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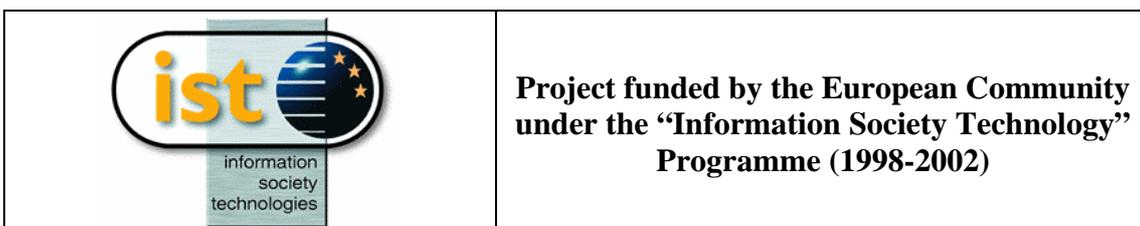
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PREFACE

TERRA was a project sponsored by the Directorate-General Information Society of the European Commission in response to the pressing need to align the creation of a global networked knowledge society (GNKS) and its accompanying New Economy with the requirements for achievement of sustainability generally and of sustainable development in general. Specifically, the project sought to create (by use of formal analytical methods) the insights necessary to inform and guide policy-making¹ leading ultimately towards the optimisation of ISTs contribution to sustainability.

This report summarises the ongoing development and fruits of the project and serves as a retrospective overview of the work of the consortium.

The project used several ‘living documents’ to facilitate its work and the exchange of ideas among the consortium and with interested parties. These include:

- A Story of TERRA document that presents the overall vision of the project, explains the key concepts, describes the *modus operandi* and the intended outputs and presents key results from project work.
- A tools document that describes the structure of models, interface tools and databases developed for and used in the project, and serves as a preface to detailed model documentation.
- An integrated modelling platform, comprising the project databases and the integrated IFs for TERRA model (the centrepiece of a range of models developed and used in the project), together with its associated tools and help system.
- An electronic ‘weak signals file’ that notes and discusses phenomena that may signal emergent aspects of the relation of the GNKS and sustainability.
- Specific thematic scenario analysis reports associated with the three central themes (Human Capital, Equity and Growth, Information Age Sustainability).

In addition, the project produces a range of external results. As discussed in the ‘Vision of TERRA’ living document, these are three-fold:

- New understandings of its topic areas in general abstracted as TERRA ‘Concept Sheets’;
- Specific insights into the mechanisms by which sustainability, IST and the GNKS interact expanded in ‘Insight Primers’; and
- Summaries of the state-of-the-art in relation to specific decision-making areas (or policy issues), presented as TERRA ‘Policy Briefings’ that identify the range of possibilities; show the firmer probabilities within them; and (by way of references to Concept Sheets and Insight Primers) point to any background material that may

¹ The current explications of the principal concepts addressed by TERRA are presented in the following section. TERRA’s understanding of Sustainable Development is discussed in Concept Sheet 1; its understanding of the relationship of Information Age to sustainability is discussed in Concept Sheet 2; and issues concerning policy formation in Concept Sheet 3.

be needed for evaluation.

In addition, the project has produced a wide range of scholarly papers on various aspects of the central problematique. The final version of the Story of TERRA contains a catalogue raisonnée of these contributions.

This document summarises the results, methodologies, outputs and (internal and external) activities of the project, together with an overview of project management and working arrangements, and of plans for the future.

The audience for this document is the European Commission, and especially individuals in DG INFSO who may wish to make specific use of the outputs of the project.

A wider audience includes policymakers who need to place the scenario-orientated TERRA reports in context and to relate them to TERRA policy briefings. This potential audience includes broader scientific and policy research communities interested in the sustainability of the Information Society or in the application of scenario and modelling methods to complex societal issues.

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1. PROJECT OVERVIEW

1.1. CONSORTIUM

The Consortium was led by the RAND Europe team. Their substantive contributions spanned the fields of economics, political science and integrative ‘world modelling.’ They worked primarily in the Integration work package (WP 15), but supported and participated in thematic analyses (WPs 12-14) and Dissemination and Exploitation (WP 16). They led work packages 11, 15 and 16.. In addition, Barry Hughes serves as the focal point for all Tools Development teams.

The team from Pol Descamps and Partners took the lead in Insight (VenSim-based) modelling (esp. tasks 12.1, 12.3). The INSEAD team led work on modelling of growth and resource use (Task 15.6) and contributed to WP 14. The team from Technische Universitat Clausthal contributed to Insight modelling (esp. in WPs 12 and 14) and the impact of networking (esp. in WP 15). The team from FAW/Ulm led work package 13, advised on work packages 12 and 15 and had a major role in work package 16. The team from University of Maastricht contributed an analysis of the role of NGOs (Task 15.7) and an associated workshop on governance.

The team from Wissenschaftszentrum Berlin contributed (particularly through sharing World Values Survey data and assisting with critical scenario analysis) to work packages 13, 14 and 15. The Finland Futures Research Centre team led work package 14 and contributed to work package 12 on the basis of ongoing work profile and MAS studies. The representative from the London School of Economics worked on Insight modelling of the networked economy in the context of work packages 12 and 14. The project member from Addico Cornix participated in work packages 12-16 in a variety of roles connected with scenario analysis, de/immaterialisation and clear communication of project results, and played a major role in the preparation of the ‘long’ and ‘short’ public Story of TERRA documents. Project staff from the University of Leuven participated in work packages 14 and 15 and facilitated interaction with the Club of Rome.

The participant from the Hogeschool West-Vlaanderen worked primarily on Insight modelling, especially paradigmatic network modelling. Subcontracted staff working at FoRSIS provided collective modelling expertise, specialist knowledge of fast heuristics and sensitivity analysis, general modelling and knowledge of the Russian situation. Further advice on work packages 12 and 15 was provided by the Russian Academy of Sciences. The specialist team from the University of Denver, subcontracted to RAND Europe, largely carried out the programming. Subcontracted staff attached to TNO will assist in Task 15.7. Professor Ayres worked under subcontract to INSEAD. Professor Mesarovic led work package 12 and contributed to the core team and work packages 13 and 15 under subcontract to RAND Europe.

These roles are summarised in the following Table.

Table 1: Consortium

<i>No.</i>	<i>Name</i>	<i>WPs (led)</i>	<i>Roles</i>
1	RAND Europe	11, 12, 13, 14, 15, 16	Co-ordinator, economics, political science and integrative ‘world modelling.’
2	Pol Descamps and Partners	12, 14, 15	Insight modelling, network economy
3	INSEAD	14, 15	Economics, modelling of growth and resource use
4	Technische Universitat Clausthal	12, 14, 15	Insight modelling, networking impacts
5	FAW/Ulm	12, 13, 15, 16	Equity and growth modelling, scenario development
6	University of Maastricht	15	Governance, role of NGOs
7	Wissenschaftszentrum Berlin	13, 14, 15	World Values Survey, scenario analysis
8	Finland Futures Research Centre	12, 14	Environmental sustainability modelling, analysis; labour, Information Society uptake
9	London School of Economics	12, 14	Insight modelling of networked economy
10	Addico Cornix	12, 13, 14, 15, 16	Scenario analysis, de/immaterialisation and clear communication of project results
11	University of Leuven	14, 15	Food and Agriculture modelling, interaction with Club of Rome
A	Hogeschool West-Vlaanderen	12, 14	Insight modelling, especially paradigmatic network modelling
B	FoRSIS	12, 15	Collective modelling, fast heuristics and sensitivity analysis, Russian situation
C	Russian Academy of Sciences	12, 15	Education, demographics, Russian situation
D	University of Denver	15	Programming IFs for TERRA
E	TNO	15	NGOs and civil governance
F	Mesarovic	12, 13, 15	Human capital, scenario analysis, dominant relations modelling

1.2. MAIN ACHIEVEMENTS

The main achievements of the project were: the clarification of the main concepts underlying the sustainability (or otherwise) of the GNKS; the elucidation of the principal underlying relationships and mechanisms behind this evolution; the development of a body of policy-relevant results; the construction of a set of thematic scenarios and methods for their exploration and modification; and the creation of a comprehensive suite of models, databases and policy analysis tools. In addition, the supporting analyses shed important light on specific aspects of the growth and impact of the GNKS, including: the essentially fitful and interrupted growth associated with the spread of general-purpose technologies; the “tipping” tendency of networked economies and societies and the consequent *laissez-faire* tendency towards market failure and unequal distribution; the emergence of ‘conventions’ in networked settings and the consequent prescription for “network-aware” policies to resolve societal co-ordination problems (e.g the appropriate matching of skill levels and product specifications); the consequent “catastrophic”² dynamics of technology adoption and adaptation; the long-term implications of current links between economic growth (and other autonomous consequences of the evolving GNKS) on one side and (indicators

² meaning in this context multiple equilibria, sudden ‘jumps’ in response to small changes and (locally) irreversible change.

of) economic sustainability (GDP growth, volatility and resilience), social sustainability (access, wealth and knowledge divides), and environmental sustainability (stress on exhaustible and common-pool resources). Beyond this a range of specific results were obtained drawing out the implications of dematerialisation and immaterialisation³; changes in intellectual property rights; etc.

The project has also had a major presence at a range of public fora at the EU level, in other countries around the world and in important international events such as the WSSD and WSIS. This has led to sustained engagements with a variety of state and non-state actors concerned with Information Society and sustainability issues.

³ Identified in earlier 5FP projects, notably XXX; analysed by TERRA in a systemic quantitative context.gg

2. PROJECT OBJECTIVES

The TERRA2000 project was developed in light of the urgent challenges posed by the phenomena collectively referred to as the “New Economy.” In many ways, the term is a misnomer – some refer to a new paradigm, a weightless economy, dematerialisation or the death of distance. These phrases are instantly recognisable, intuitively appealing and provocative – they fire the imagination by hinting at still larger insights. To date, however, their links to consistent and verifiable evidence, explicit modelling, comprehensive visions of the future and holistic discourse on broad societal issues remain weak. TERRA2000 addressed this weakness across a number of related fronts. The overarching objective was to seize the moment before the opportunities offered by the New Economy slip away and the issues moved beyond resolution, or are resolved in ways that do not preserve and enhance European values, institutions and interests. Below, this objective is refined to take account of specific challenges, the approach taken and the competences of the project team.

The target audiences of TERRA2000 are policy makers⁴, economic and social actors in the unfolding of the New Economy⁵, ‘final users’ affected by new forms of interaction, activity and policy and research communities – in short, those whose efforts to understand and productively engage with the New Economy may benefit from an open and integrated explication of the issues involved.

The challenges facing these parties are profound and urgent; some must act early and appropriately despite pervasive uncertainty, while others should avoid precipitate action. Moreover, the issues are highly interlinked, crossing policy regimes, issue areas, regional jurisdictions and disciplinary boundaries. The well-understood dynamics that underpin existing policy frameworks and divisions of responsibility are themselves shifting rapidly. These new phenomena are susceptible to treatment through new models, data and methods, but these efforts are themselves highly uncertain and must be focused, motivated and placed in a context that ensures their linkage to policy and other projects.

