Interacting with the Global Systems Simulator

by

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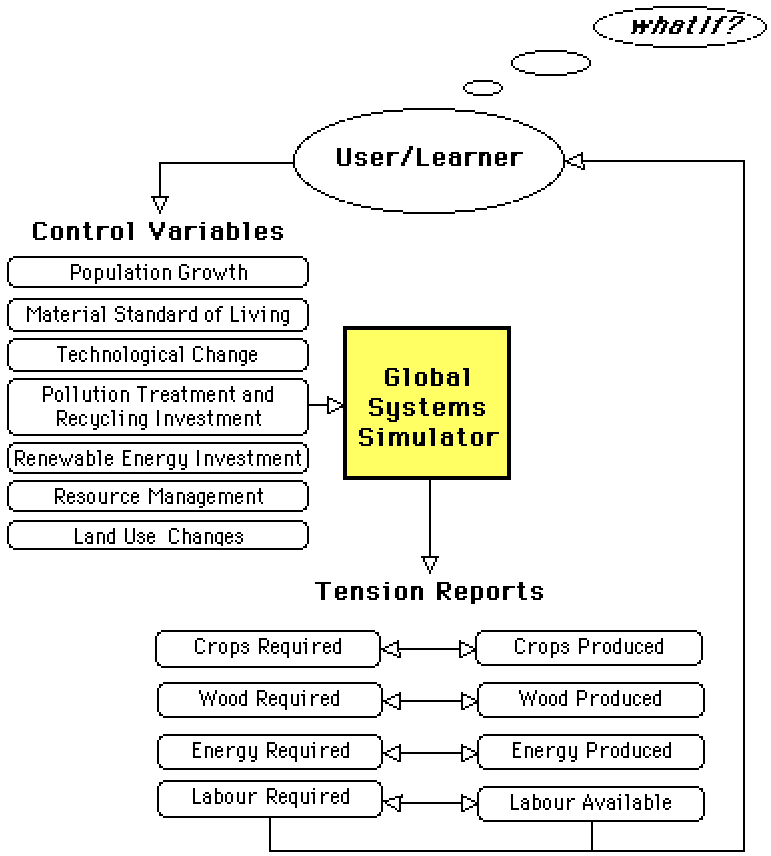
The Global Systems Simulator is an interactive computer based simulation model that can be accessed by means of the internet. It serves as proof-of-concept for the systems learning approach adopted by the Global Systems Centre and applies it to the issues of the global problematique. In this approach, simulators are seen as a means for making explicit and communicating an understanding of the salient features of global systems from the perspective of their ability to sustain human populations. This first version of Global Systems Simulator is designed to explore the relationships among human population, lifestyle, technology and the natural resource base at a global scale.

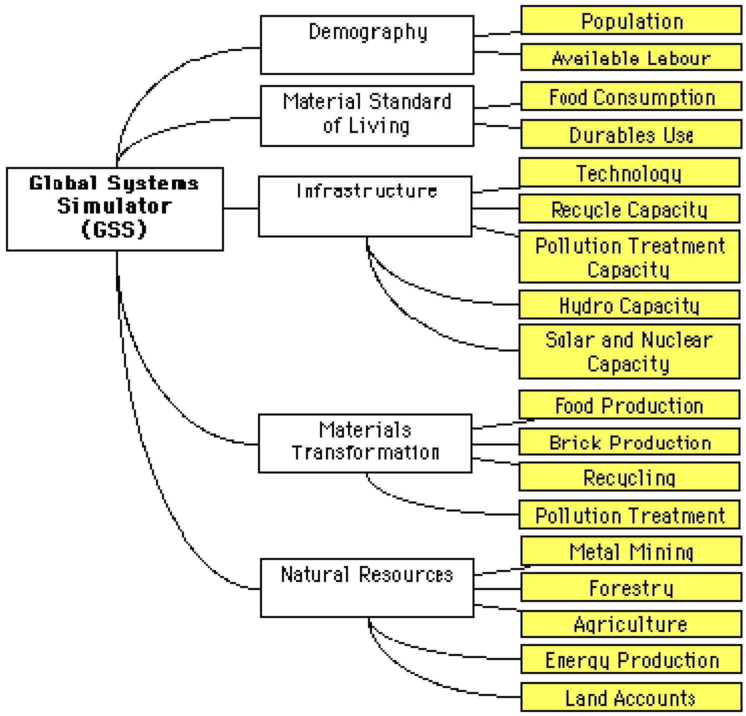
The new approach emphasizes learning rather than prediction. The Global Systems Simulator plays the role of a global flight simulator: learning is accomplished by exploring the responsiveness of global systems to potential societal actions involving population growth, lifestyle and technology. Complex behaviour for a system-as-a-whole emerges out of dynamic interactions among relatively well understood processes. Each process is independently and interactively controlled. Particular settings of the control variables may give rise to inconsistencies among processes, - tensions - that the user/learner attempts to resolve by experimenting with settings of the control variables. It is this interaction between the user/learner and the simulator that generates a greater understanding of how the system works. Learning is accomplished by experiencing.

