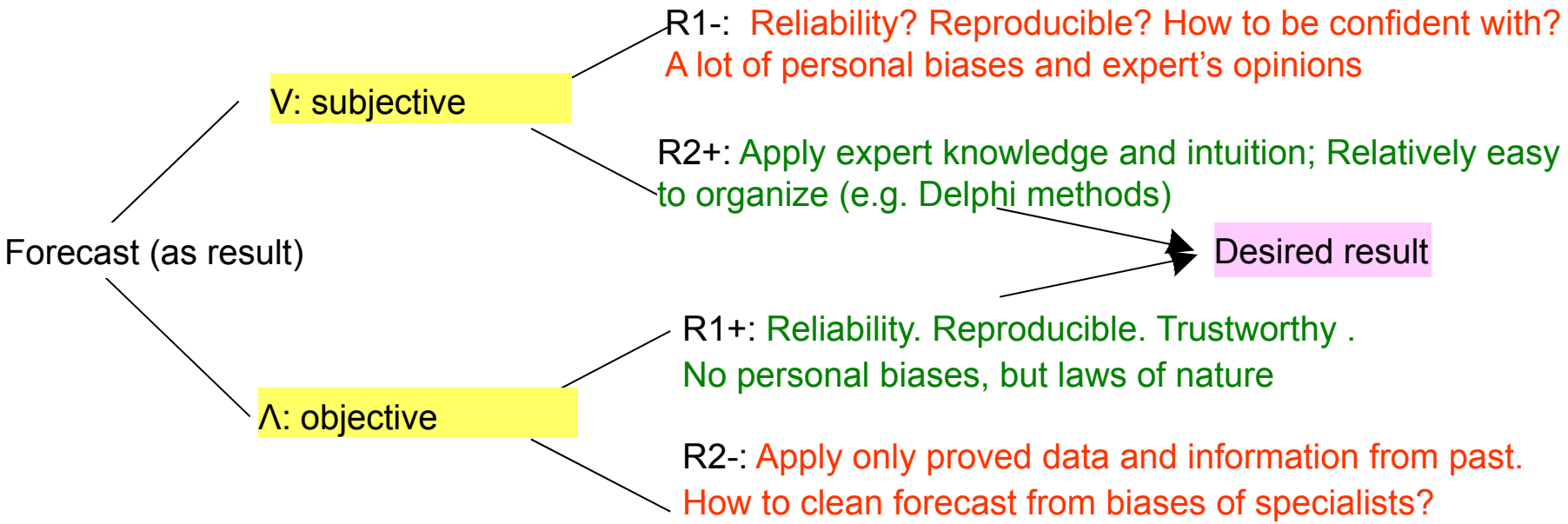
– attributed to Niels Bohr

Specific (particular) vs. Generic (universal) methods

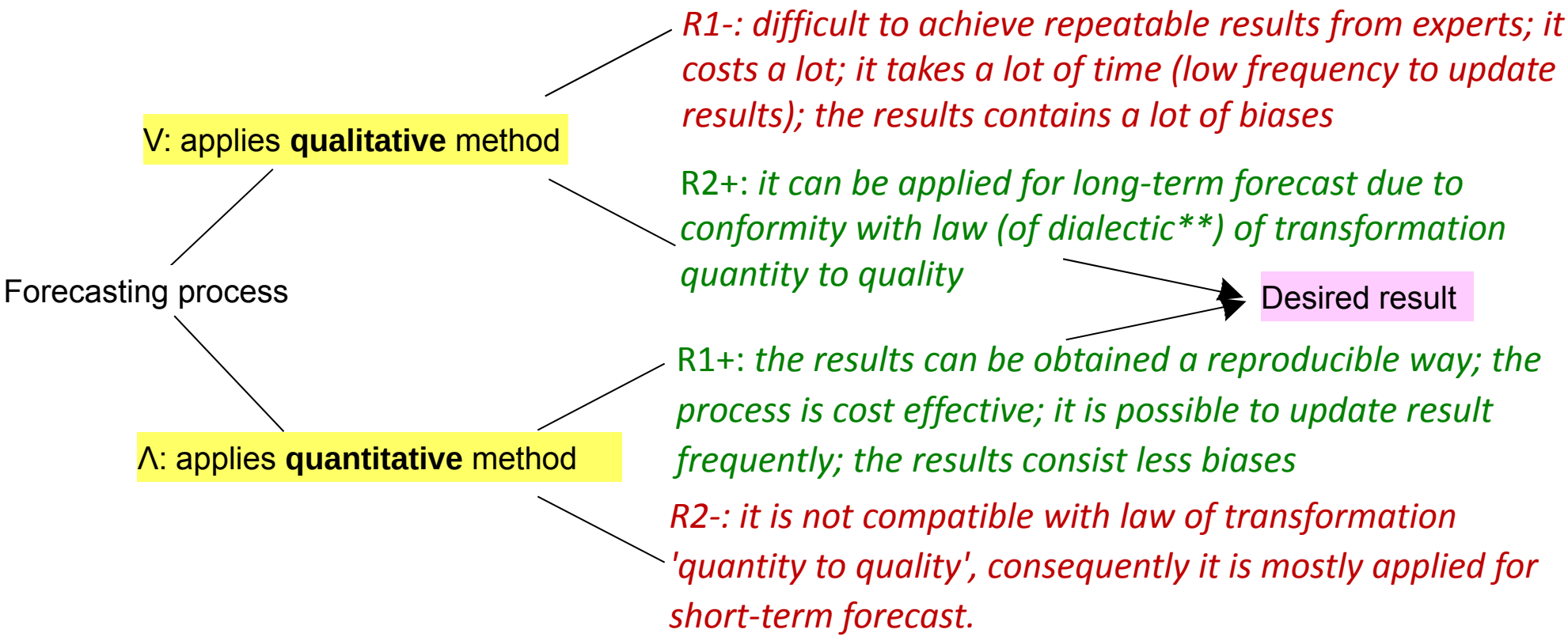
METHOD – 1) is a process by which a task is completed; a way of doing something [wiktionary]
2) is a systematic procedure by which a complex scientific or engineering task is accomplished;