TERRA2000 addressed these target audiences by participation in existing and new fora in order to contribute to important initiatives while at the same time building a collection of organised knowledge, vision, tools and new platforms for societal dialogue to provide longer term benefits. The scope of these outputs and the interactive way they were developed contributed to incentives and constituencies for future development and integration of sustainability considerations into societal, analytic and policy discourse.

The fundamental object of study goes beyond the New Economy or even the Information Society. Within the project, it became known as the Global Networked Knowledge Society (GNKS). This term highlights the specific perspective (Europe in a global context), the structural and dynamic alteration due to Information Society Technologies (networking), and the ‘weightlessness’ of economic activity and the

⁴ In national governments and multinational organisations.

⁵ Representing a wide range of sectors and socio-economic interests.

importance of human and societal capital (knowledge society). The sustainability of the GNKS was studied through the investigation of a set of fundamental propositions (see Section 4.1.1)

Concretely, the objectives are three-fold. The primary objective is to produce a library of scenarios that combine:

- Informed and consistent assumptions about the current state, latent trends, critical uncertainties and important actors in the unfolding New Economy;
- Focused and filtered identification of a coherent set of key global issues of particular relevance to European policy and development;
- Assumptions about the motivations and responses of a range of key actors;
- Closely-integrated projections drawing on state-of-the-art rendering of important components of the New Economy closely linked to policy issues; and
- An assessment, drawing on multidisciplinary policy analysis and dialogue, of the implications, opportunities, threats, and obligations latent in the scenario.

These elements, and particularly the assessment, were represented in terms of social, economic, environmental, governmental and other dimensions. The picture that emerges was focused on the role of Europe and European values in the global context.

Current tools for supporting this type of scenario definition and analysis were not best suited to developing a vision with the validity and robustness of specific knowledge⁶, the generality and flexibility of long-term integrated models and the responsiveness, openness and validity of open social discourse.

Accordingly, a secondary objective was the creation of integrated state of the art tools for supporting further scenario and policy development and analysis. These tools include the following.

- An integrated modelling and scenario analysis system including:
 - Retrospective database
 - State-of –the art modules covering important New Economy domains
 - Flexible and accurate rendering of policy options, critical uncertainties and strategic assumptions
 - Ability to address issues and objectives derived from scenarios and dialogue
 - A database of model runs with a user interface that facilitates exploration of ‘scenario space’ to support prospective analysis and societal dialogue
 - Modelling tools and components to provide insight, strategic analysis and

⁶ E.g. modern economic models dealing with information goods, endogenous growth, long-term macro forecasting; sustainable development models dealing with the impacts of process and product innovation on environmental states; demographic models analysing the growth, location and changing nature of populations; sociological models of the changing social fabric; political models of the shifting role of public, private and non-governmental entities, etc.

policy analysis capability to users and, at the insight level, to support further collective development

- Integrated modules for three domains specific to understanding the New Economy.
- A ‘policy cockpit’ that puts the components at the user’s fingertips to facilitate:
 - In-depth analysis of specific aspects of a given scenario
 - Rapid identification and exploration of promising alternatives, contingencies or trends.
 - Easy assembly of components to create, project and analyse new scenarios
 - Support for decision making, policy debate and societal discussion of important issues, including: robustness of projections to shocks, data, parameter values and modelling/strategic assumptions; and careful multidimensional analysis showing the magnitude, timing and incidence of costs and benefits
- A set of indicators giving a multidimensional view of sustainable development in terms related to the important scenario aspects, accessible to wider audiences and consistent with (but not limited to) specific data in the databases and models.

Neither the scenarios nor the tools could achieve the hoped-for utility and impact without active engagement with societal developments and active and important players in the unfolding New Economy. To ensure validity of the issues, values and assumptions embedded in the scenarios and tools, TERRA2000’s third objective was active participation in societal dialogue to engage the wider world in the project activities and lay the foundation for continuing contributions.

Success in meeting these objectives was measured by *timeliness* in engaging with important European policy initiatives, *comprehensiveness* and *validity* in analysis of important issues, *utility* and *relevance* of products for target audiences and *effectiveness* in informing public debate and helping shape policy throughout Europe.

3. METHODOLOGIES

3.1. BASIC METHODOLOGY

The project used three overlapping tools (modelling, scenario development and discourse) to explore the underlying issues surrounding the sustainability of the Information Society. The original idea was for each of these to produce a single output and for the three to adopt a unified, convergent perspective. It soon became apparent that neither the state of the art nor the consensus view of the underlying concepts would support this approach, and that the real objective of the project should be to clarify and explore the concepts and develop a set of tools and methods adequate to support a balanced exploration of the issues in the future. To provide the necessary coherence, the project divided the issues into three broad themes (human capital, equity and growth and environmental sustainability); each of these was explored through a dedicated (but consistent) set of scenarios and appropriate models. In most cases, the models and the teams overlapped, and the work was pursued in sequence. To provide thematic coherence, the focus of work in the project as a whole was exploration of an overarching “IST proposition” by means of thematic sub propositions. From this work emerged a further “distributional proposition.” These are briefly described in section 4.1.1. The remainder of this section describes the modelling and scenario methods applied.

3.2. LENSES ON THE WORLD

The world is uncertain and information is diffuse. To inform policy and discussions, various sorts of thinking/discussion aids, consistency checks and validation are necessary. In particular, understanding evolution of a complex system requires a combination of data, models and scenarios.

The development and use of models in TERRA took place on several levels. *Hindsight* is based on databases and statistical analyses, *insight* is based on models and scenarios describing the function and linkages of underlying mechanisms and *foresight* uses such mechanisms to project (not forecast) future evolution and the impact of policy under different circumstances.

Analysis begins with statistical data summaries, high-level, aggregate and/or specific models⁷ and scenario and trend extrapolations. These support detailed analysis and identify “things we didn’t know that we knew.” They also pose conceptual puzzles beyond the reach of formal – or at least numerical – models about e.g. commoditisation of intellectual property, diffusion of new ideas, chains of secondary innovation, coevolution of network connections and cooperative behaviour, etc. These simple models are at least explicit, easy to comprehend and (given appropriate assumptions) reasonably robust.

⁷ Including computational dominant relations and integrated models and thematic scenarios.

By contrast, the ‘hidden features’ of the GNKS were addressed through more detailed⁸ and disaggregated analyses, based on complex methods and more sensitive to assumptions and other uncertainties – they are a way of investigating “things we know that we don’t know.”

TERRA drew on and developed different models for prediction, policy simulation and policy analysis. Prediction models are primarily data driven trend extrapolations. Policy simulation models are used for ‘what-if’ exploration of alternative policies (policy levers). Policy analysis models expose mechanisms underlying observed behaviour to logical scrutiny; numerical results depend as much on theoretical as empirical considerations.

Data⁹ provide calibration, face validity and a proportion. But their provenance and interpretation are influenced by definitions, coverage, collection methods etc. The models and scenarios unlock the information and meaning hidden in the data. TERRA collected and used both 'hard' (naturally quantified, objectively measurable) and 'soft' (only measured through indicators and/or subjectively defined) data.

Models help to unlock latent tendencies in data, test understanding of system structure and dynamics, and present policy issues in ways that expose assumptions and rules of inference. Models can use and/or generate data, but not all models do so. Models in TERRA fall into three broad categories:

- *Computational models* of varying complexity, completeness and fidelity to empirical data (paradigmatic high-level *insight models*, strategic medium level *dominant relations models* and policy-analytic detailed *integrated models*);
- *Empirical models* to test specific hypotheses against real data and develop predictions from proven hypotheses. Predictive empirical models expose underlying – as opposed to apparent – trends and extrapolate them into the future under alternative assumptions.
- *Theoretical models* derive useful conclusions from starting assumptions and rules of inference.

These are not disjoint: Figure 1 fits some of the TERRA models¹⁰ into this framework.

⁸ Theoretical models describe underlying mechanisms in detail; integrated computational models are detailed in scope.

⁹ Data sources described in “Tools and Models Final Report” and references therein.

¹⁰ More details on these models are provided in Table 3 below.

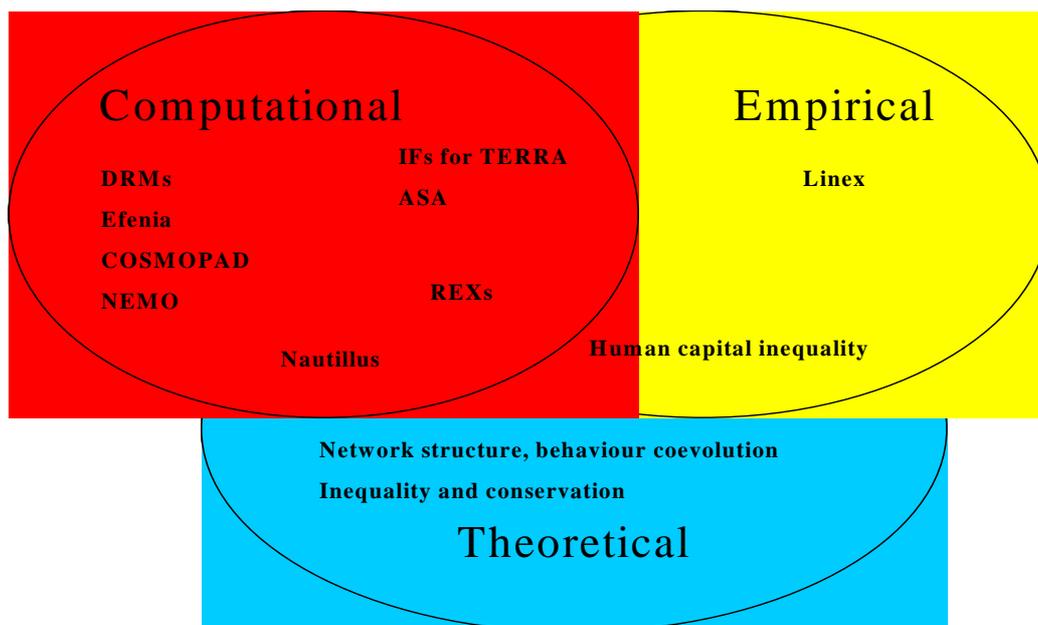


Figure 1: Model types in TERRA

As the perspective shifts from prediction to policy analysis, the tools evolve as well. Many of the phenomena tackled by TERRA are not measurable – some are not even quantifiable – so the models are (and should be) at different stages of development. It is no accident that the latter stages of the project saw an increase in paradigmatic and theoretical modelling; this appropriate for fundamental developments exposed as essential by computational modelling and accompanying scenario analysis.

Scenarios provide a common basis for discussion and analysis to ensure that progress towards understanding the strength and policy implications of the propositions is logically consistent, reasonably comprehensive, comprehensible and engaging for stakeholders, calibrated to data where possible, sensitive to hard and soft data and policy relevant. They are thus a tool for exploring knowledge and improving coordination.

TERRA scenarios were used as a framing device for describing the current situation, identifying trends and possible interventions, and making visible important criteria. This was particularly true of the primarily numerical Human Capital scenarios, which used explicit computations to calibrate the issues considered, quantify direct and side effects of specific policies and highlight attractive policy combinations. The Equity and Growth scenarios were more explicitly laid out along two critical dimensions in ‘scenario space,’ but also used dominant relations models for calibration. The Information Age Sustainability scenarios were described in welfare and environmental stress terms and scenarios developed by feasible trend extrapolation.