The following diagram illustrates the interaction between the user and the GSS in the resolution of tensions between the requirements for agricultural crops, wood, energy and their availability from the natural resource base and between the requirements for labour in all the processes that transform materials and energy and the availability of labour from the population.



Structure of the Global Systems Simulator

The Global Systems Simulator accounts for the stocks and flows of natural resources, land, materials, energy, finished goods, and wastes over a 100 year time horizon. It represents the physical substrate of the global socio-economy in terms of both human designed and naturally occurring processes that transform flows of material and energy. The eighteen processes represented as sub-models in the simulator were chosen as the minimum number required to explore the concept of sustainability.



The yellow boxes on the right hand side of the following diagram are the individually executable sub-models or calculators. Each calculator is documented by a design diagram that shows the control variables and the output variables, the procedures that transform values of inputs into values of outputs and the connections among the procedures.

The Structure of the Global Systems Simulator is presented in more detail in a paper entitled , An Overview of the Global Systems Simulator.

The Continuing Trends Scenario

The Continuing Trends Scenario was intended to explore the question 'what happens if we (humankind) pursue the goals of betterment for humankind by continuing to do what we have been doing'. It represents a first attempt in the cycle of set control variables, calculate the tensions, adjust control variables.

The starting point for the first scenario is global population, shown in Figure 1. Historically, the human population of the globe has doubled since 1950, increasing from just under 3 billion in 1950 to 6 billion at the present time. In this scenario, population increases to 12 billion in 2080 before leveling off and slightly declining. This population scenario is based on the assumptions for total period fertility and life expectancy for birth shown in Figures 2 and 3 respectively. Fertility was assumed to continue declining from current levels (3.5 births per female) to replacement (2.1 births per female) by 2050. Life expectancy from birth was assumed to increase from 65 years for females and from 60 years for males to 80 years by the end of the simulation period.

With respect to the material standard of living, food per capita was increased by 10% and durables stock per capita was assumed to double over the simulation period.

The trend to labour saving technology was assumed to persist. Historically, labour has been substituted for by bundles of energy and physical capital; in the goods production sector, this substitution has just about gone as far as it can go; but in the service sector, this substitution has only recently been important as information technology displaces labour.

Investments in energy and material saving research, pollution treatment and recycling capacity, and forest management were assumed to be minimal.

The energy system was assumed to rely to a large extent on fossil fuels, particularly oil and gas. Investment in solar/nuclear and hydro capacity was assumed to be minimal.

In terms of land use, the amount of high quality and medium quality agriculture land continued to decrease, as it has historically, due to urbanization and desertification. The amount of poor agriculture land was assumed to increase as land is transferred from forestry to agriculture.