source of information vs. reliability

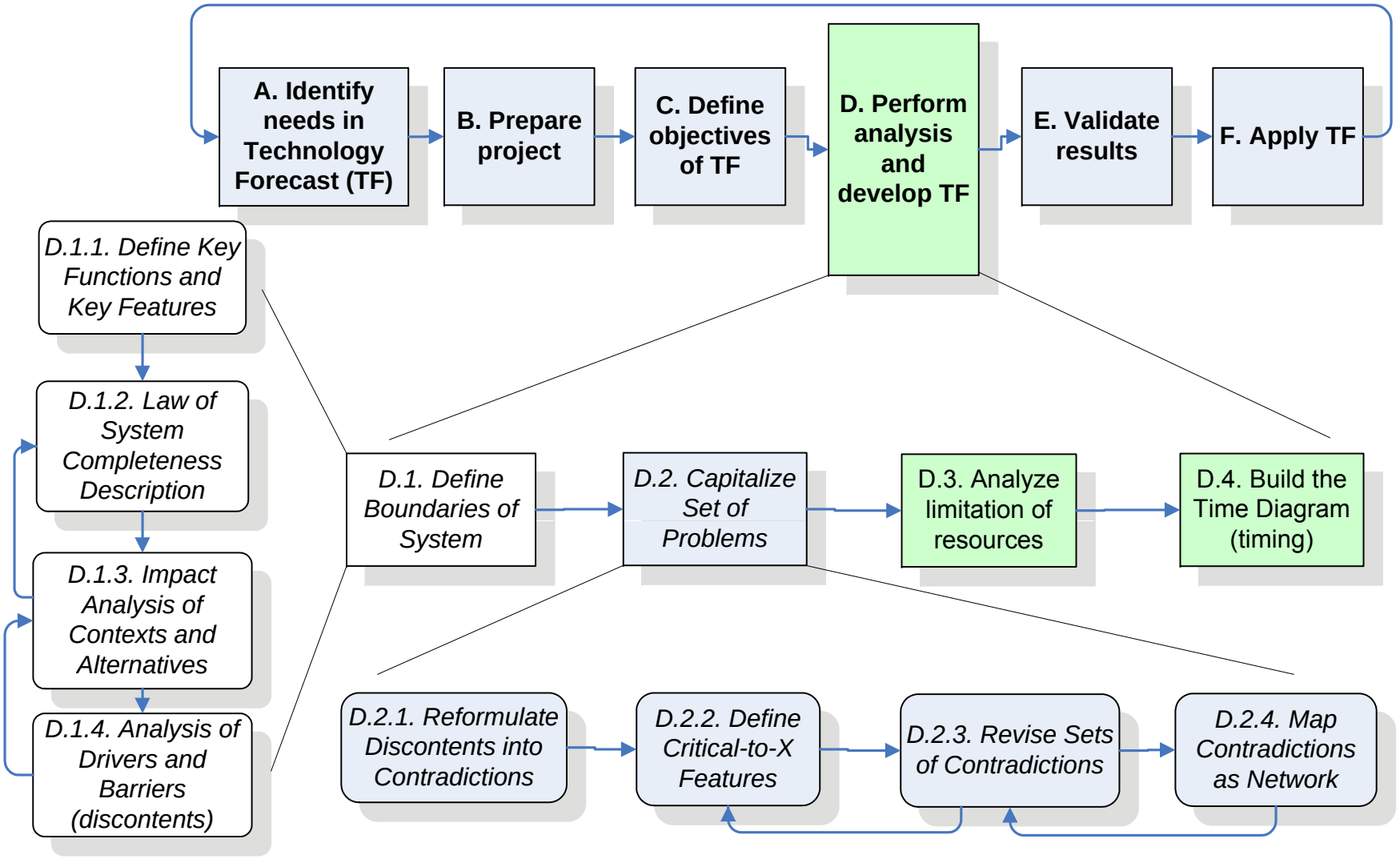


a problem of a method for exploratory LONG-TERM forecast



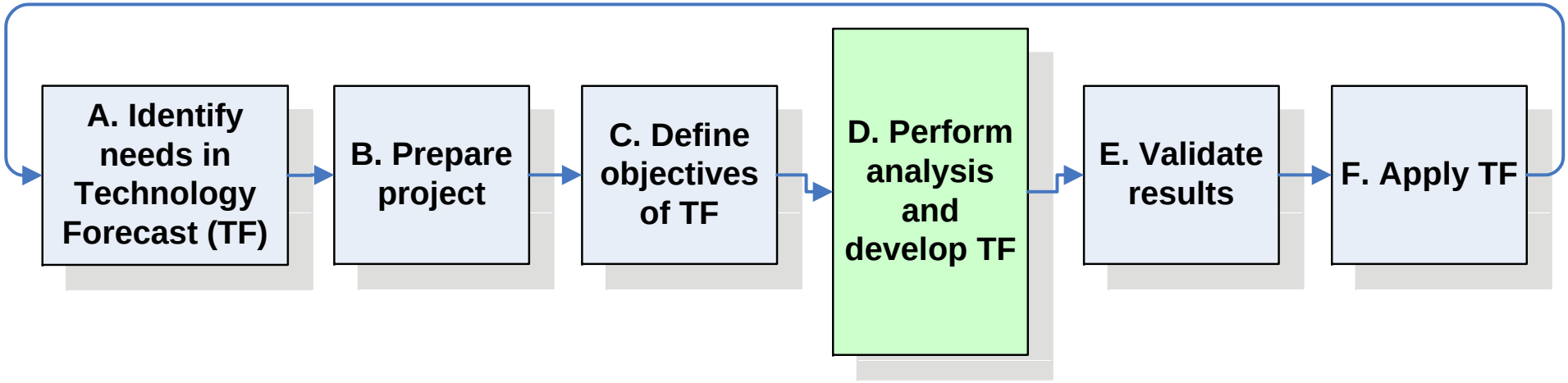
** The law of transformation of quantity into quality: *"For our purpose, we could express this by saying that in nature, in a manner exactly fixed for each individual case, qualitative changes can only occur by the quantitative addition or subtraction of matter or motion (so-called energy)."* [Engels' Dialectic of Nature. II. Dialectics. 1883]

flowchart of the suggested method



flow chart of method

"…providing a consensual vision of the future science and technology landscape to decision makers."
[Kostoff and Schaller, 2001]



before studying the trends

A. Identify needs

- What are main objectives and expected outputs?
- How it will be applied for decision making process?
- Can we satisfy formulated needs without TF?
  -> *Go / Not to Go*

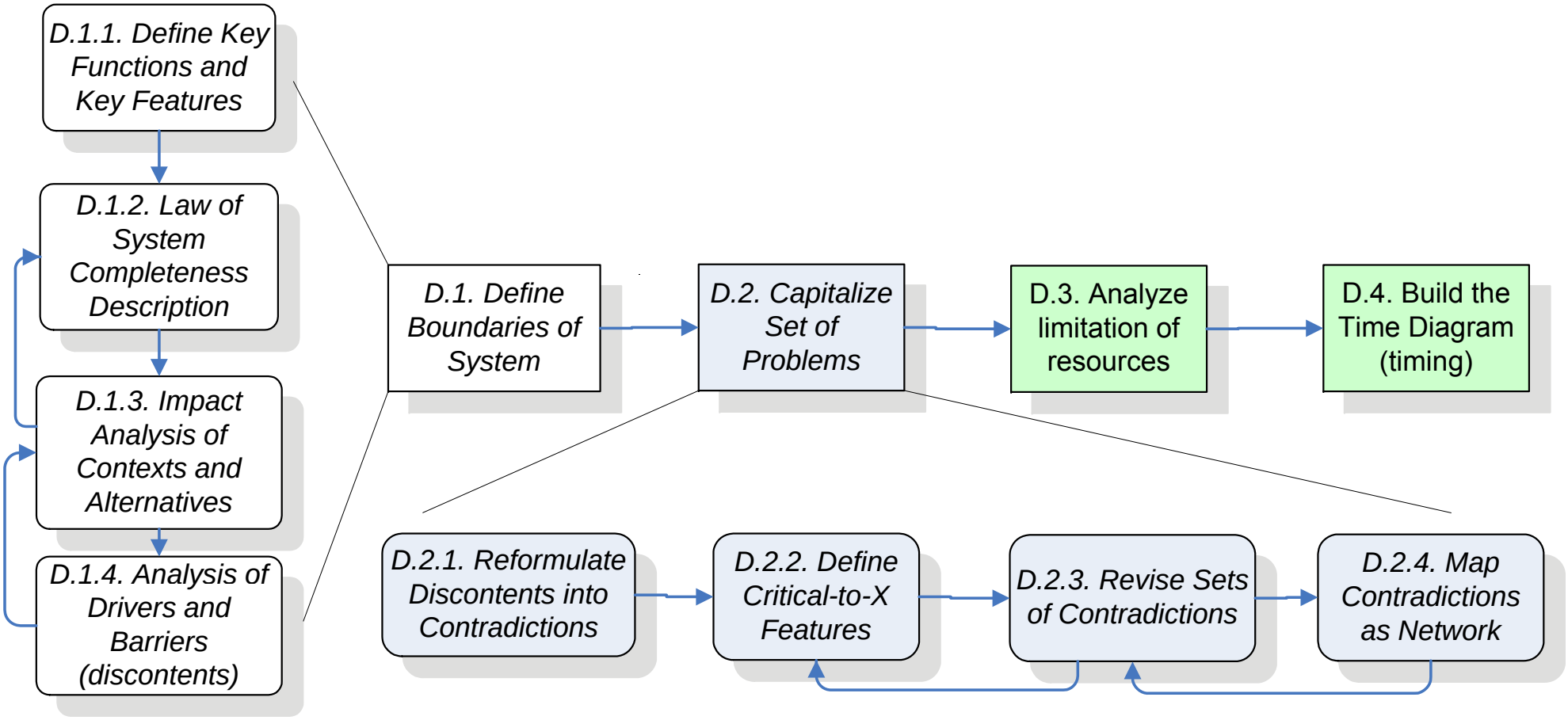
B. Prepare project

- What are available and necessary resources to perform study?
- What is an optimal time span to realize project?
- Who are clients, core team, and necessary external participants?
  -> *Detailed plan of project*.

C. Define objectives

- What kind of question should be answered?
- What would we need a technology forecast for?
- How would we like to use the forecast?
- What are the data sources…? -> *Validated project specification*