A further set of integrated scenarios were developed with the IFs for TERRA model to track possible futures from an empirical point of view. This analysis was built up from the necessary conditions for and spillover consequences of sustainability in all thematic areas. This therefore represents the ‘virtuous corner’ of scenario space.

Ultimately, the aim remains to support the interactive use of this set of scenarios in combination with the models and exploration tools. These elements provide a context for discussion to combine knowledge of participants whilst minimising impact of ‘foregone conclusions.’ Eventually, and beyond the bounds of this project, a more active approach is to use combined scenarios and tools to facilitate interchange among experts through gaming. At the current phase of scientific and policy development, the greatest contribution of these efforts is to shed light on the relevant complexities of the central concepts of Globalisation, Networking, the Information Society and Sustainable Development.

3.3. VALUE OF MULTIPLE LONG DATA SETS

TERRA studied phenomena connected to long-term trends and development. On the GNKS side, much that was written and concluded on the basis of short-term trends turned out to be exaggerated – or was regarded that way when the ‘dotcom bubble’ burst. Many concluded that the whole New Economy paradigm was an overblown fiction. Recent econometric growth analyses¹¹ have begun to distinguish long-term trends and trend-breaks from short-term cyclical or idiosyncratic behaviour. This is particularly apt for sustainability analysis, which addresses medium- to long-term consequences of short-run behaviour. Moreover, the initial and ultimate effects of any transforming technology tend to drive in opposite directions; systemic effects may be both long in coming¹² and widely spread. This does not mean that near-term data are irrelevant – analysis of the GNKS¹³ suggests that some dynamics may be very fast and that behaviour may change even when the ‘fundamentals’ do not.

3.4. THE STRENGTH OF SOFT DATA

Many important features of the GNKS resist quantification or objective measurement. This does not diminish their importance either to the policy issues or to even quantitative scenario development. In particular, information on the distribution and evolution of values (as measured by surveys) are vital factors shaping the emergence of mass support for democracy, environmental protection, gender equality and other cultural changes; and the interaction of this support with political institutions and other structural factors.

Effective support for sustainable development requires political support for often-painful policies. This cannot be limited to backing for specific policy proposals. First, there are many steps between the initial conception and ultimate implementation of policy, and support from the public is required at every step. Second, policies work, or fail to work, in a context defined by other policies and individual behaviour. Support for sustainable development must be embedded in societal values rather than specific initiatives if meso- and macro-level actors (e.g. governments and businesses) are to achieve consistency and workable co-ordination. Moreover many aspects of the problems faced by the GNKS require changes in individual behaviour that can only

¹¹ See esp. the ‘Markov switching’ literature.

¹² Impacts of 19th century developments relating to steam and electricity are still unfolding.

¹³ Berg (2001).

partially be mobilised by external incentives. It has frequently been observed¹⁴ that people say one thing and do another in matters of e.g. equity and the environment – this does not mean that speech and action are unrelated, but only that the relationship between them – which depends critically on communication and exchange of information and opinion – must not be taken for granted. This understanding is based in part on theoretical considerations (e.g. the evolution of conventions considered in the theoretical modelling) but equally on the empirical rendering and projection of value change.

The integrated modelling system (IFs for TERRA) considers change in three cultural dimensions identified by the World Values Survey (Inglehart 1997); materialism/post-materialism, survival/self-expression, and traditional/secular-rational values. These are measured by a wealth of variables. The TERRA data set includes a subset most directly linked to the key dimensions of cultural change, together with such additional substantively interesting variables as a society's attitudes toward state ownership versus private ownership or support for democratic institutions. Factor analysis of the WVS data showed that the survival/self-expression, and traditional/secular-rational dimensions span the space, while materialism/post-materialism tracks a curved path through this space followed by the cultural development measured in the survey.

Also material from MERIT relating to civil society and GNKS. Point here is salience of data relating to values and the linkage from values to actions - while these things are inherently conceptual; there are valid measures that have proven to be valuable as variables in quantitative relationships, as indicators in semi quantitative and scenario analyses and as calibration points in discussions and debates.

3.5. MODELS

As mentioned above, TERRA undertook a broad range of modelling activities. An overview of most of the computational models and their relation to one another and the overall project is provided in Deliverable 15.3. This section provides a summary of that structure extended to include the theoretical models.

In TERRA, models were used all along the 'backbone.' For hindsight, the main integrated model (IFs for TERRA) and the related indicator-based model focussing on sustainable development (ASA) provide comprehensive tools for exploring the past and the *status quo*. Of course, the empirical models (esp. Linex and the panel equations estimated for the study of the relation between human capital inequality and growth), being estimated using historical data, provide summaries of past outcome and trends.

Integrated computational models

Computational models produce numerical outputs, and are thus appropriate for engaging with stakeholders whose actions rely on quantitative representations of the *status quo ante*, the impending future and the impact of policy options. These models include integrated data/indicator models used to give a broad view over the holistic

¹⁴ See e.g. Schauer (2003), Kaivo-Oja, *et. al.* (2003).

evolution of the Information Society. The underlying framework is IFS for TERRA, based on the International Futures (IFs) model. This system combined a very wide range of data with sophisticated multi-sectoral modelling to provide a tool for exploring both the past and the future. For TERRA, this was modified in order to highlight the centrality of the GNKS, to provide a ‘policy cockpit’ for exploring the impact of policy scenarios and the design of adaptive multi-policy programmes. A related view concentrating on indicator-level description of sustainable development is presented (within the overall framework) by the Advanced Sustainability Analysis (ASA) approach, which rests on two basic postulates for improving sustainability: non-decreasing welfare and non-decreasing environmental stress. Conditions suitable for empirical analyses and policy formulation are derived mathematically from four identities (“master equations”) that relate the environmental stress variable (ES) chosen for an analysis to the basic indicators of economic, technological and social development. The explanatory power of the theory relies on new concepts and formulas for sustainable policy making and new empirical results for comparisons among countries and regions as well as between policy targets and results achieved. The use of such identities in ASA and other ‘dominant-relations’ type models necessarily abstracts from the specifics of ‘bottom-up’ behaviour. In complex, multi-layer system and broad range of actors make interlocking decisions that determine overall system behaviour over time. Dominant relations models and trend analysis provide descriptions of this behaviour. Explanation uses models estimated from empirical data to test theoretical formulations of dynamic behaviour. Within the TERRA system of models, such explanation is provided (in an integrated, sustainability-orientated sense) by REXs.

What the different types of models tell us

The TERRA computer modelling toolkit contains models at three levels: paradigmatic, dominant relations and policy-analytic. These names combine different characteristics, so a word of explanation of how they interact is in order. Essentially, the paradigmatic models are used for ‘playing with ideas’ to investigate the implications of different ways of formalising concepts (networking, globalisation, immaterialisation, etc.) that are difficult to measure and which lie well below the level at which data are collected. Dominant relations models are based on accounting identities¹⁵, and are used to identify major trends and draw attention to areas requiring specific investigation. For instance, the ASA approach developed for the project discusses a characterisation of sustainability in terms of abstract measures of welfare and environmental stress. These can be linked to a range of indicator data. One particular aspect is the linkage between economic growth (which feeds incomes and thus welfare) and environmental stress. This linkage is sometimes addressed in terms of derived indicators like eco-efficiency, which in turn can be measured using other data. This sort of investigation allows broad comparisons and trend identification, but also points towards the need for specific types of refinement. In particular, the aggregate picture abstracts from or places an envelope over the complexities of individual and system behaviour. In order to focus on mechanisms of policy action,

¹⁵ This does not imply that DRMs are limited to aggregate data. The Human Capital DRM discussed in Section **Error! Reference source not found.** is largely disaggregated along national and sectoral lines, while the ASA DRM discussed in Section **Error! Reference source not found.** concentrates on aggregates.

understand trend-breaking developments take account of rational behaviour or changes in the way individuals interact, and in order to accommodate the resulting dynamics, it is necessary to construct more detailed, dynamic and behavioural models, whose parameters are typically estimated econometrically. The outcomes can thus be quantified fairly precisely, as can the associated uncertainty.

3.6. SCENARIOS

This section discusses the uses of scenarios within the project. It draws on the first scenarios document, and adds text explaining why the different thematic efforts each developed their own scenarios, how they are broadly consistent with the crosscutting themes (dimensions) of the SOT, and why integrated scenarios should await further development of the propositions.

A scenario is a partial description of a set of possible futures based on a description of the *status quo ante*, a set of actors (with motivations, powers, and information), a system (with well-defined boundaries and mechanisms), and specific dimensions along which it is described or tracked. The narrative core of the scenario constitutes an implied storyline about future evolution, which may include branches and critical uncertainties. Scenarios should be described in concrete terms, be internally and logically consistent, and illustrate the major issues. As predictors of the future, their only common feature is that they are false in detail. As a result, multiple scenarios are preferable to single ones, and their construction is not only non-trivial, but may prove to be more important than the end result. Ultimately, therefore, they must be experienced interactively.

A set of scenarios can be described by a common *status quo ante*, and variations on four main elements.

- Exogenous or uncontrolled *uncertainties* that are at least potentially important - these are the main features distinguishing different scenarios. In some instances, the scenario development is orientated along policy lines, or expressed in terms of success (or otherwise) in attaining specific policy targets, but this implies uncertainties relating to the underlying mechanisms or drivers.
- Policy levers that can be adjusted or debated by scenario users - in most cases, and particularly for the Growth and Equity and Information Age Sustainability frameworks, the emphasis is on the effects of policy or the endorsement of policy targets rather than specific policy mechanisms, but this implies the use of specific policy instruments.
- Mechanisms or relationships among the factors – these range from aggregate-level descriptions of the necessary logical connections among the main indicators to specific behavioural models and from relationships calibrated to or estimated from real data to paradigmatic or theoretical models. The responses of other actors to policies and the resolution of uncertainties should be seen as part of the underlying mechanism.
- Indicators by which scenario evolution is tracked and performance evaluated.

The inclusion in all scenarios of important factors whose values are known or can be predicted is important to ensure acceptance and relevance. Less important known

factors can be included to make the scenario seem more concrete and relevant. The factors that are at the same time uncertain and important define the dimensions of ‘scenario space’ – they differentiate the scenarios from one another. Uncertain factors of minor or narrow importance are included to give colour and life to the scenario and to serve as the springboard for ‘weak signal’ analysis of developments whose likelihood and importance can be imagined but not assessed.