The tension between the requirements for agricultural crops and the crops available is shown in Figure 4. This graph shows that the requirements for crops began to exceed their availability at approximately the year 2020. Before that time, crop production could meet requirements. The requirements for crops beyond 2020 follows the population; the availability is limited by the amount of land devoted to agriculture and yields which in turn depend upon a number of factors. This scenario is therefore not feasible after the year 2020. As such, it is clearly not a prediction or forecast because it incoherent.

The tension between the requirements for wood and the amount of wood harvested is shown in Figure 5. This graph shows that the amount of wood harvested could not meet the requirements for wood beyond the year 2020 and that the wood that could be harvested declined rapidly at that point and beyond. This is an indication that forests were being harvested at an unsustainable rate; once the stock of primary forest was depleted, harvesting was limited by forest productivity.

The tension between the requirements for energy and the amount of energy available is shown in Figure 6. This graph shows that the amount of energy produced could not meet the requirements for energy beyond the year 2020. The peaks on the energy production curve represent running out of reserves ofoil at 2020, running out of gas at 2030 and running out of coal at 2050.

It is up to the user of the Global Systems Simulator to experiment with the settings of the control variables to find coherent scenarios.

The Foresight Scenario

Scenario 2, the Foresight Scenario, assumes that humankind understands that a change in behaviour at a global scale is required if the human population is to be sustained harmoniously. Scenario 2 was developed as an attempt to find a feasible scenario without reducing either the population or the material standard of living. Scenario 2 as reported in Figures 7, 8 and 9, is coherent, as all three tensions have been resolved

In all, twenty-four control variables were changed from Scenario 1 in order to create Scenario 2. These include

- first increasing then reducing fertilizer per hectare
- increasing the genetic yield factor - i.e. increasing the efficiency of plants
- increase sharply the labour intensity of agriculture - this has a positive impact on yields as agriculture practices take on the character of market gardening
- increasing the capacity to treat pollution - this will increase yields (untreated pollution has a negative impact on crop yields) and reduce the natural mortality of trees
- reducing crop per unit food - i.e. improving the efficiency of the process that transforms crops into food - using animals to transform crops into food (meat) is inefficient - this implies a more vegetarian diet
- phase out the use of wood as a fuel - historically about half the wood harvested is burned as a fuel
- increase the ratio of land reforested to land harvested to .9 and reforest all the forest land that was unstocked at the beginning of the historical period
- reduce the wood content of materials
- increase the labour intensity of production - this saves both energy and material
- Increase the effort devoted to energy saving research - this will deploy technology that is more energy efficient
- Increase the effort devoted to material saving research - this will deploy technology that reduces requirements for wood and metal - and save the energy and labour that would have been required to produce those materials
- Increase the capacity to recycle
- Increase the useful lives of durable goods and plants - this has the effect of reducing materials for replacement, but at the cost of increasing the length of time for the deployment of more efficient technology
- Increase capacity to produce renewable energy - double hydro capacity - and increase solar/nuclear by a factor of ten
- modify the fossil fuel shares to effect a more rapid transition from oil to gas to coal
- increase labour force participation rates for the 65+ category
- increase the work week for the next ten years as needed to support reforestation , research effort, and investments in pollution treatment, recycling , renewable energy capacity - after ten years the work week can be reduced by about two hours

Observations and Conclusions

It became clear from Scenario 1, that if humankind continues to ‘muddle along’ in much the same way as it has in the past, expectations for a sustainable and harmonious future will not be met. Change is inevitable. The only question is whether the change will be for a future that we intend or one that emerges as we react to the crises that are the result of conflict over scarce resources.

Even in the highly simplified representation of global systems of the GSS, it became clear that finding feasible solutions was a difficult task. There did not appear to be a single intervention, such as population control, or even a small number of interventions that could effect a reasonable result. It may be concluded that any resolution strategy will involve carefully coordinated combinations of actions. Those who advocate single actions, whether it is population control, renewable energy, or reliance on the ideological market forces have insufficient understanding of the complexity of the system. The actions they advocate may be necessary, but they are certainly not sufficient.