D. Perform a study and develop TF

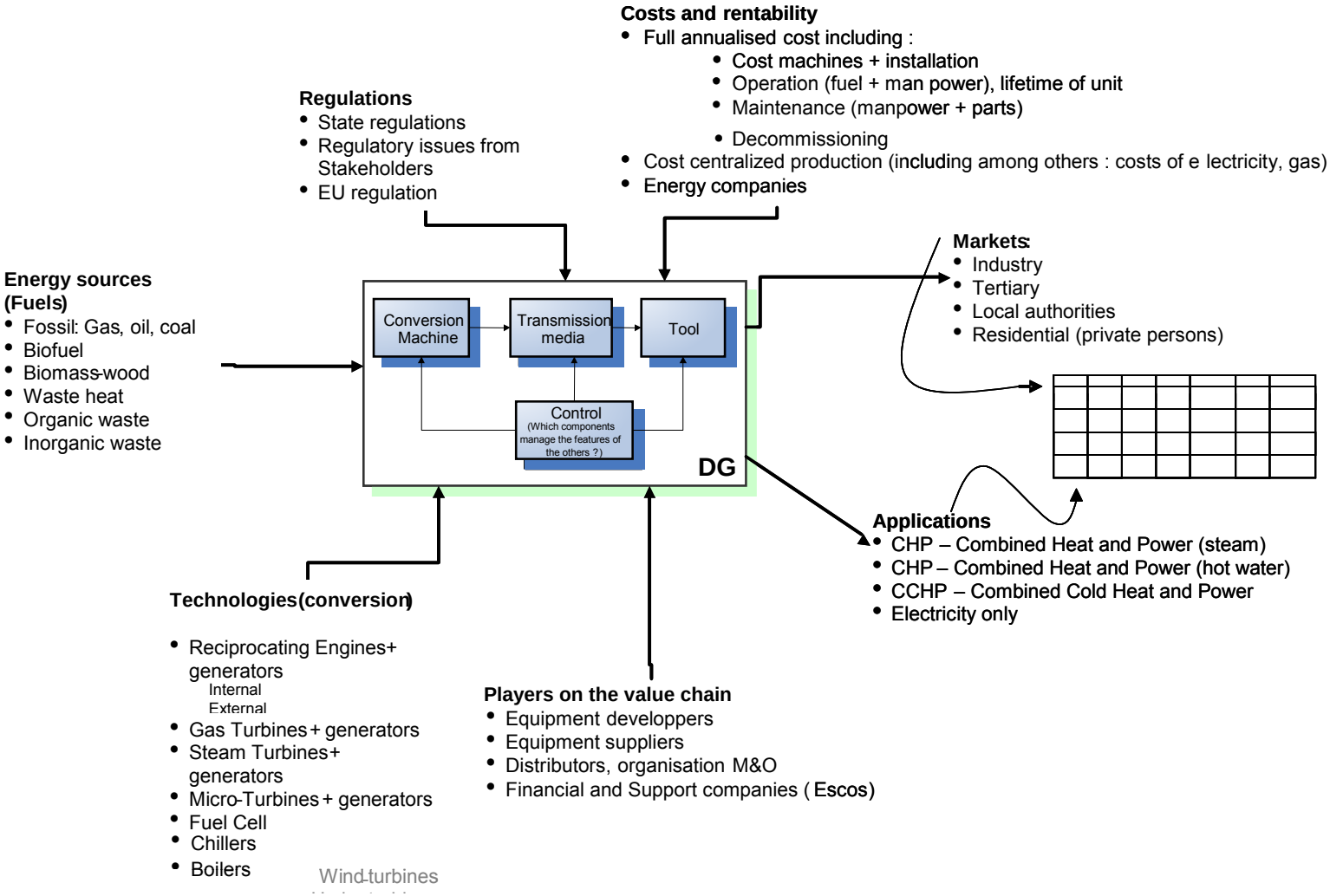


D.1. define boundaries of a system

D.1.1. Define key functions and key features	• What are main function (set of major functions) and what are significant traits? *-> First approximation to boundaries of system to be studied.*
D.1.2. Law of System Completeness	• What are four major components of system? What are product and tool? How energy passes through system? *-> Defined system with boundaries and major sub-systems.*
D.1.3. Impact analysis of Contexts and Alternatives	• How system is positioned according to Economic, Social, Environmental and Technological contexts? *-> Definition of system and major super-systems.*
D.1.4. Analysis of Drivers and Barriers	• What are driving forces and obstacles on evolution of system? *-> Preliminary lists of resources and dissatisfactions.*

D.1. boundaries of a system (example)

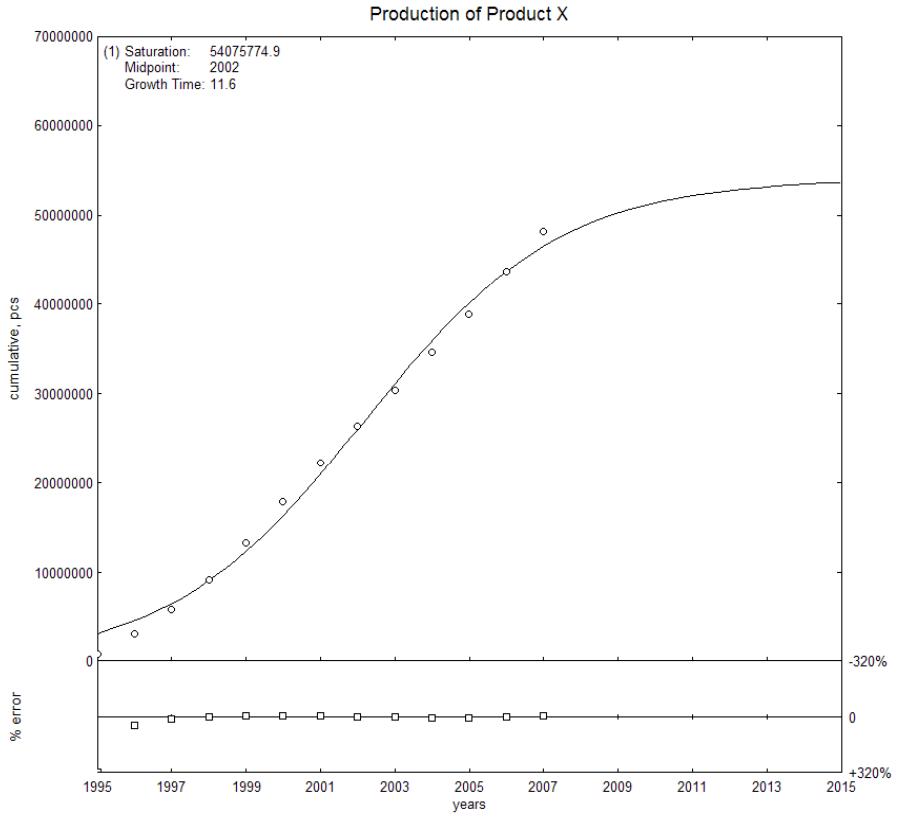
Law of System Completeness: Distributed Energy Generation system



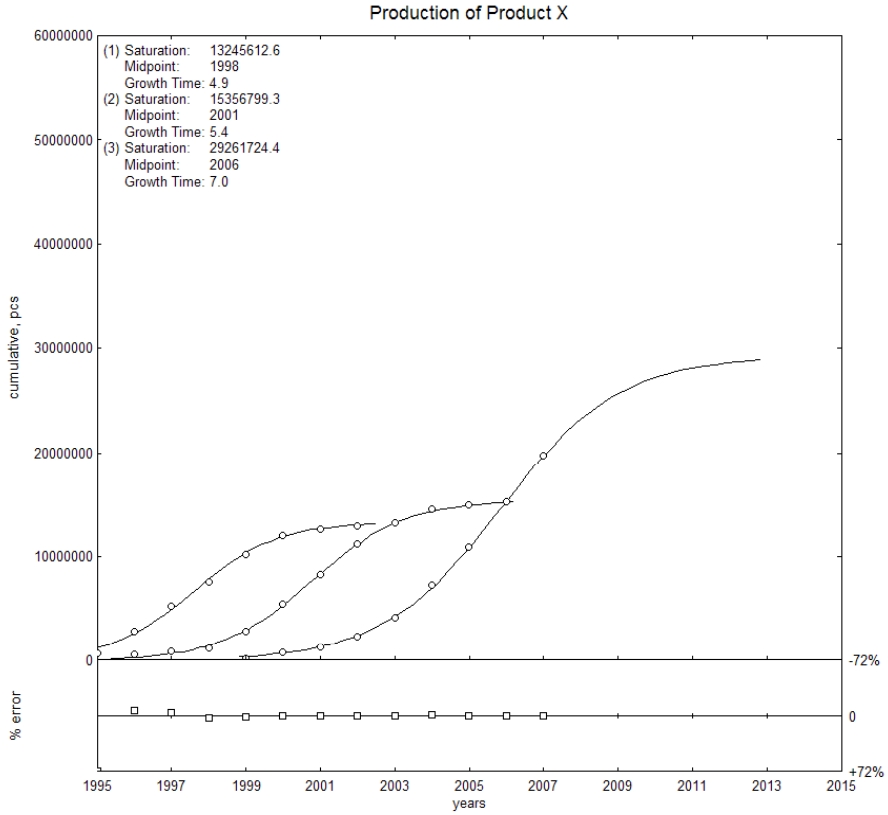
* Information provided courtesy of EIFER, Karlsruhe [Henckes, L. et al., 2006]

what is the future of some “X” technology?