Table 2: Elements of the main scenario frameworks

<i>Scenario Framework</i>	<i>Uncertainties</i>	<i>Policy levers</i>	<i>Mechanisms</i>	<i>Indicators</i>
Human Capital	Output, consumption growth, population	Investment, education, migration, outsourcing, labour productivity	Aggregate dominant relations focusing on global ICT sector, paradigmatic model of network economy.	Skills supply and demand, consumption, unemployment, population (size, migration), GNP growth, trade balance, social support.
Equity and Growth	Internalisation of ecological constraints, consensus/human-rights-based governance	Market mechanisms, co-financing, global contract, security measures, trade/aid requirements.	Dominant relations among prosperity, equity, human domination of the earth, ‘Information Age’	Equity value, GNP growth, Global Hectare Equivalent, carrying capacities
Information Age Sustainability	Dematerialisation, rebound, economic growth	Factors affecting dematerialisation, immaterialisation, rebound effects, welfare productivity of GDP, GNKS development	Indicator-based models of interrelated economic, population and material intensity changes, Macroeconometric growth model, paradigmatic agriculture model	GDP, environmental stress, population; dematerialisation, immaterialisation, ASA-sustainability, energy use, land requirements
TERRA apocrypha	Separating weak signals from noise, emergence	Potentially, all.	Coevolution of network structure, flows, behaviour of networked entities; emergent behaviour, innovation	New indicators relating to network structure, efficiency, equity, resilience

Because scenarios are experienced individually, but identified and interpreted collectively, the relationship of a set of scenarios (or ‘scenario space’) helps to distinguish scenarios from mere projections. Since a scenario does not completely describe the future, it partially describes many possible futures. Ideally, a set of scenarios should be constructed, differing along a few dimensions or possibilities that

highlight important features of the analysis. In the TERRA project, the main dimensions are:

- Globalisation/networking: whether worldwide flows (of people, ideas, resources, economic activity, etc.) continue to increase in extent and complexity;
- Integration: whether internalisation and cooperation characterise the world order; and
- Division: whether ‘divides’ based on digital access, income, education, access, etc. increase.

Not all the logically possible alternatives are relevant – in particular, it seems fairly obvious that globalisation will proceed, although its equity, inclusiveness and efficiency are open to debate and analysis. Moreover, the scenarios developed for the specific thematic analyses (Human Capital, Growth and Equity and Information Age Sustainability) framed and interpreted these dimensions in slightly different ways. This is a natural consequence of the role of scenario space in highlighting relevant features.

3.7. THE USE OF THESE COMPONENTS WITHIN THE PROJECT

The TERRA project architecture combined modelling with scenario development and analysis and combined forecasting with backcasting¹⁶ in an iterative fashion. To start the iteration, the underlying concepts were clarified, the unfolding situation was assessed using the integrated model¹⁷ and these elements used to define the propositions, the three thematic lines of development and the three overarching scenario dimensions just described.

Within each theme, initial scenarios were developed to identify the key variables and relationships and the appropriate modelling developments. As the model results were incorporated into the scenarios, further suggestions for modification of the modelling structure were derived and instantiated. For this reason, some of the more theoretical and complex models have only now begun to emerge – this is consistent with the interactive nature of the exploration, the need to provide insights at different levels of the policy process and the specific interests and expertise of the consortium members.

The initial scenarios were based on forecasts or trend extrapolations. Where the issue and level of detail warranted, these were refined to take account of specific mechanisms, possible shocks and policy levers (particularly in the dominant relations models). Roughly, these models and the scenarios they inform are stories about the development of the GNKS. At the same time, the focus on sustainability (with its emphases on the medium-to long-term view and on resilience to shocks) and on global issues called for the formulation of ‘landing-place’ scenarios; stories about where the GNKS might arrive eventually. The analysis of such scenarios is more of a backwards-looking exercise to identify sufficient and necessary conditions for

¹⁶ See [Mesarovic (2003), Kaivo-Oja, *et. al.* (2003), and TERRA (2002a) – version 1 of Story] for descriptions the distinction between forecasting – and forward-looking (positive) scenarios – on one hand and back-casting – and backward-looking (normative) scenarios on the other.

¹⁷ Hughes (2003a).

reaching the landing place (with sufficiently high likelihood). To test these conditions, further forecasts should be performed – the overall ‘bouncercasting’ process helps to effectively narrow the gap between positive and normative scenarios and build a common understanding of appropriate steps to take forward into policy.

The Human Capital and Equity thematic work started from an issue relating to human (initially economic) concerns and developed the analysis of member-state or EC concrete policy options in response to that issue. Of course, these ‘solutions’ raise wider societal concerns, which must be addressed by ‘policy’ at a different (more global, more fundamental) level and thus call for a different style of analysis (though one based on a consistent understanding of the world). Along the way, other specific issues were identified and analysed, which deepen our understanding, engage stakeholders from a range of disciplines and point the way to a more nuanced debate as better data and tools are developed.

The Environmental Sustainability thematic work followed the analysis of scenarios relating to sustainability in a system-wide sense centred on human interaction with the environment. It began with a top-level view of sustainability based on global aggregate data and the dominant relations that must exist among them. This led to the elaboration of fore- and back-cast scenarios and policy guidance in terms of the directions in which these high-level indicators *must* evolve. This identified a set of problems and set the common boundaries of an overall policy framework for application both within and among nations. To go further, we are led to ask *why* we see the behaviour that we observe, *what* is the nature of its evolution (as a system with internal and external feedback loops and based on imperfectly rational human choices) and *how* (at a precise level) can we intervene to assist that evolution.

It is worth noting that the policy issues considered in the Human Capital and Equity thematic work flowed from disaggregated, short-term concerns to their aggregate medium-term spillovers, while those considered in the Environmental Sustainability thematic work started with the aggregate medium-to-long-term sustainability problem and work back to a more explicitly dynamic and disaggregated perspective.

The final thematic work picked up the weak signals aspects of the framework by relating the thematic scenarios to the three overall dimensions and developing the analysis of underlying aspects of the GNKS that are either resistant to measurement or difficult to reconcile with numerical models.

4. PROJECT RESULTS AND ACHIEVEMENTS

4.1. ANALYTIC RESULTS ON THE SUSTAINABILITY OF THE GNKS

The project proceeded by investigating a sequence of propositions relating to the sustainability of the GNKS. These propositions are results in themselves; they are stated below, followed by a section identifying the main results of studying them.

4.1.1. The Terra Propositions

TERRA provides the means to test the fundamental ‘IST proposition’ and its sectoral sub-propositions, and offers guidance on how the vision they embody may be made a reality.

The IST Proposition

The new technologies of the Information Society (ISTs) seem likely to offer scope to enable economic growth, and to allow a more equitable distribution of wealth, without necessarily increasing consumption, pollution and energy use.

Skilled, talented, innovative and fulfilled people constitute human capital, which fuels economic growth. All people everywhere have the potential to contribute. One major policy dilemma already facing decision makers is how to secure the supply of human capital with the declining and aging population.

Economic sustainability propositions

ISTs can catalyse human capital expansion and thus promote sustainable economic growth

Expansion of the GNKS can sustain and diffuse increases in productivity and market efficiency throughout the globalised economic system.

“Social capital is the glue that holds a society together.” A major dilemma for the 21st century will be how to balance the economic growth needed to reduce unemployment with the reduction of inequality needed to secure social capital.

Social sustainability propositions

While initial deployments of ISTs and ‘New Economy’ dynamics have tended to exacerbate welfare, digital and/or income ‘divides,’ the unfolding of a GNKS based on open and universal access can harness the same technological, market and social forces to promote greater equality of opportunity compared either to recent experience or the pre-GNKS era.

The GNKS encourages and influences the processes of globalisation and can foster collective awareness of collective problems, mobilise local responses and promote

emergence of new governance institutions to balance local and global problems, incentives and powers to act.

While the mere fact of globalisation – the connection of each to all – does not of itself imply either integration or convergence, ISTs can facilitate mutual awareness and respect.

The GNKS can encourage peace and minimise conflict by substituting a complex interlocking maze of global allegiances for previously narrow tribal and racial allegiances.

On one hand, ISTs bring a burgeoning middle class, increasing consumption loads; on the other, they allow more efficient extraction, accelerating exhaustion and delaying development of substitutes. Rebounds and secondary and tertiary effects are already well understood in some circumstances – but by no means all. Policy issues include informational approaches to enhancing efficiency of resource use, corrective taxation, support for development of alternatives, etc.

Environmental sustainability propositions

Emergent technologies based on information (from ICTs to bioengineering) can dematerialise production and distribution of goods and services by reducing associated material inputs and waste outputs.

The new technologies and the new forms of human interaction they support can lead to substitution of immaterial goods and services for material production and consumption.

Dematerialisation and immaterialisation reduce the opportunity cost (price) of material inputs and environmental sinks and increase the welfare content of income and wealth. The relative price changes can induce substitution of material for immaterial inputs. Increased purchasing power can stimulate consumption of both material and immaterial goods and services. These substitution and income effects can outweigh the benefits of the original changes.

The distribution of access to inputs (including human capital) can provide a better explanation of growth and convergence than total or average input levels; the welfare implications of inequality are strongly affected by the reference groups considered by people around the world – and thus by those portions of the global distribution in the IS spotlight; and environmental sustainability and resilience depend on the spatial and temporal dispersion of economic resource exploitation and discharges. Conversely, the impacts of economic, societal and ecological development on these important distributions can only be understood if the mechanisms of dispersion and differentiation are included in the analysis.

The distributional proposition

Distributions (e.g. inequalities) matter at least as much as aggregates because: i) welfare and incentives are relative; ii) globalisation and the network economy hold out the promise of greater equity while increasing the likelihood that laissez-faire policy will exacerbate divides; iii) different parts of distributions have potentially

divergent values and sustainability footprints and responses to policy and economic/political, etc. forces; and iv) network evolution can lead to small worlds, stable diversity, global convergence, etc. with only minor changes in the underlying parameters.

4.1.2. Other relevant results

Much of the initial work of the project was concerned with the identification and clarification of underlying concepts. This work found expression in a series of documents, beginning with an annotated glossary of terms relating to the GNKS, a series of conceptual papers summarising the literature relating to the thematic areas and, latterly, a series of “Concept Sheets” and “Insight Primers” describing the main concepts and the important mechanisms, respectively.

At a more analytical level, the sweep of TERRA research has produced a host of results, findings and recommendations that are difficult to summarise concisely. The Story of TERRA document provides a comprehensive overview of the project and a catalogue raisonn e of the various deliverables, models and published articles. Among the significant thematic findings are:

Results relating to Human Capital

A policy portfolio judiciously selected to meet multiple policy objectives via a participatory time incremental scenario analysis process is a prerequisite for solving the human capital problem. Participatory scenario analysis offers the best prospects for public acceptance of and support for policy implementation.

Immigration of high tech professionals has to be part of the policy package. It provides a range of economic benefits: increased prosperity through economic growth accelerated by technology diffusion throughout the economy; meeting EU needs for highly skilled professionals by effectively mobilising foreign investment in EU human capital¹⁸; and potentially positive multiplier effects on employment to meet support needs of relocating professionals and families. The societal impact of immigration, of course, has to be addressed separately.

Complementary outsourcing provides more local societal and economic negatives than immigration. Outsourcing highly skilled work that cannot be done locally supports complementary lower skilled local employment, which may help lower-skilled workers to find employment more readily than they would if global competition threatened e.g. manufacturing. It can also help EU-based companies financially through (limited) positive impacts on economic growth. Outsourcing of lower-skilled work may increase the private and social returns to (and investment in) local human capital, but may at the same time make lower-skilled and/or less able individuals worse off.