The simulation experiments indicated an imbalance between effort devoted to increasing energy supply, such as oil and gas exploration and the development of solar/nuclear options and those devoted to increasing the efficiency of energy use. Increasing energy efficiency by an order of magnitude or more is likely to be a necessary element of the resolution. Further, it would appear that using biomass as a source of energy is apt to be counterproductive as land that is capable of producing biomass is more urgently required for food and perhaps wood production and as a sink for carbon.

It would appear that the continued substitution of energy and material for labour is exacerbating the situation. This substitution is propelled by the institutionalization of market forces and reliance on competitiveness, which rewards minimization of internal costs. The world is not facing a shortage of labour; it is facing shortages of energy and materials; yet the metric for measuring the efficacy of production processes is the efficiency with which labour is used.

With respect to fossil fuels, it would appear that the limiting factor in their use might be the lack of sinks for the by-products of their combustion rather than the depletion of resources. Further, it was speculated by some of the participants that forests might be more valuable as a sink for carbon than as a source of wood fiber or fuel.

In several instances, the response of the system to changes in the control variables could not be foreseen in that neither the magnitude nor the direction of the changes could be anticipated. Further, the response of the system depended on the state of the system at the point where the change was introduced. Evidently, the magnitude and the direction of the change to the system depended upon the values of parameters sometimes once or twice removed from the direct impact of the change. Under these circumstances, expectations based on intuitions could very well prove to be wrong.