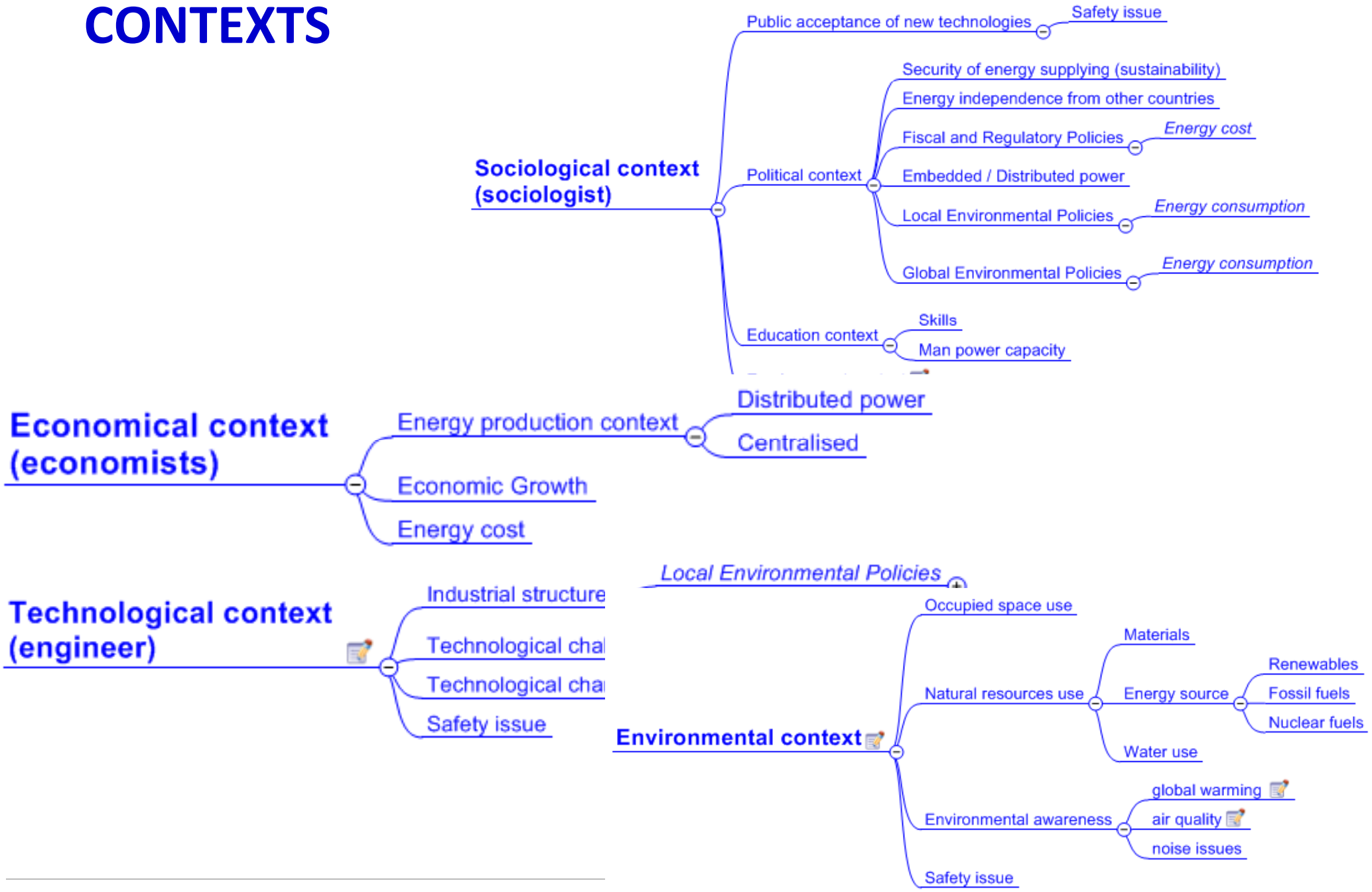
intuitive prediction



extrapolation of trends



CONTEXTS


Sociological context (sociologist)
Public acceptance of new technologies
Safety issue
Political context
Security of energy supplying (sustainability)
Energy independence from other countries
Fiscal and Regulatory Policies
Energy cost
Embedded / Distributed power
Local Environmental Policies
Energy consumption
Global Environmental Policies
Energy consumption
Education context
Skills
Man power capacity
Economical context (economists)
Energy production context
Distributed power
Centralised
Economic Growth
Energy cost
Technological context (engineer)
Industrial structure
Technological cha
Technological cha
Safety issue
Local Environmental Policies
Environmental context
Occupied space use
Natural resources use
Materials
Energy source
Renewables
Fossil fuels
Nuclear fuels
Water use
Environmental awareness
global warming
air quality
noise issues
Safety issue

D.1. boundaries of a system (example)

List of Drivers and Barriers: Stationary Fuel cell

Sociological context		Economic context	
Drivers	***Barriers***	***Drivers***	***Barriers***
Good image of fuel cell Local policy to reduce GHG effect (demand-side management) Security of energy supply Lower electricity dependence from other countries Manpower demand	Safety issue Public ignorance of CHP: conservative market Decrease of heat demand Need of education for manpower Unemployment in old technology field Uncertainty on distributed generation development (dependant of fiscal and regulatory policies)	New business creation (premium power, domestic CHP, energy services, back-up power, market for gas utilities) Possible synergies with mobile sector will help cost reduction	In recession period, hard to introduce new technologies Allowable cost evaluation influenced by several factors, i.e. future energy cost Profitability not demonstrated (standby attitude of investors)
Technological context		**Environmental context**	
Drivers	***Barriers***	***Drivers***	***Barriers***
Modularity Reduction of electricity transmission losses Heat available High power to heat ratio Lower maintenance cost High efficiency at low power High efficiency at part load	Technical difficulties to grid connection for large scale integration of FC Availability of components Reliability on field (lifetime, maintenance)	High electrical efficiency: reduction of GHG emission and natural resources consumption Large choice of primary energy sources to produce H2 (fossil, renewable, nuclear…) Very low pollutant emissions (NOx, SOx, particles..) CO2 sequestration potential	Occupied area use

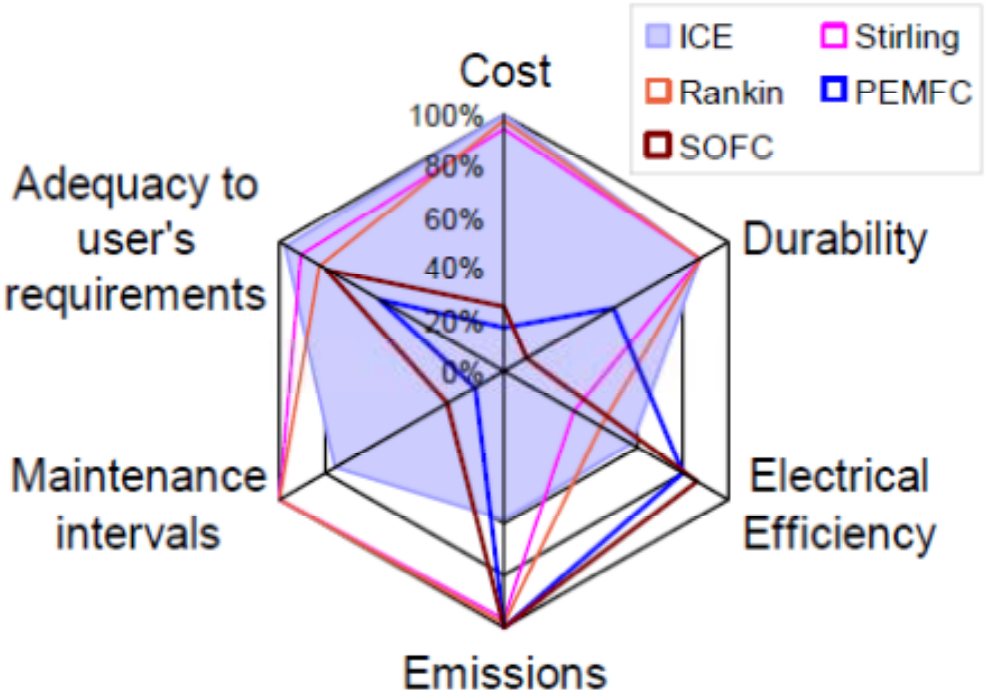
* Information provided courtesy of EIFER, Karlsruhe [Gautier, L. et al., 2005]