ICT adoption has many effects on unemployment. Employment increases with high growth rates, though outsourcing cannot but increase short-run unemployment -

¹⁸ This also brings potentially positive spillovers: ‘demand-pull’ improvement of world-wide education and increased willingness to invest in foreign education by EU governments and businesses.

though this is partially compensated by rebound effects – e.g. increased profitability of EU private sector. Longer-term structural readjustment may produce long-term unemployment. Human capital imports have both interesting and controversial impacts. Immigrant professionals and entrepreneurs increase growth both directly and through the competition their presence provides. Furthermore, the support and services they require generate secondary growth. The scenario computations show the reduction of unemployment due to this rebound effect.

Higher education is always considered expensive. Yet, viewed in the context of lifelong learning and for the total labour force, the cost of university education is not prohibitive.

Finally, from a societal point of view, the positive and negative impacts of high- and low-skill immigration and outsourcing are likely to be very different depending on, for instance, the degree to which the social fabric is eroded or strengthened by cultural and ethnic differences on one hand or unemployment and skill obsolescence on the other. Clearly, dangerous combinations are possible – for instance if poorly-coordinated immigration, outsourcing and education policies lead to cultural disruption combined with unemployment and a lack of support for individual and societal effort. On the other hand, these policies can be ‘recoupled’ to reverse the effect: for instance, immigration can reinvigorate local values (by participation) and revitalise local culture, while at the same time increasing economic productivity and welfare, and encouraging both technical and social education (as was the case during the ‘Golden Age’ of US growth during the late 19th and early 20th centuries). Remittance incomes and overseas employment can, as part of the same process, stabilise the ‘source’ regions and reduce current security challenges.

As mentioned, these policies have spillover effects. Some TERRA results address the specific impact of human capital on growth and income distribution. They show that features specifically associated with the GNKS can contribute to increasing inequality among countries, between skill levels and within skill levels. These features are: networking tendencies towards winner-takes-all equilibria; increased globalisation and reduced communication costs that increase international volatility in response to emergent technologies; and creative destruction as general purpose technologies diffuse through the economy in fits and starts, rewarding flexibility and slowing measured growth through adaptation costs. The upshot is that increasing inequality reflects both the direct result of *laissez-faire* market-mediated unfolding of the GNKS and an unintended consequence of insufficiently GNKS-aware domestic and foreign policies.

Results relating to Equity and Growth

TERRA research is consistent with findings in the literature on the relation between income inequality and growth. Taken at face value, data indicate at best a U-shaped (‘Kuznets curve’) relationship, suggesting that a balance of growth rates and levels of equality may be preferable to extremes of either. However, the real ‘punch’ of this research concerns the underlying relationships, the specific impact of the GNKS, the sustainability implications of possible trajectories and the international implications.

In terms of the underlying relationships, econometric analysis shows that, while the relation between *income* inequality and growth is decidedly not monotonic, greater

inequality in *human capital* is always and robustly associated with lower growth. A second finding is that income inequality has complex and location-dependent connections to welfare, depending on, for instance, the degree to which the means of life are publicly provided (or subsidised), the security and resilience of quality of life, and the degree to which individuals, households and communities judge themselves by absolute standards or by comparison with local or global reference groups. Clearly, the GNKS, by changing incomes and the dynamics of careers and economic sectors, and by making people aware of the lot of others in remote parts of the world, profoundly affects these relationships.

A second aspect of the GNKS is that inequality of *access* to the opportunities and knowledge it affords may exacerbate existing societal and other divisions, or may protect valuable cultural and societal diversity. It is not obvious *a priori* that market forces will necessarily lead to a good combination of these possibilities – more specifically, that people will be able to choose the degree and nature of their involvement with the GNKS and, through it, with each other. The basics of informed choice, in the form of partnership, communication and the provision of GNKS infrastructures, skills and services on an equitable and affordable basis would seem to be a *sine qua non* of this development. Due to a combination of cost, political, educational and other factors, at present the distribution of access to the GNKS is (at least on a world-wide scale) even less equitable than the distribution of income. Moreover, at (both) extremes of the income distribution the potential significance of the GNKS is not well-appreciated, and thus short-termism can threaten long-term sustainability.

Finally, as the thematic scenario analysis shows, the sustainability of economic development depends not only on the recognition of these systemic factors but also on the nature of governance. The economic engine is driven by informed and appropriately constrained choice; societal, governmental and business decision making require the same lack of undue compulsion and sensitivity to externalities. This analysis has led some members of the project to propose bold new partnership initiatives in which countries with different immediate objectives (e.g. economic development, market access, adherence to standards) effectively cooperate or trade with one another using the engagement of the GNKS to permit negotiation about fundamentals that cannot be wholly captured in property rights.

Results relating to Environmental Sustainability

TERRA produced, as part of its work on the environmental sustainability impact of the GNKS, an indicator-based sustainability assessment tool (ASA). With the aid of this tool it was possible to derive an empirical view of the impact of new technologies on the relations among rates of growth in economic output (GDP), welfare and environmental stress. It is by now a commonplace that technological advances that appear to offer relief for (and in some cases are directly traceable to) the supply-side environmental consequences of economic growth ('dematerialising' innovation) can have contrary 'rebound effects' that swamp gains in eco-efficiency. More specifically, GNKS technologies and practices can improve the efficiency with which non-renewable inputs are used or reduce the adverse environmental consequences of resource extraction, transportation and use in production. Such advances have the effect of reducing the opportunity cost of such uses, and thus both encouraging substitution of these for other, less-affected inputs and reducing total production cost.

Both effects lead to increased use of such resources. This rebound effect is, paradoxically, magnified by policies that internalise environmental costs associated with depletion of non-renewable resources or contamination of “commons.” Indeed, there may be a positive feedback if ‘internalisation’ policies spur dematerialising innovation, whose rebound effects lead to further corrective policies.

There are complementary effects on the demand side. GNKS advances encourage *immaterialisation* – the substitution of immaterial for material goods and services. Many of these are substantially different from their predecessors – for example, while books or music delivered on-line may be very similar to their physical counterparts, the substitution of information and communications activities for XXX in time budgets involves a change in values and preferences as much as a different means of realising those values. The immediate effects are to lighten the material content of daily life or at least to substitute consumption of electricity (with its material ‘knapsack’) for consumption of e.g. petrol – in other words, a *substitution* from material to immaterial. However, to the extent that these changes increase purchasing power (aided by more competitive on-line markets and the salaries paid for more-productive knowledge-intensive jobs), there is a countervailing *income effect* – richer people buy more of everything, not just more of environmentally friendly immaterial goods and services. This has two other specific dimensions. One, reflected in the global equity perspective, is a likely by-product of any retreat of poverty; with increasing national wealth and increasing equity come middle-class aspirations and middle-class levels of consumption; the global consequences of this shift (exacerbated by demographic changes leading to an older and wealthier average population) are deeply threatening to sustainability. The second concerns a certain perverse quality in some of the value shifts that attend increasing wealth, as can be seen in some of the GNKS’s most successful economies. With the rapid productivity increases and even more rapid increases in disposable income that accompanied the initial deployment of the GNKS came a certain weakening of commitment to collective values; a feeling that relative wealth could be demonstrated by materially ‘heavy’ forms of consumption which, as a result in part of policies internalising environmental externalities, were known to be expensive. These forms of conspicuous consumption (e.g. SUVs) then became markers of individual status, thus increasing the environmental footprint of middle-class aspirations.

The TERRA analysis demonstrated these effects and quantified the balance among them. It was found that this balance was more favourable in some countries and domains of activity than in others. Taken together, the findings call for a rebalancing of policy to integrate cross-effects of e.g. R&D support, eco-taxation, standardisation and trade policy. By drawing attention to international differences and the uneven dynamics of environmental stress, they also call for policy coordination on a broader front than hitherto.

4.2. EXTERNAL COMPARISON

4.2.1. Connection to other projects and initiatives

The TERRA project has overlapped extensively with a range of other FP5 projects. These tended to have more specific foci on, for instance, the measurement of the Information Society (SIBIS), the development of new methods of work and their

societal implications (STAR, FAMILIES, e-GAP, etc.), the evolution of communications networks and the security and other considerations to which they give rise (DDSI), changes in business environment and behaviour (BEEP), the changing face of European Business (Digital Europe) and others. For the most part, this engagement has consisted of TERRA members participating in workshops, reviewing documents and providing input to these projects, while at the same time bringing insights from their ongoing work into the project's internal discourse. The reason for this is primarily that these other projects were developing their outputs at the same time as TERRA, which complicated the inclusion of their results into the formal TERRA framework.

TERRA has also been involved (again through exchange of personnel and joint working rather than formal input-output relations) in a range of initiatives concerned with sustainability in the Information Age. Significant among these are the UNECE effort to assess readiness for the Knowledge Economy, the ongoing work of Club of Rome (especially the Brussels Chapter) and the world-wide initiatives centred on poverty and development (WSSD) and the Information Society (WSIS). Within the latter frame, TERRA personnel have also contributed to a number of specific initiatives and threads dealing with environmental issues, intellectual property rights, open access to scientific knowledge, etc.

4.2.2. Policy implications

As mentioned above, the implications of TERRA analysis for policy are both methodological and substantive. Of course, most of these lessons are not new, although perhaps their combination does suggest novel strategies of engagement and alter more parochial assessments of their relative magnitude.

In addition, the experience of the project in dissemination, discourse and policy engagement has drawn out some lessons for increasing the likelihood that these lessons are understood and acted upon. The implications of the GNKS for labour markets, competitiveness, income distribution, migration, governance, environmental sustainability and so on have been known for some time – in some cases for a very long time. Nonetheless, effective policies seem very thin on the ground. Study succeeds study and solemn declarations of principle resound, yet almost all the problems seem to be growing at least as fast as the promised solutions. Part of the answer can be found in the history of TERRA's methodological antecedents. World modelling came to prominence in the 1970-'s with the publication by the Club of Rome of "Limits to Growth," which drew the world's attention to the environmental consequences of economic progress. The warning was novel, stark and clear, and the public impact was enormous. In response, policies were implemented that had the combined (and often inadvertent) effect of mitigating many of the *symptoms* of the underlying syndrome – though as subsequent experience shows, they conspicuously failed to address the underlying disease, traceable to the simplistic way private market incentives are harnessed to the public interest, to mankind's collective inability to deal rationally with deep uncertainty and pending catastrophic change (the 'boiled frog' syndrome) and to asymmetric distribution of knowledge, understanding, motivation and the means rationally to act on these. By providing a common set of easily accessible and transparent tools, by illustrating with clear examples the potency of crosscutting and rebound effects and by combining hard and soft knowledge with

hindsight, insight and foresight and by introducing this framework into scholarly, business and policy for a, TERRA points the way to a more evidence-based policy process that could enhance both deliberation and leadership as complements to the more myopic satisfaction of current preference and pursuit of novelty. However, the task remains difficult: the message to be brought to the world's attention is no longer 'new' – while the potential for disaster is greater than ever, we have become inured to prophecies of doom. The message is also complex – the fault does not lie with an easily-identifiable 'enemy' and the remedy does not lie elsewhere than with the fault. The underlying (physical and social) science are complex and easily misunderstood. Finally, the human dimension is increasingly unavoidable and increasingly difficult to address.