Figure 1

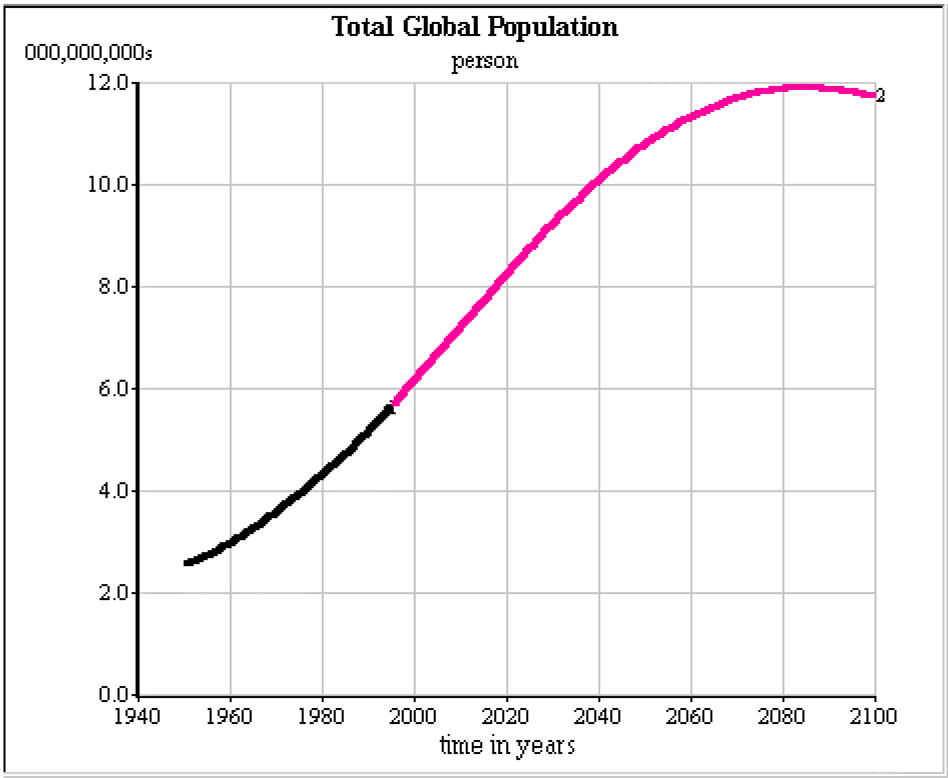


Figure 2

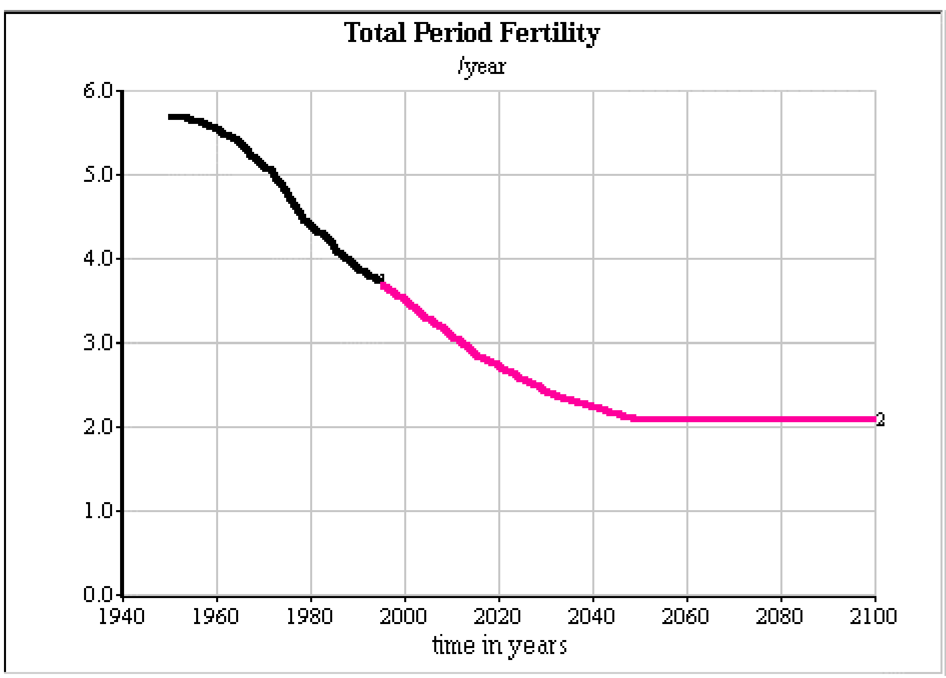