D.2. Capitalize Set of Problems

D.2.1. Reformulate Discontents into Contradictions	• What are the problems behind of discontents and barriers? *-> List of contradictions (technical contradictions – TRIZ).*
D.2.2. Define Critical-to-X Features	• What are root causes of discontents and contradictions? *-> Set of metrics to measure evolution of system*.
D.2.3. Revise Sets of Contradictions	• How root causes are relevant to formulated contradictions? *-> Prototypes of contradictions of parameters (physical contradiction - TRIZ).*
D.2.4. Map Contradictions as Network	• How formulated contradictions are linked? What is the network of contradictions? *-> 'one page' presentation of interconnected contradictions.*

capitalize set of problems

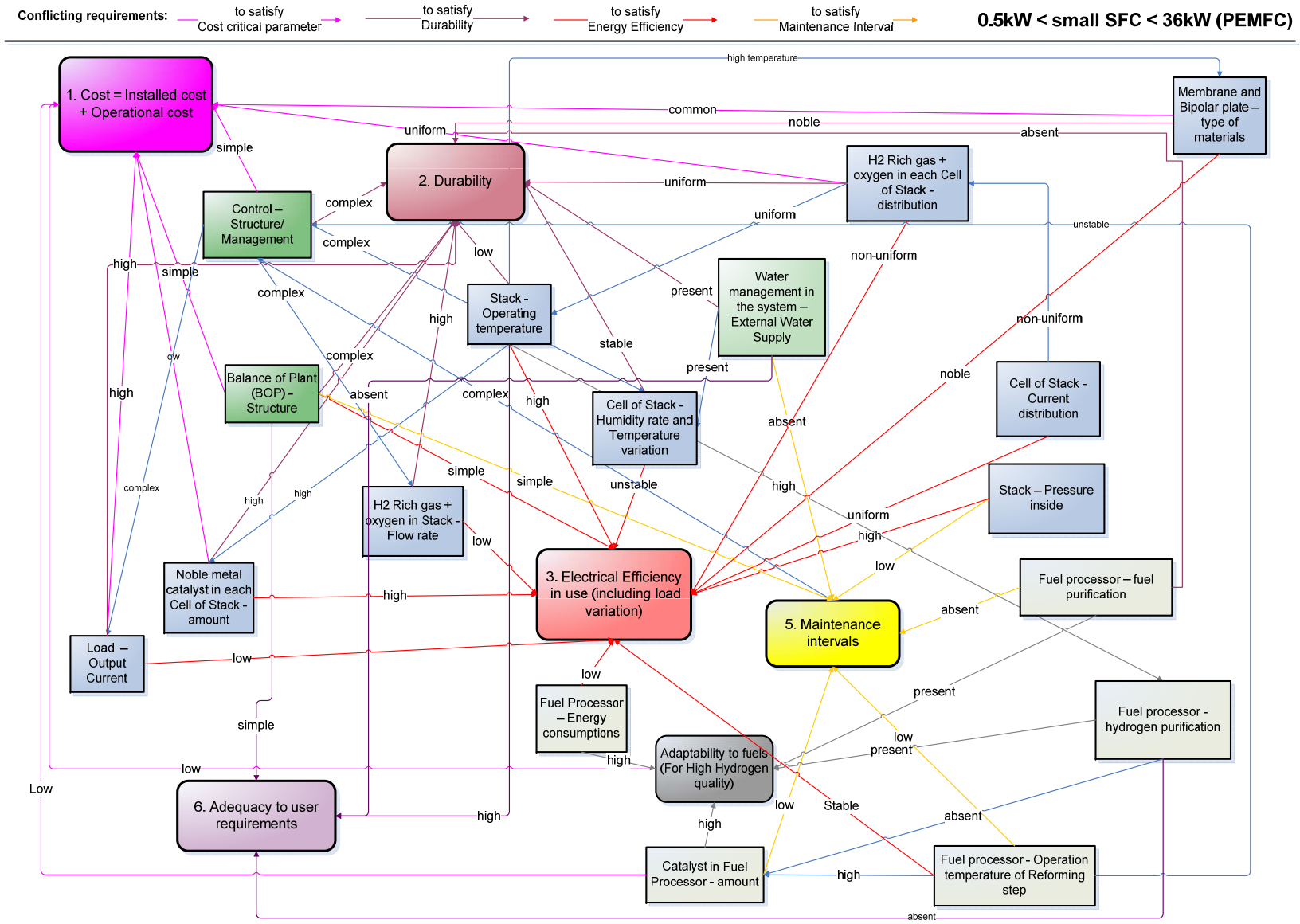
Critical-to-Market features: Stationary Fuel Cell



		PEMFC			SOFC		
		actual	market target	performed	actual	market target	performed
1.	Cost:	17%	100%		25%	100%	
1.1.	Installed Cost NG, EUR/kW	15000	4000	27%	10000	4000	40%
	Importance: High						
1.2	Operational cost, EUR/kWh	0.3	0.02	7%	0.2	0.02	10%
	Importance: High						
2.	Durability:	49%	100%		10%	100%	
2.1	Durability in operating conditions, years	2	15	13%	2	15	13%
	Importance: High						
2.2	Cycling ability, number of stops per year	125	125	100%	10	125	8%
	Importance: High						
2.3	Start up time, min	90	15	17%	240	15	6%
	Importance: Moderate						
3.	Energy Efficiency, %	85%	100%		93%	100%	
3.1	Electrical efficiency, %	28%	35%	80%	30%	35%	86%
3.2	Thermal efficiency, %	59%	65%	91%	55%	50%	100%
3.3	Ratio Electrical power / Thermal Power	0.51	0.04		0.04	0.04	
4.	Emissions	100%	100%		100%	100%	
	Importance: High						
4.1	Substances, ppm	40					
			CO < 50ppm	100%		CO < 50ppm	100%
	Importance: High		NOx<200 ppm			NOx<200 ppm	
4.2	Noise, dB	0		100%	0		100%
	Importance: High						
5.	Maintenance interval, h	1000	8000	13%	2000	8000	25%
	Importance: Moderate						
6.	Adequacy to user requirements,	56%	100%		79%	100%	
6.1	min. temperature return, °C						
	Importance: High	50	60	83%	500	70	100%
6.2	min. flow temperature, °C						
	Importance: Moderate	70	90	88%	800	90	100%
6.3	size, m	1.5x0.85x1.7	0.5x0.5x1		0.55 x 0.55 x 1.60	0.5x0.5x1	
	Importance: Moderate	2.17	0.25	12%	0.48	0.25	52%
6.4	weight, kg	500	70	14%	170	70	41%
	Importance: Moderate						
	Average for technology:	39%	100%		40%	100%	

* Information provided courtesy of EIFER, Karlsruhe [Gautier, L. et al., 2005]

what are we doing to cope with unknown?



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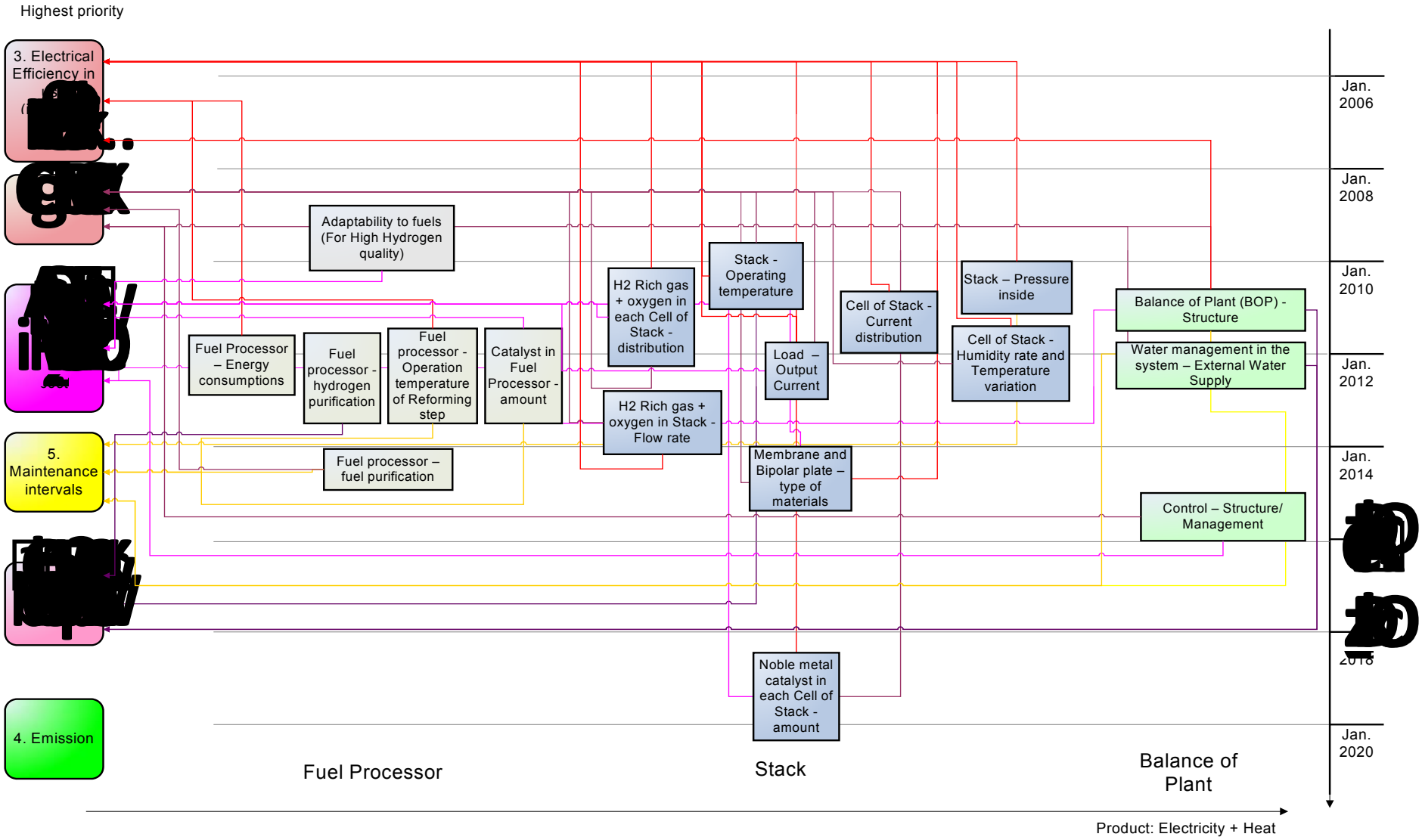
D.3. Analyze the limitations of resources

Technological barriers assessment:

- What are Science and Technology + Research and Development activities addressed to identified problems?