5. DELIVERABLES AND OTHER PRODUCTS

5.1. FORMAL DELIVERABLES

Number	Date	Title	Description (where not obvious from title)
D 1.1	Month 3	Report on TERRA2000 vision, structure and key concepts	
D 1.2	Month 4	Project presentation document	
D 1.3	Month 7	Report on model requirements, framework and protocol	Ground rules for the modelling efforts
D 1.4	Month 14	Initial dissemination and use plan	
D 2.1	Month 3	Initial working paper on NEMO representation	Papers relating to the first-generation Network
D 2.2	Month 6	Preliminary NEMO requirements definition	Effects Model covering spread of knowledge and
D 2.3	Month 9	NEMO data dictionary	the knowledge economy (the networking theme was ultimately taken up in NAUTILLUS)
D 3.1	Month 6	Initial working paper on social fabric representation	Papers relating to the first-generation models of
D 3.2	Month 12	Preliminary SOFI model definition	social dimension of the GNKS (which fed ultimately into the Social Accounting Matrix in IFS for TERRA)
D3.3	Month 2	Measuring Social Fabric: Indicators and data dictionary	
D 4.1	Month 9	Report on modification of US macro module	Papers relating to the macroeconomic growth and
D 4.2	Month 9	Preliminary MARGRET requirements definition	energy use models (which form the basis for the
D 4.3	Month 12	MARGRET data dictionary	REXS modelling system)
D 4.4	Month 12	Report on additional major country macro modules	
D 5.1	Month 12	Initial working paper on sensitivity analysis and collective, modular model development	Papers relating to the collective modelling framework (used to develop the paradigmatic
D 5.2	Month 12	Initial working paper on collective modelling technology	VenSim models) and structures behind the policy cockpit in IFS for TERRA
D 6.1	Month 6	Initial report on data needs, sources, and responsible teams	Papers relating to the modelling of IFs for TERRA
D 6.2	Month 10	Report on data-handling and data-analysis capabilities	and to project-wide data collection and documentation
D 6.3	Month 12	Databases for WP 2-4	
D 6.4	Month 12	Help system documentation	
D 7.1	Months 8	Model prototypes	
D 8.1	Month 3	Report on policy oriented input scenarios	Papers relating to project-wide scenario
D 8.2	Month 6	Working paper on Scenario Formulation and Analysis	development framework. 8.2 Includes a large number of scenarios and framework dimensions.
D 9.1	Month 15	Identification of discourse partners	Papers relating to societal discourse activities during
D 9.2	Month 18	Conference report	first phase of project
D 10.1	Month 6	Website and short report on website creation and activities	
D 11.1	Month 13	TERRA 2000 Annual Report, Year 1	
D 11.2	Month 25	TERRA 2000 Annual Report, Year 2	
D 11.3	Month 36	TERRA 2000 Final Report	
D 12.1, 13.1	Month 22	Human and Social capitals in the Information Age	Combined thematic analysis for Human Capital (WP 12) and Equity and Growth (WP 13), including dominant relations modelling of ICT economy and equity/growth dynamics, a range of scenarios and policy prescriptions relating to these themes.
D 13.1	Month 26	Thematic analysis report on Growth and Equity	Report by FAW that highlights the work done on equity and growth.
D 14.1	Month 28	Thematic analysis report on Sustainability in the Information Age	A <i>comptes rendus</i> on the work of the consortium as it relates to the sustainability analysis of the GNKS in the economic, social and environmental domains. This includes: specific descriptions of the indicator based Advanced Sustainability Analysis and IFs for TERRA (as related to the environmental theme) modelling systems; exploratory, Finnish and global framework scenarios; a range of case studies; and policy perspectives and recommendations
D 15.1	Month 23	The Story of Terra (short)	This is the 'short story' of TERRA, produced in various fora as a brochure and finally as a document for wide dissemination. It describes the propositions, the project's approach and the main results.

Number	Date	Title	Description (where not obvious from title)
D 15.2	Month 18	The Story of Terra (long)	This provides a more complete account of the substantive work of the project, covering: the propositions; the project backbone and conceptual framing; the data, analysis and scenario tools; specific policy perspectives relating to human and social development and to environmental and ecological considerations; and a road map of future work.
D 15.3	Month 19	Modelling platform	Final version of the IFs for TERRA software, including all databases, policy cockpit and online tutorial, documentation and help files.
D 15.4	Month 32	Scenarios living document	Presents a unified summary of the scenario frameworks and scenarios developed in the thematic and crosscutting work.
D 15.5	Month 32	Tools and Models Final Report	Outlines tool development over the project. Discusses conceptual foundations, development paths, and the status of tools created within TERRA.
D 16.1	Month 20 and 33	Brochure	

5.2. OTHER OUTPUTS

5.2.1. Peer-reviewed publications

Please see Annex.

5.2.2. Computer models and modelling frameworks

Following on from the framework described in Section 3, the following Table describes the main available TERRA computer and other models.

Table 3: classification of some principal TERRA models

<i>Model</i>	<i>Type</i>	<i>Focus</i>
Conceptual System Dynamics Model of Planetary Agricultural & Biomass Development (COSMOPAD) ¹⁹	Computational - Insight	Human-induced worldwide biomass production and its effects
Effects on Environment of Internet Applications (EFENIA) ²⁰	Computational - Insight	Environmental requirements of key elements of GNKS infrastructure for IT applications
Networking Effects Model (NEMO) ²¹	Computational - Insight	Examination of competing SD paradigms: constraints and technological potential

¹⁹ See Weiler and Tesch (2003).

²⁰ See Tulbure (2002).

²¹ See Tesch and Descamps (2001).

<i>Model</i>	<i>Type</i>	<i>Focus</i>
Dominant relations human and social capital model(s) (DRM) ²²	Computational - Dominant relations	Foresight into power of immigration, education, and growth in labour productivity to overcome projected skill shortages and examination of social capital and equity development.
Advanced Sustainability Analysis (ASA)	Computational - Integrated	Crosscutting SD analysis based on 'master equations' relating welfare and environmental stress to indicators of economic, technological and social development.
Collective Modelling Platform	Computational - Integrated	Collecting and integrating systems dynamics models
IFs for TERRA (IFs)	Computational - Integrated	Large-scale integrated global modelling system adapted to GNKS features and policy levers. Serves data exploration and scenario development/analysis.
Resource Exergy Services (REXs)	Empirical - Integrated macro econometric forecasting model	New formulations of important components of economy-energy models: capital accumulation, resource use and technology-innovation
Linex macro production function	Empirical	Accounting for role of physical work in growth
Human capital inequality model	Empirical	Panel model of relationship of human capital inequality to growth.
Network structure, behaviour coevolution	Theoretical	Game-theoretic model of evolution of co-ordinated behaviour and network structure, used to analyse network aspect of SD
Inequality and conservation	Theoretical	Game-theoretic model of inequality and conservation of commons
Networking Activity Understanding and Testing Instrument Linking Logic reasoning and the Use of Simulation (NAUTILLUS)	Theoretical-computational	Simulation tool for examining growth and properties of random networks.

5.2.3. Web sites

The project maintained five web sites. The first was an internal (Project Place) site used extensively for exchange of information and dialogue within the project, co-

²² See Mesarovic *et. al.* (2003).

ordination of deliverables and other activities, and exposure to 'expert' interested parties.

The second, also internal, was the Socionet platform that hosted the collective modelling platform and was used for exchange of data, equations and other technical materials among project modellers and invited outside experts.

The third is the public website (<http://www.terra-2000.org/>), used for discussion with the public, circulation of project outputs, and general information. This website has also been used as a platform for disseminating the Story of Terra and attracting audience through WSIS.

The fourth and fifth websites focused on work done on the Information Age Sustainability theme by the team at INSEAD (<http://terra2000.free.fr>) and FFRC (<http://www.tukkk.fi/tutu/terra2000/>).

5.2.4. Presentations

A large number of presentations have been given demonstrating the insights gained in the Terra 200 project to various audiences.

The project has made an attempt to integrate all those societal forces that influence future development according to a large number of different motivations and has thus engaged in societal dialogue about the implications and shape of the new Information Society. This activity (and the associated dissemination tasks in each of the themes) could be subtitled "Bridging the gap between science and society."

Workshops have been organised involving overlapping – but distinct – audiences, fitting the relevant issues and timed to coincide with outside events to maximise leverage and exposure. A first workshop was held mid October 2002 together with the EBEW 2002 conference in Prague, which fitted neatly into the human capital issue. Apart from the separate TERRA2000 workshop, various papers on TERRA2000 research were presented in other sessions and a stand was set-up at the conference, demonstrating the models and results from the Human Capital theme to a diverse audience. The excellent opportunity of the conference was extensively exploited by drawing substantial attention to the project and its outcomes. The public web site has been used to show the contributions by Consortium members to the Conference.

Another workshop on the topic of "equity and diversity in the information age" was organised in the Spring of 2003 by the leader of Work package 13, bringing together many participants including the members of the Global Society Dialogue.

A further aspects of the project's engagement with the wider world was the specific scheduling of work and production of materials for major public events, such as the World Summit on Sustainable Development (Johannesburg) and the preparatory conferences and first World Summit on the Information Society (Geneva). These materials included presentations, documents and model demonstrations.

The Conference and workshop events initiated and in many cases pursued follow-up discussion with different actors in society, international governmental organisations, with business and particularly civil society representatives who deal with Information

Society and sustainable development issues. These discussions included basic underlying political/ethical questions and their policy implications in a globalising information society. In particular, they examined the central question of whether and what kind of new global governance frameworks and new global civil society contracts are necessary to ensure sustainable development and an adequate quality of life for all citizens from the viewpoints of human capital (the networked knowledge economy), equity (division of benefits in the networked knowledge society) and environmental sustainability (living within the limits of the physical world). The activities have helped to ensure that major issues of the international debate on global governance frameworks for a worldwide sustainable Information Society were reflected in the project. Conversely, these events brought the project's experience and results into this global debate.

5.2.5. Brochures

The TERRA2000 brochure produced at the start of the project in 2001 has been extensively distributed, demonstrating the aims and goals of the project. As results became available, further brochures were developed for dissemination activities at various international fora:

A second brochure was developed as contribution to the WSSD in Johannesburg (August/September 2002) and widely distributed there.

Building on the "Johannesburg Contribution", a third brochure was developed as contribution to the e-business and e-work conference (EBEW) in Prague (Oct 2002) and was widely distributed there at the various sessions in which TERRA2000 papers were presented, the specific TERRA2000 results session and at the demonstration stand at the conference. The brochure including Concept Sheets was also made available at the public web site.

Further brochures were developed for and distributed at two WSIS PrepComs and at the 1st WSIS Summit in Geneva during 2003.

6. PROJECT MANAGEMENT AND CO-ORDINATION

6.1. OVERALL ASSESSMENT

The scale, scope and resource situation of the project led to a number of difficulties in co-ordination. By and large these were successfully overcome, but the process was necessarily lengthy and so hampered the consortium from completing its initial, (perhaps overly-ambitious) agenda. In retrospect, these difficulties could have been largely avoided by utilising a smaller, more cohesive group of participants with a more unitary project focus and a better matching of expected intellectual commitments to resource levels. This would have facilitated the earlier institution of changes made during the project (and with the help of the reviewers), specifically: the creation of a project Board; the definition of a concrete set of outputs aligned with the project 'backbone;' the adoption of a common set of conceptual definitions and central propositions and the adoption of a streamlined, thematic and phased method of working.