Figure 3

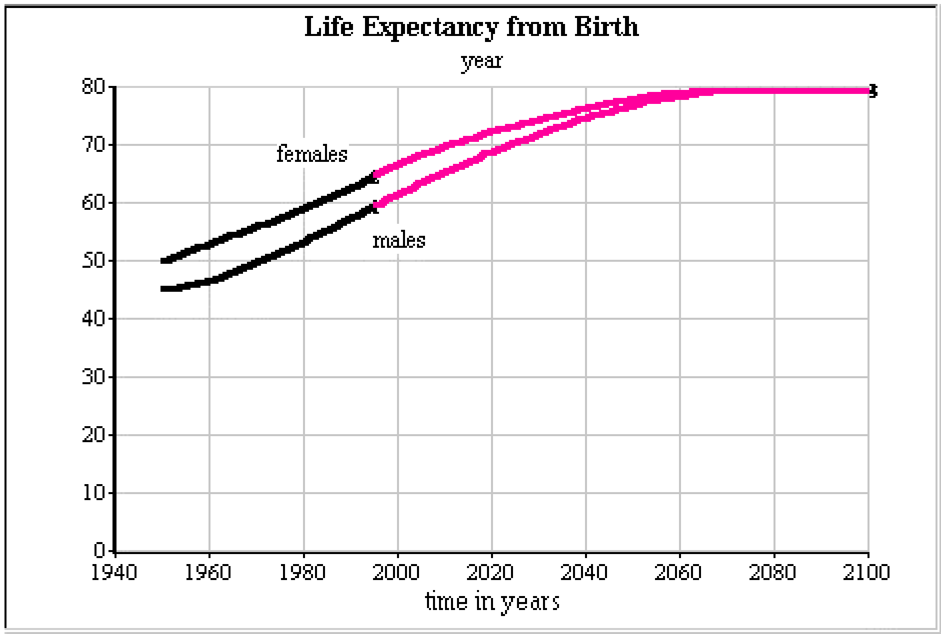


Figure 4

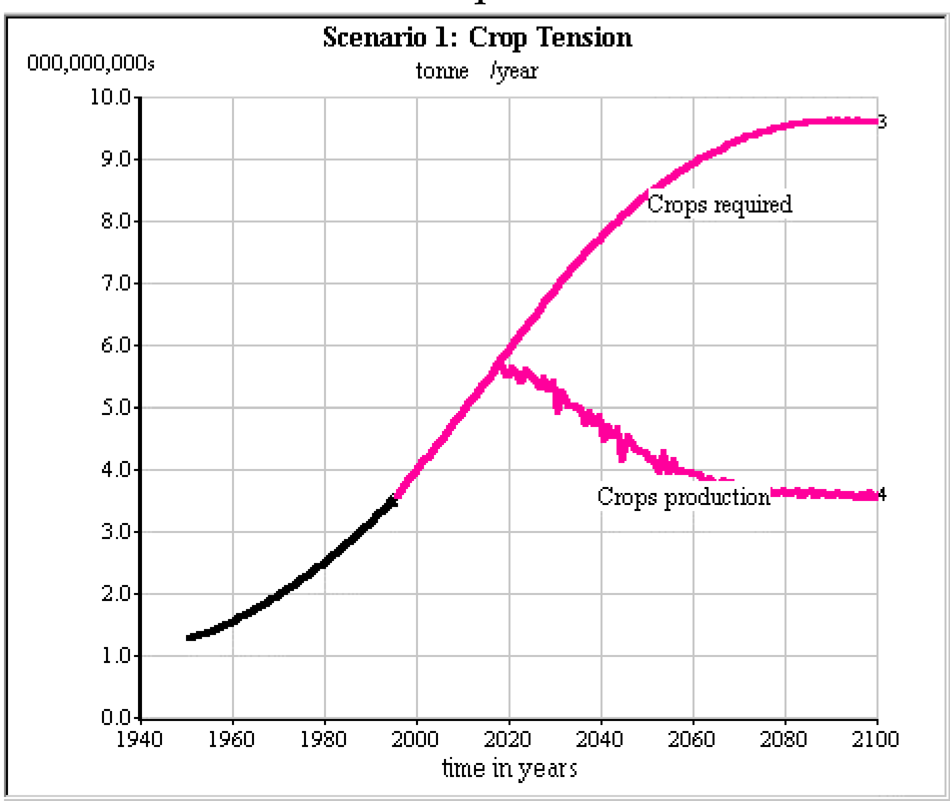


Figure 5