Element-Feature	Value 1	Value 2 (opposed)	Limiting resources	S&T, R&D activities, Project names	Exploration, years	Experimentation & examination, years
Noble metal catalyst in each Cell of Stack - amount	Low	High	Platinum needed at low temperature (<400°C)	<Project 1 name>	<Project1 duration>	<Time for field tests>
<E2 – F2>	<V>	<Λ>	<Substance, Field, Time, Space etc.>	<Project 2 name>	<Project2 duration>	<Time for field tests>
<E3 – F3>	Present	Absent	<Time, Space etc.>	No specific project	<Project3 duration ??>	<Time for field tests ??>
<…>	<…>	<…>	<…>	<…>	<…>	<…>
Fuel processor - Quality of outlet gas	Low	High	complex fuel processing technology for NG and biofuels	<Project N name>	<Project N duration>	<Time for field tests>

what are we doing to cope with unknown?



* Information provided courtesy of EIFER, Karlsruhe [Gautier, L. et al., 2005]

E. validate and F. apply the forecast

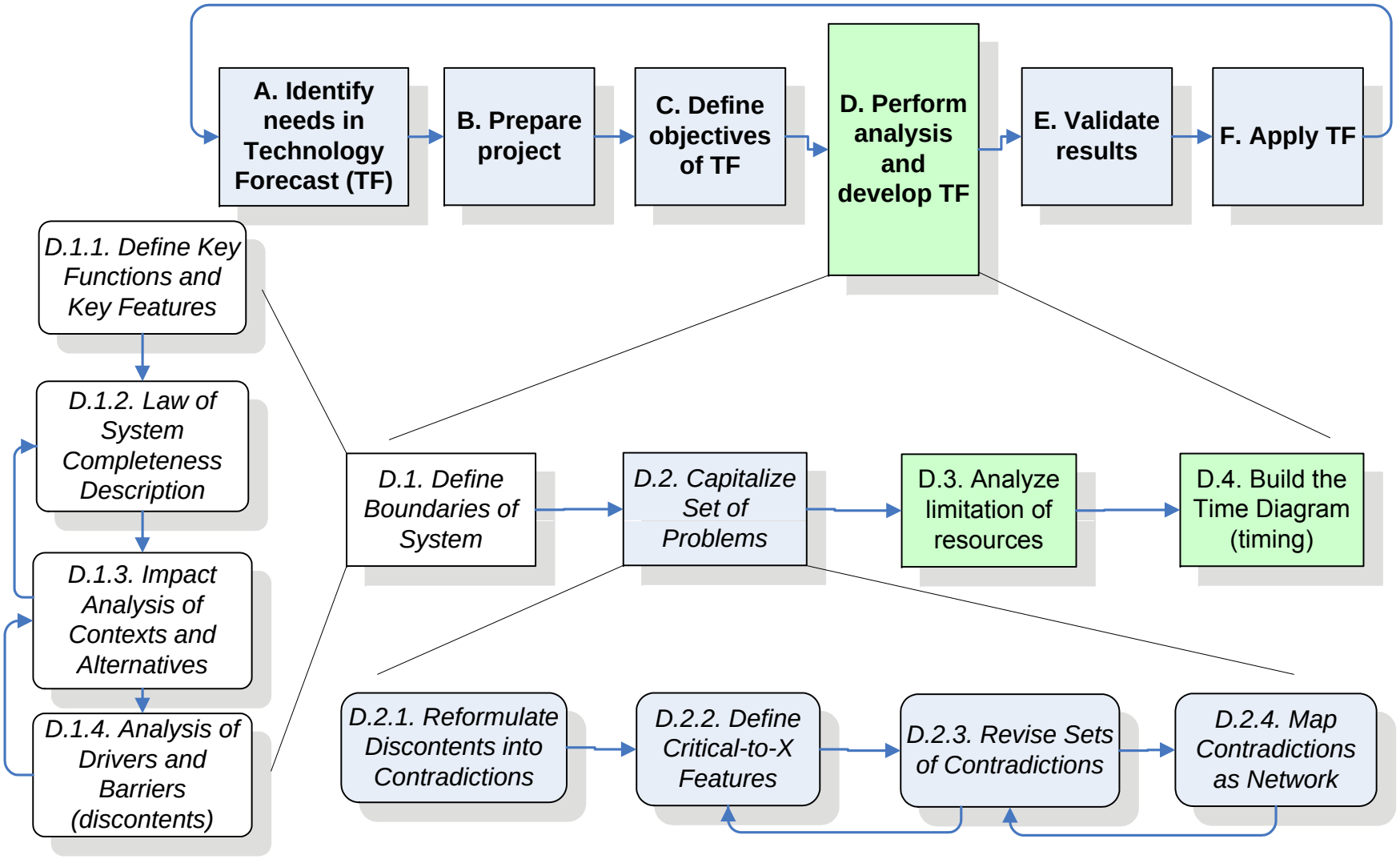
E. Validate results (peer review)

- For consistent validation of TF the major clients and partners should agree on:
  - key functions of the analyzed system,
  - key enabling technologies
  - major trends in the evolution of the surrounding super-systems

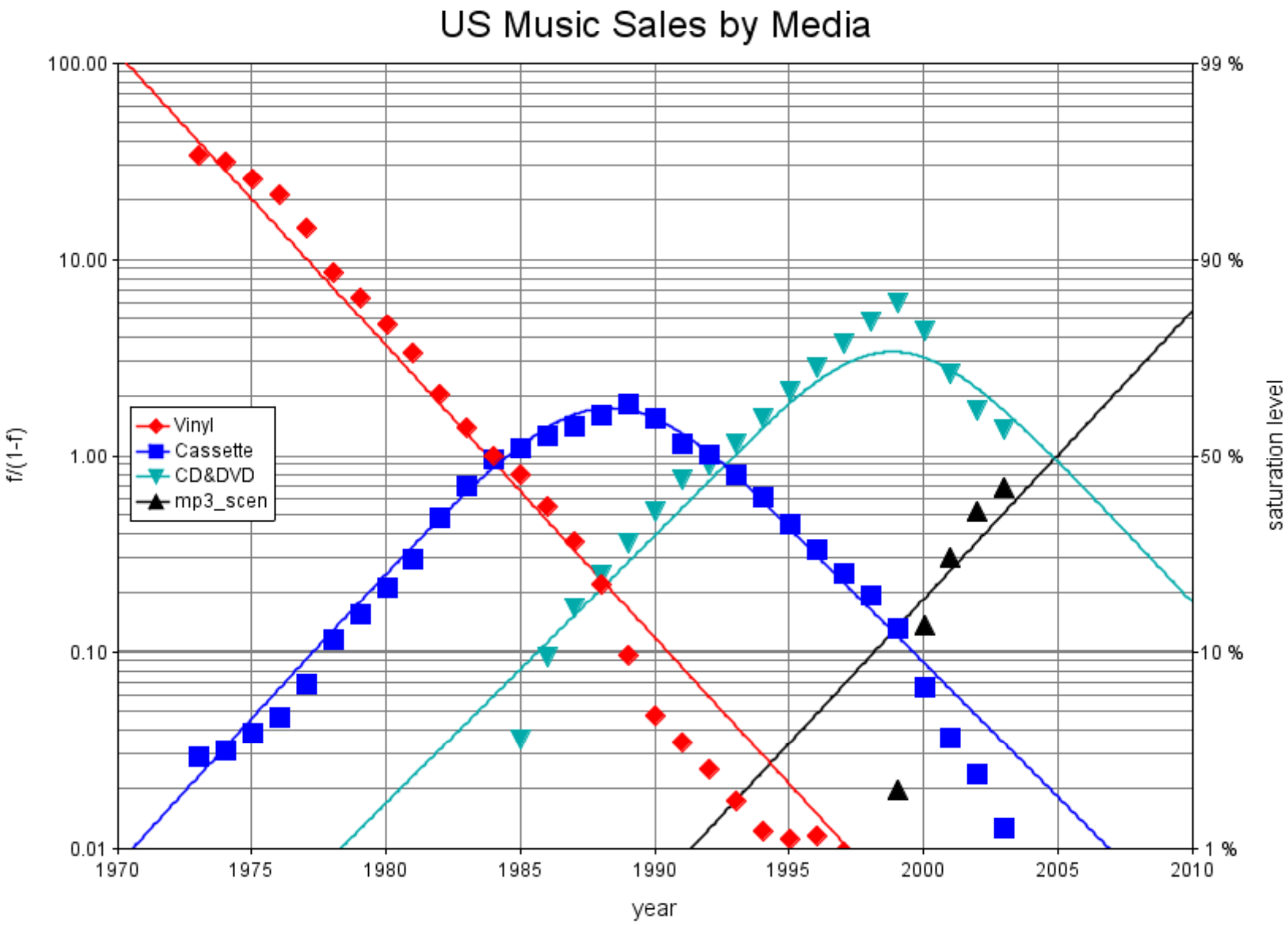
F. Apply the forecast

- Depends on:
  - needs and formulated objectives,
  - transparency and intelligibility,
  - credibility and consistency of the technology prediction.

flowchart of the suggested method



US music recording media



* Sources [5, 6]:

what are we doing to learn unknown?