6.2. INTERNAL AND EXTERNAL INTERACTIONS

The project met frequently, though only five times in plenary session. There were frequent meetings of subgroups involved in particular work packages and sharing common interests. Notable among these were the group meetings for the Information Age Sustainability theme, the meetings of those involved in economic and network analysis and the series of "modellers' group" meetings. In view of the wide and keen interests of the group, it was found useful to separate the procedural and substantive parts of the meetings, to include space for presentation and discussion of work-in-progress and outside opportunities, and to encourage documentation and communication around *ad hoc* and subgroup meetings.

Internal interactions were also greatly facilitated by the shared information spaces provided through socionet (for the collective modelling effort) and ProjectPlace (for exchange of documents, computer programmes, presentation materials, agendas, etc.) This proved an attractive alternative to bulky emails, helped maintain configuration control and kept consortium members aware of each other's activities. The independent TERRA websites maintained by the INSEAD and FFRC partners also provided very useful private and public interaction space.

The project team engaged in a large number of external interactions as well. In part this was a natural consequence of the active career profiles of many of the project participants, who were easily able to introduce TERRA material and thinking into their conference, workshop, expert group, etc. commitments. Some of the engagements sprang directly from project activities (e.g. the TERRA input to and presence at the World Summits on Sustainable Development and the Information Society and participation in a range of EC-sponsored conferences); others were by-products of the collaboration afforded by membership in the TERRA consortium (e.g. the activities of the Brussels Chapter of the Club of Rome and such related projects as SASKIA).

In terms of other projects, members of the consortium brought the fruits of their TERRA work to their participation in a range of other projects on related themes. This form of leverage often afforded win-win results, since it sharpened the testing of TERRA materials and increased the input from as-yet-unpublished research elsewhere as well as, we believe, strengthening the work of those other projects – especially in relation to the boundary between Information Society research and sustainability analysis. Beyond this, TERRA members also made extensive indirect contributions to other projects, acting as panellists, invited speakers and reviewers.

Emphasis was on sharing our findings with the participants of the World Summit for the Information Society in Geneva. During the meeting in December and leading up to that meeting in the Preparatory Meetings the Terra 2000 contribution was widely shared. It was submitted to the official web site and several members of Terra contributed with presentations and discussions. Beyond these event- and project-driven activities, TERRA members also interacted with a range of NGOs and interest groups (e.g. WWF, Millennium Project), contributed ‘op-ed’ articles and other material to various news and analysis articles, and appeared on broadcast media to talk about the work and results of the project and their implications for issues of current interest.

6.3. PROBLEMS ENCOUNTERED

The project encountered a range of problems, most of which were successfully overcome. Some of these were specific to the project, but others are generic to crosscutting large-scale projects and may be expected to arise in similar efforts (e.g. Integrated Projects).

The initial difficulties arose during the proposal and negotiation process. The project was born out of an EC workshop event, and its portmanteau nature reflected the overlapping aspirations of a range of participants. These were involved to a greater or lesser extent in the drafting and negotiation of the proposal, with the inevitable consequence that differences in conception and opinion existed ‘after the event.’ Perhaps the largest such differences concerned the relative importance of modelling, scenario development and societal discourse and the precise scope and meaning of scenario analysis. These tensions were ultimately resolved by the project restructuring arising from the reviewers’ suggestions and instantiated in the revised Annex I and by the creation and discussion of a glossary of important terms with ‘working definitions’ for use in the project and ‘auxiliary meanings’ for use in interactions with the outside. Where the project work provided important clarification and refinement of these concepts, the results were documented in the public ‘concept sheets.’

Some subsequent difficulties were a consequence of the enormous number and breadth of participants. In the event, some partners took such different approaches to common issues that it proved difficult either to frame a common approach or, indeed, to make comprehensive team working arrangements. This too was ultimately resolved by the restructuring and by an ‘internal market’ arrangement whereby team leaders and consortium members exchanged information about the projected research and arrived at a mutual agreement on roles and contributions.

A related set of issues arose as a result of concerns about internal equity. It became clear that different participants had different degrees of commitment to the work of the project. To some extent, this is inevitable, especially in projects that, for all their aggregate size, form a small part of the portfolios of key players. In addition, an exploratory project stretching over three years naturally encounters certain changes of direction and it is often difficult to keep all parties sufficiently engaged, especially when changes in direction reduce their interest in the work of the project, or when the natural course of work means that some parties' contributions must await the work of others. To some extent these were resolved by changes in consortium membership and resource reallocation, although the legalities of a joint partnership arrangement made this a cumbersome and sometimes unsatisfactory business. These arrangements were only ultimately attainable through the firm recommendations of the first Review and the support and affirmation of subsequent Reviews. Indeed, the reviewers provided invaluable assistance throughout the project, both substantively and through providing internal and external 'leverage' to facilitate change.

Another issue was quality assurance. The original plan was to implement a full and rigorous peer review system along the lines of the RAND Quality Assurance programme (every deliverable reviewed by an independent (not anonymous) person with written comments and suggestions; author(s) required to respond; and reviewer to indicate whether or not the responses adequately addressed the concerns; final decision to rest with project management). In the event, this was implemented for the WP 15 deliverables and the outputs of other Work Packages were reviewed by the responsible Work Package leader. Behind this external issue, issues arose due to differing quality standards and particularly around the willingness of some authors to accept criticism, suggestions or added materials from other consortium members. The restructuring that helped resolve difficulties of coherence and team-working made issues of common standards and collegiality more difficult to resolve.

7. OUTLOOK

The consortium members joined TERRA largely because they cared passionately about the issues involved and because the work fit in with their ongoing careers. In many cases, this involvement led to cross-fertilisation – to the initiation of new lines of work and to an appreciation of the lacunæ in policy debates (e.g. a foreshortened view of IPR, a neglect of network effects or market failures in analysing the Information Society, lack of consideration of rebound effects, etc.). These consequences of TERRA work are being carried forward in a variety of ways reflecting different individual characteristics. For academics, the concrete manifestations are a stream of articles based on TERRA research making their way through the extended peer-review and editorial processes of the scientific literature; the initiation of new lines of research; and new teaching material (in the form of curricular material and new courses). For members of the non-academic research community, the further development naturally finds expression in other (primarily non-FP) research and consulting projects for a range of clients and in a range of fields. In addition, many have joined networks of excellence on the strength of TERRA-derived material, tools and concepts, and are driving forward the extended TERRA research agenda in the directions of e.g. modelling (especially of networking, rebounds and systemic effects), GNKS institutions (especially IPR and information-rich goods, services and methods of work) and sustainability analysis (especially resilience and multi-domain sustainability).

Both types of participant have also become somewhat more engaged with international fora (including the ongoing WSIS process and the UNECE Knowledge Economy initiative) and non-governmental groups (ranging from the Club of Rome to the GESI initiative).

There have also been some initiatives based more directly on specific TERRA outputs. Notable among these are the continuing development and wider application of the IFs for TERRA tool, which has found an increasing range of application, the ongoing evolution of the computerised network model (which evolved from NEMO through NAUTILLUS during the project and is now being developed as part of a PhD thesis and being used to analyse patterns of research collaboration around the FP. The work of the Human capital theme has led to the drafting of a number of labour economics papers; the work of the Equity and Growth theme has supported the elaboration of a specific policy proposal (the Global Marshal Plan) and The ASA tool has already been used for a number of published analyses and is being extended to other countries.

At a more theoretical level, the scenario analysis approach and theoretical network modelling has been applied in a range of other contexts and to other specific aspects of the GNKS – e.g. trust in cyber economies.

8. CONCLUSION

TERRA was an ambitious project involving a very diverse range of people and interests, a broad set of disciplines and methods, a profoundly ambitious and diverse set of expectations and a truly global scope. It was almost inevitable that this would result in a turbulent project, both administratively and intellectually – with hindsight, many things would have been done differently, or at least earlier. In the event, the hard-learned lessons can be enormously useful in tackling such projects in the future.

The project also was enormously productive, directly and indirectly. This is demonstrated by the wide range of engagements, publications, presentations, models and computerised tools, and by the impact of the project on the careers and achievements of those involved. A less diverse project could certainly have progressed further along one of the thematic lines, or down a single methodological pathway, but is unlikely to have advanced the broad frontier so far. This is particularly true as regards the central *problematique*. The cultural divide between the worlds of Information Society or GNKS research (particularly in the EU policy arena) and sustainability analysis remains very wide, and a productive engagement must therefore have many points of contact. Not only does this require a diversity of approaches (e.g. different types of models, multiple scenarios or a range of sustainability domains) but it also requires a *portfolio* approach combining modelling, scenario development and discourse to provide points of engagement with a range of members from both sides and to ensure that TERRA results will be regarded as parochial. Of course, the full expression of the TERRA approach would require further progress in terms of data (especially measurements of the GNKS), modelling (especially in the integration of network effects into the growth and SAM components aggregated model and methods for finding and interpreting multiple equilibria and catastrophic or chaotic dynamics) and scenario development. This makes the system – of necessity – open and neutral, and thus provides a ‘trusted’ platform for supporting societal discourse. It is not evident that such a trusted platform is preferred to dedicated evidence and analyses that support specific positions. One valuable result of the project is the demonstration that a more intelligent engagement between science and discourse is possible, by providing tools that allow users to explore even deep uncertainty together, and by providing objective or at least quantifiable evidence in a form that does not result in neglect of either ‘soft’ or ‘hard’ data, the resolution of empirical questions through adversarial debate or a one-sided choice between the balance of scientific data or deeply held belief. The proper use of these tools and their acceptance in public fora will depend on continued use and ongoing changes. As governance shifts to more cooperative modes, as voice, standing and responsibility shift among government, private and civil society actors and above all as the data and modelling – and their public understanding – advance, the TERRA products will be succeeded by more fully implemented and directly used versions.

Even now, the TERRA results, outputs and activities show that this approach *can* succeed in a particularly problematic area. The deeper challenge for the future is to see that such methods *do* succeed in this area (sustainability of the GNKS) and that they are applied to other, equally challenging problems (e.g. terrorism).

9. ANNEX: PEER-REVIEWED PUBLICATIONS

Author(s)	Title	Published in	Year
Ahokas, I; Kaivo-oja, J.	Benchmarking European information society developments	Foresight – The Journal of Futures Studies, Strategic Thinking and Policy, Volume 5, No. 1, 44-54.	2003
Ayres, R.U.	Towards a new economic paradigm	WorldWatch, October 2001	2001
Ayres, R.U.	Economic growth models and the role of physical resources	Bartelmus, Peter (ed), Unveiling wealth – on money, quality of life, and sustainability, Kluwer Publications	2002
Ayres, R.U.; Ayres, L.W.; Warr, B.	Exergy, power and Work in the US. Economy; 1900-1998	Energy 28, pp. 219-273	2003
Ayres, R.U.; Ayres, L.W.; Warr, B.	Is the US Economy Dematerializing ? Main Indicators and Drivers	Jeroen C.J.M. van den Bergh and Marco A. Janssen (Ed). "Economics of Industrial Ecology: Materials, Structural Change and Spatial Scales". MIT Press	To appear
Ayres, R.U.; Warr, B.	Dematerialization vs. Growth: Is it possible to have our cake and eat it?	Submitted to peer review process	2004
Ayres, R.U.; Warr, B.	Accounting for Growth; The role of physical work	Forthcoming in, Structural Change and Economic Dynamics	To appear
Ayres, R.U.; Warr, B.; Williams, E.	Economic Growth: Japan vs. the US	Submitted to peer review process	2003
Berg, C.	Nachhaltigkeit und Technikentwicklung aus einer theologischen Perspektive (Sustainability and technology development from a theological perspective)	Berg C. et al. (Hg.), Der Mensch als homo faber – Technikentwicklung zwischen Faszination und Verantwortung (The man as homo faber - technology development between fascination and responsibility), Münster/ Hamburg/ London, p.: 59-83	2001

Author(s)	Title	Published in	Year
Berg, C.	Nachhaltigkeit oder Futerumanum? Zur Kritik eines Begriffs zehn Jahre nach "Rio" (Sustainability or Futerumanum? - A critique of the notion of sustainability 10 years after Rio)	Berg, C., Tulbure, I., Charbonnier, R. (eds.), Folgenabschätzungen. Forum Clausthal 15/2002, Clausthal-Zellerfeld 2002, 69-80	2002
Berg, C.	Rationale Suffizienz? Anmerkungen zur normativen Rationalität im HGF-Projekt "Global zukunftsfähige Entwicklung - Perspektiven für Deutschland" (Rational sufficiency? Comments on normative rationality in HGF-project: Global sustainable development in Germany)	Technikfolgenabschätzung –Theorie und Praxis Nr. 1, 11. Jg. 3/2002, 103-107	2002
Berg, C.	Warum wir eine Ethik der Technik brauchen, (Why do we need an ethics of technology?)	TU Contact, 10 (May 2002), 20-22.	2002
Berg, C.	Vernetzung als Syndrom. Chancen und Gefahren globaler Vernetzung für eine Nachhaltige Entwicklung, (Engl.: Networking as a Syndrome. Chances and Challenges of global networking for a sustainable development),	Carsten Stahmer/ Susanne Hartard (Ed): Sozio-ökonomisches Berichtssystem für eine nachhaltige Gesellschaft (Statistisches Bundesamt), Wiesbaden 2003, in print	2003
Berg, C.	Sustainable Consumption and its Relation to Value Systems	Exploring a Worthwhile Future For All - tt30 - the young think tank of the Club of Rome, Valencia 2003, 178-186	2003
Cave, J.	Capitalising on human knowledge in global networked society	E-Business and E-Work Conference. Prague 16-18 October 2002.	2002
Descamps, P.; Tesch, T.	The impact of growth patterns on random network topology parameters	Forthcoming	2004
Descamps, P.; Tesch, T.	The Emperors New IPR (Intellectual Property Rights)	Forthcoming	2004
Descamps, P.; Tesch, T.; Weiler, R.	GSD MaMod: Generic System Dynamics Manufacturing Model	Forthcoming	2004

Author(s)	Title	Published in	Year
Descamps, P.; Tesch, T.; Weiler, R.	MarGrET: Macro Generic Energy Transfer Model	Forthcoming	2004
Dolfsma, W.	Metaphors of Knowledge in Economics	Review of Social Economy, 59(1): 71-91, 2001 (London: Routledge)	2001
Dolfsma, W.	The mountain of experience: how people learn in a complex, evolving environment	International Journal of Social Economics, forthcoming 2001 (Bradford: MCB University Press)	2001
Dolfsma, W.	Benchmarks voor de 'Nieuwe Economie'	" I & I: Nieuwe Media in Perspectief 19(2): 31-4, April 2001	2001
Dyer, B.; Millard, K	A generic framework for value management of environmental data in the context of ICZM	Journal of Ocean and Coastal Management, 45, pp59-75, Elsevier.	2002
Hoffrén, J.; Luukkanen, J.; Kaivo-oja, J.	Decomposition Analyses of Material Flows: The Case of Finland 1960-1996	Journal of Industrial Ecology. Vol. 4, No. 4, pp. 105-125	2001
Hoffrén, J.; Luukkanen, J.; Kaivo-oja, J.	Statistical Decomposition Modelling on the Basis of Material Flow Accounting.	Pre-proceedings. Volume 1. Hersonissos, Crete 18-22 June 2001. NTTS & ETK 2001. New Techniques and Technologies for Statistics. Exchange of Technology and Knowhow. Eurostat. European Union. Institute for Systems, Informatics and Safety. JRC In Association with NSIG ITY department in Crete. ABS. ISI, pp. 515-524.	2001
Hoffrén, J.; Luukkanen, J.; Malaska, P.	Sustainability Evaluation Frameworks and Alternative Analytical Scenarios of National Economies	Population and Environment Vol. 21, No. 1.	2001
Hughes, B.H.	Enhancing human capital: analysis using an integrated model	E-Business and E-Work Conference. Prague 16-18 October 2002.	2002
Inglehart, R.	"Exploring the Unknown: Predicting Mass Attitudes in Countries that have not yet been surveyed."	Forthcoming in International Review of Sociology, Spring, 2004	2003

Author(s)	Title	Published in	Year
Jischa, M.	Operationalisierung von Nachhaltigkeit durch Technikbewertung;	S. Hartard, C. Stahmer (Hrsg.): Magische Dreiecke - Berichte für eine nachhaltige Gesellschaft; Band 2/Bewertung von Nachhaltigkeitsstrategien, Metropolis, Marburg, S. 175-195	2001
Jischa, M.	Operationalisierung von Zukunftsfähigkeit durch Technikbewertung;	R. Coenen (Hrsg.): Integrative Forschung zum globalen Wandel, Campus, Frankfurt/Main, S. 205-227	2001
Jischa, M.	Technikgestaltung gestern und heute - Zusammenhang von Energieversorgung und Zivilisation (Technology development yesterday and today - Relationship between energy consumption and civilisation);	Grundwald, A. (Ed.): Technikgestaltung zwischen Wunsch und Wirklichkeit". Springer, Berlin, 2003, p. 105 - 115	2003
Kaivo-oja, J.	Scenario learning and potential sustainable development processes in spatial contexts: towards risk society or ecological modernization scenarios?	Futures Research Quarterly. Vol. 17. No. 2. Summer 2001, pp. 33-55. © World Future Society.	2001
Kaivo-oja, J.	Challenges of Visionary Management in Multilevel Planning Environment: How Murphy's Laws May Emerge in Global Sustainability Policy?	Tony Stevenson, Eleonora Barbieri Masini, Anita Rubin & Martin Lehmann-Chadha (Eds.) The Quest for the Futures: A Methodology Seminar in Futures Studies. Selection from the Methodology Seminar in Futures Studies, Turku, Finland, June 12-15, 2000. Finland Futures Research Centre. World Futures Studies Federation. Painosalama Oy, Turku, pp. 71-93.	2001
Kaivo-oja, J.	Social and Ecological Destruction in the First Class: A Plausible Social Development Scenario.	Sustainable Development. Vol. 10, No. 1, pp. 63-66.	2002
Kaivo-oja, J.	Foundations of Futures Studies and Foresight Research.	Keenan, Mike, Loveridge, Denis, Miles, Ian & Kaivo-oja, Jari (2003) Handbook of Knowledge Society Foresight. Prepared by PREST and FFRC for European Foundation for the Improvement of Living and Working Conditions. Final Report. European Foundation. Dublin. 166 pages.	2003
Kaivo-oja, J.	Seeking for Foresight Intelligence: Knowledge Management Challenges and Tools in Foresight Research.	Keenan, Mike, Loveridge, Denis, Miles, Ian & Kaivo-oja, Jari (2003) Handbook of Knowledge Society Foresight. Prepared by PREST and FFRC for European Foundation for the Improvement of Living and Working Conditions. Final Report. European Foundation. Dublin. 166 pages.	2003
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Author(s)	Title	Published in	Year
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Kaivo-oja, J.; Luukanen, J.; Malaska, P.	Sustainability Evaluation Frameworks and Alternative Analytical Scenarios of National Economies.	Environment and Population. A Journal of Interdisciplinary Studies. Vol. 23, No. 2, 193-215. © Kluwer Academic Publishers.	2001
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Kaivo-oja, J.; Luukkanen, J.	The European Union Balancing between CO ₂ Reduction Commitments and Growth Policies: Decomposition Analyses.	Forthcoming in Energy Policy.	2003
Kaivo-oja, J.	Sustainable Development as a Futures Challenge: Research Articles in Spatial Sustainability Analysis, Planning and Evaluation.	PhD study. Department of Regional Studies and Environmental Policy. University of Tampere. Under review process.	2003
Kapitza, S.	The Statistical Theory of Global Population Growth	Formal descriptions of developing systems, Kluwer Academic Publishers, The Netherlands	2003
Keenan, M.; Loveridge, D.; Miles, I.; Kaivo-oja, J.	Handbook of Knowledge Society Foresight.	Prepared by PREST and FFRC for European Foundation for the Improvement of Living and Working Conditions. Final Report. European Foundation. Dublin. 166 pages. http://www.eurofound.eu.int/publications/files/EF0350EN.pdf	2002
Luukkanen, J., Karppi, I.	Conditioning global and local climate, biodiversity and development policies –changing institutional and environmental contexts of tropical forests.	Käyhkö, J. Talve, L. (Eds.) Understanding the Global System. The Finnish Perspective. Finnish Global Change Research Programme FIGARE. Painosalama Oy, Turku, pp. 207-212.	2002
Luukkanen, J.; Kaivo-oja, J.	G-7 Countries on the Way to Sustainable Energy Systems?	International Journal of Global Energy Issues. Vol. 20, No. 1, pp. 58-74.	2003
Luukkanen, J.; Kaivo-oja, J.	An analysis of the long-run socio-cultural changes in the energy sector of the wealthiest industrialised countries: Comparison and analysis of G-7 countries energy and CO ₂ efficiency dynamics in the years 1960-1997	Proceedings of the Science and Culture of Industrial Ecology. Abstracts for the Inaugural Meeting. International Society for Industrial Ecology, 12-14 November 2001, Leiden, the Netherlands, pp. 84-85.	2001

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Luukkanen, J.; Kaivo-oja, J.	Sustainability of Energy Use and CO ₂ Emissions in ASEAN Countries: Decomposition Analysis of Energy and CO ₂ Efficiency Dynamics.	Global Change and Sustainable Development in Southeast Asia. A SARCS Regional Science - Policy Conference. Chiang Mai, Thailand, 17-19 February 2001. ABSTRACTS, Session C4. Greenhouse Gas Emissions and Policies. p. 66.	2001
Luukkanen, J; Kaivo-oja, J.	The European Union Balancing Between CO ₂ Reduction Commitments and Growth Policies.	TUTU-publications 7/2002. Finland Futures Research Centre. Turku School of Economics and Business Administration. Turku. 43 p.	2002
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