- Extrapolation of past trends in accordance with laws of evolution:
  - simple logistic S-curve, component logistic model, logistic substitution model, time series analysis…
  - Genrich Altshuller, Cesar Marchetti, …
- What is different: study of the key problems but not the solutions
  - analysis of contradictions, networks of contradictions, learning the future limits of resources;
  - social, economic, environmental and technological contexts.

Those who have knowledge, don't predict.

Those who predict, don't have knowledge.

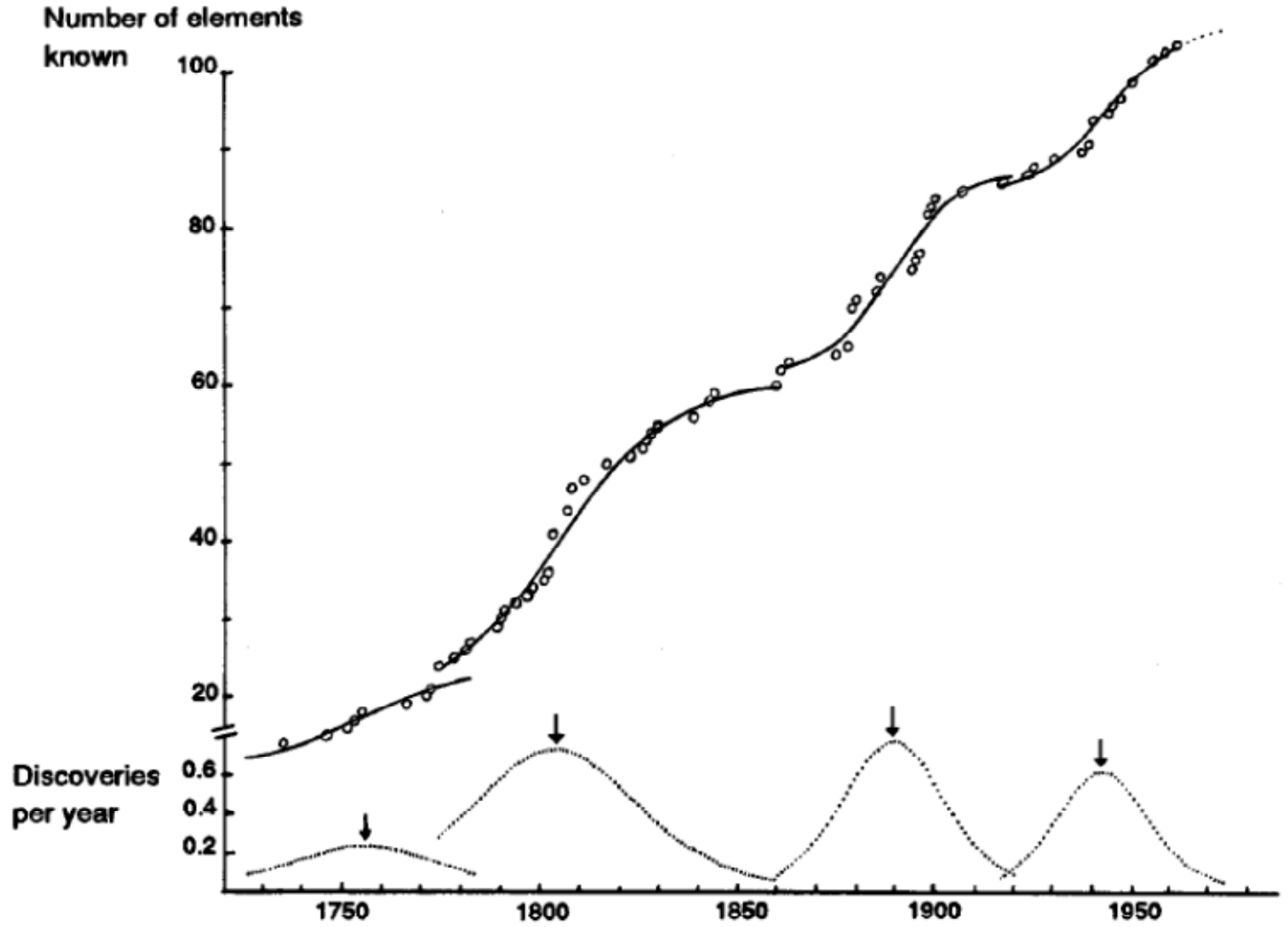
-Lao Tzu

How to improve reliability of forecast?

How to improve reliability of technology foresight?

1. Adaptation of logistic models of growth for emerging technologies (towards quantitative methods).
2. Adaptation of knowledge about cycles, trends and patterns in super-systems (towards system approach).
3. Improvement of repeatability and reproducibility of forecasting with evolutionary computation methods (towards independency of expert's biases).

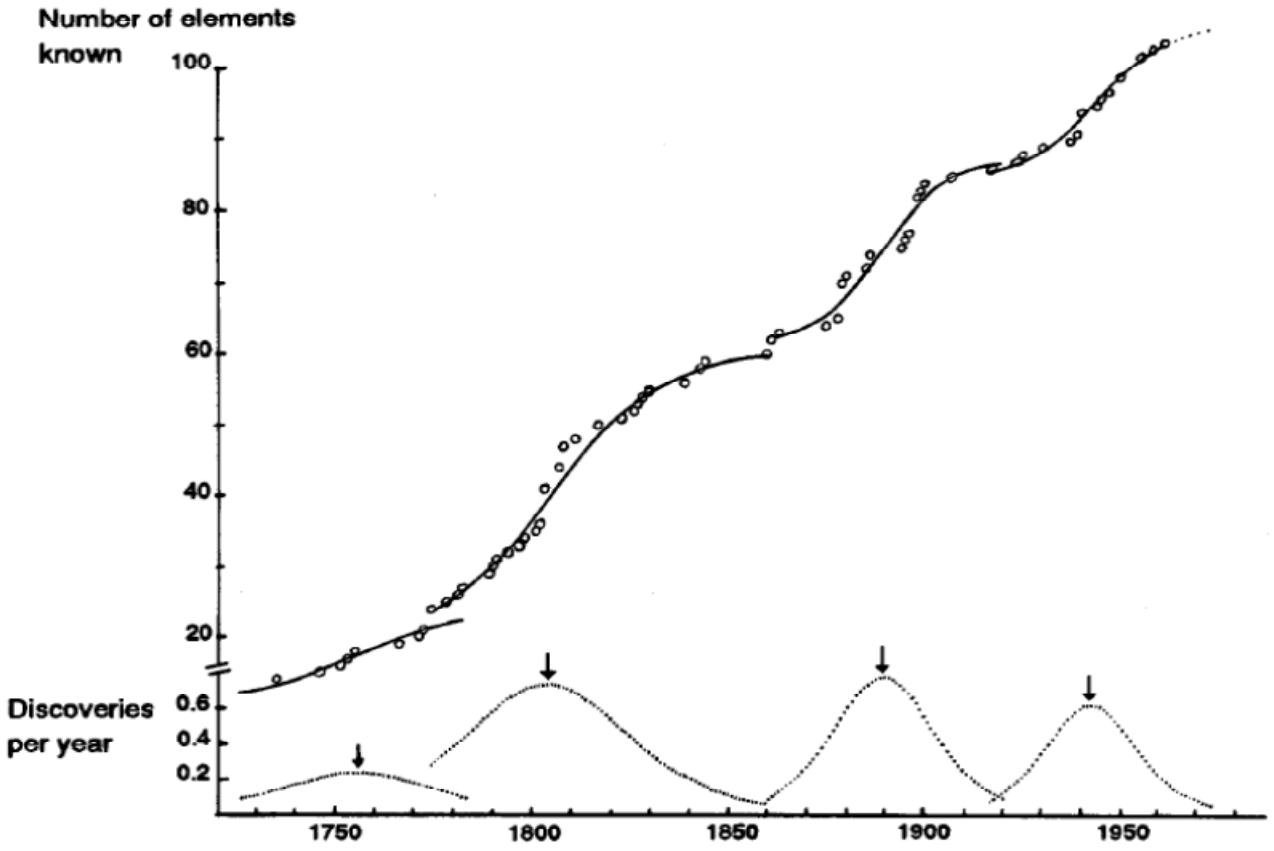
how the stable elements were discovered



* Source: Modis, T. Predictions - 10 Years Later. (Growth Dynamics, Geneva, Switzerland, 2002), pp. 149. ISBN 2-9700216-1-7.

Component logistic model

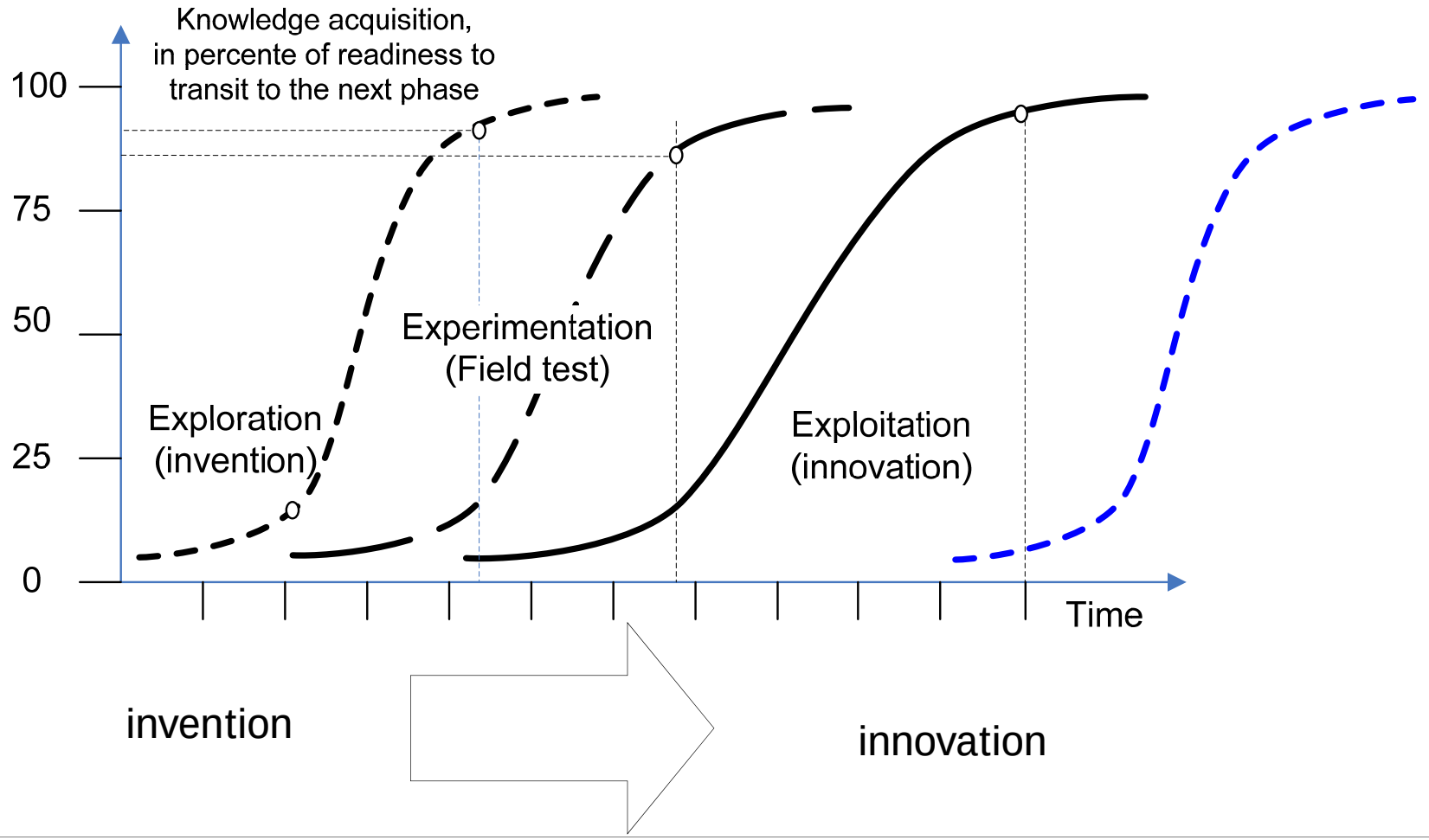
THE STABLE ELEMENTS WERE DISCOVERED IN CLUSTERS



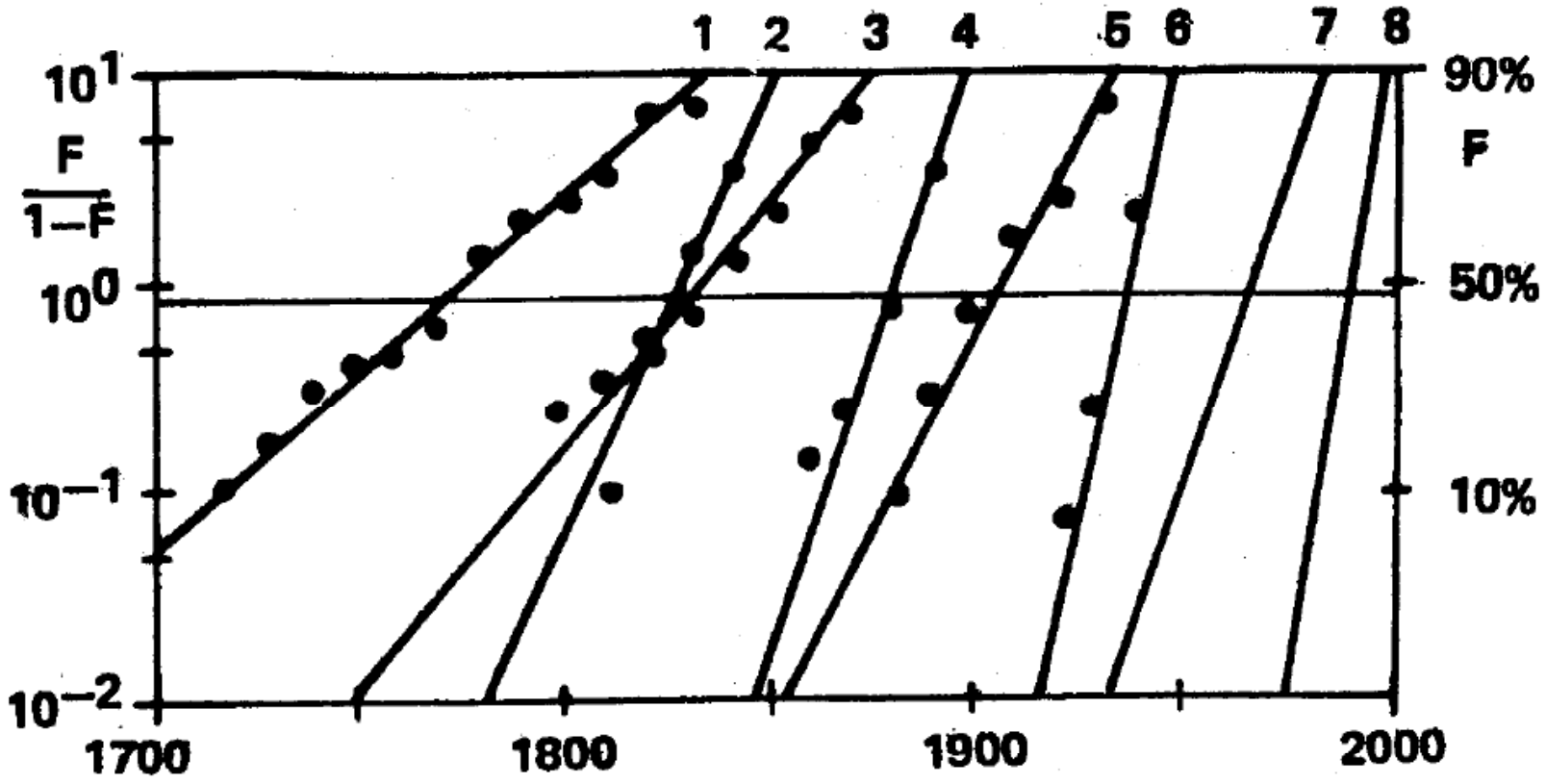
* Source: Modis, T. Predictions - 10 Years Later. (Growth Dynamics, Geneva, Switzerland, 2002), pp. 149. ISBN 2-9700216-1-7.

Growth of knowledge and logistic models

What kind of information about knowledge should be measured ?
before system passes the 'infant mortality' threshold;
before having enough data for growing variable trend.



*"…the distance [between invention and innovation] decreases regularly inside a certain wave, but starts larger again in the next [wave]…"**



The distance between center points of invention-innovation waves (1-2; 3-4; 5-6; 7-8) is always about 55 years, one Kondratiev cycle.

* Marchetti, C. Time Patterns of Technological Choice Options. p. 20 (International Institute for Applied Systems Analysis, Laxenburg, Austria, 1985).

THANK YOU !
:)

http://lgeco.insa-strasbourg.fr/lgeco/elements/equipe/licia.php

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