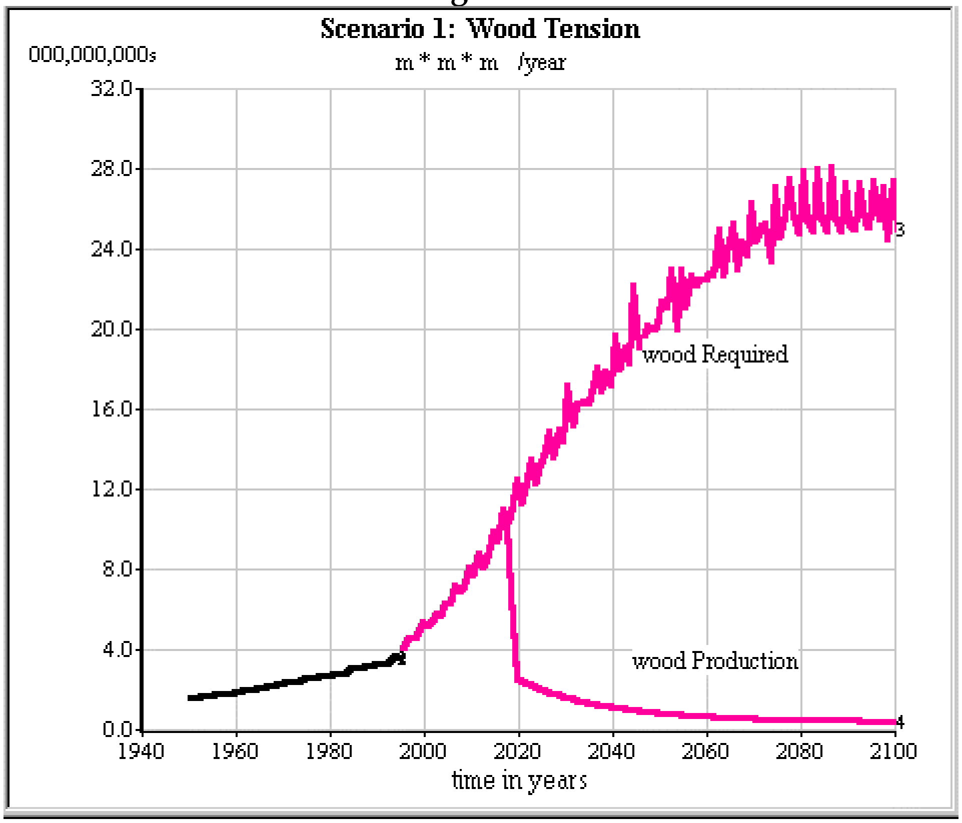


Figure 6

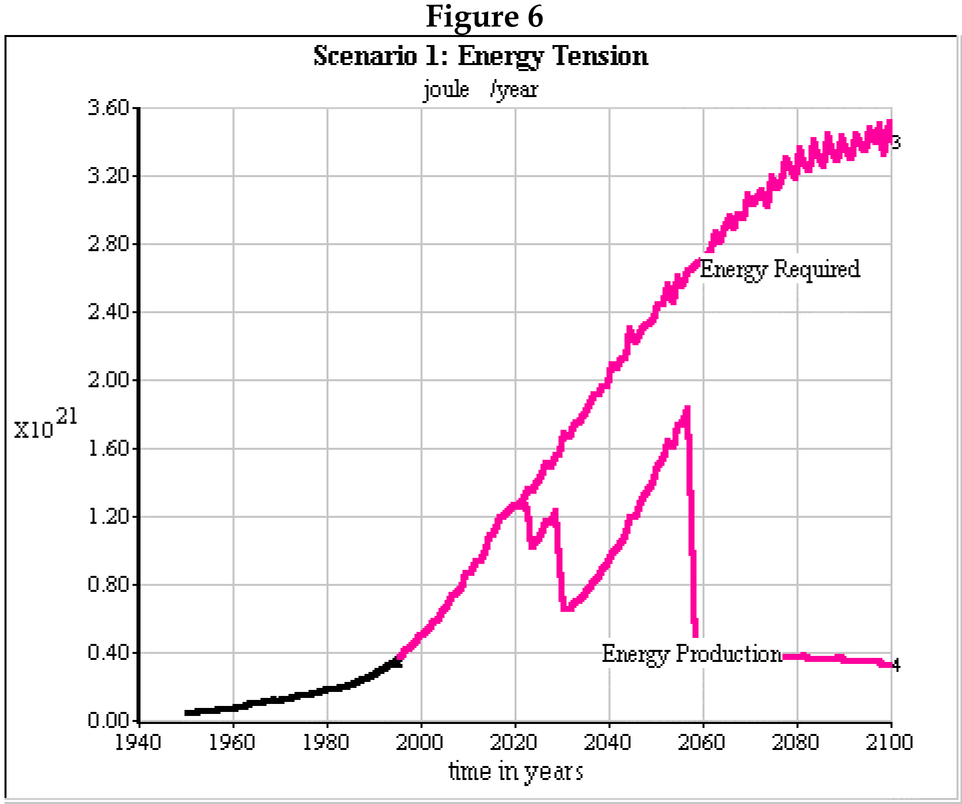


Figure 7

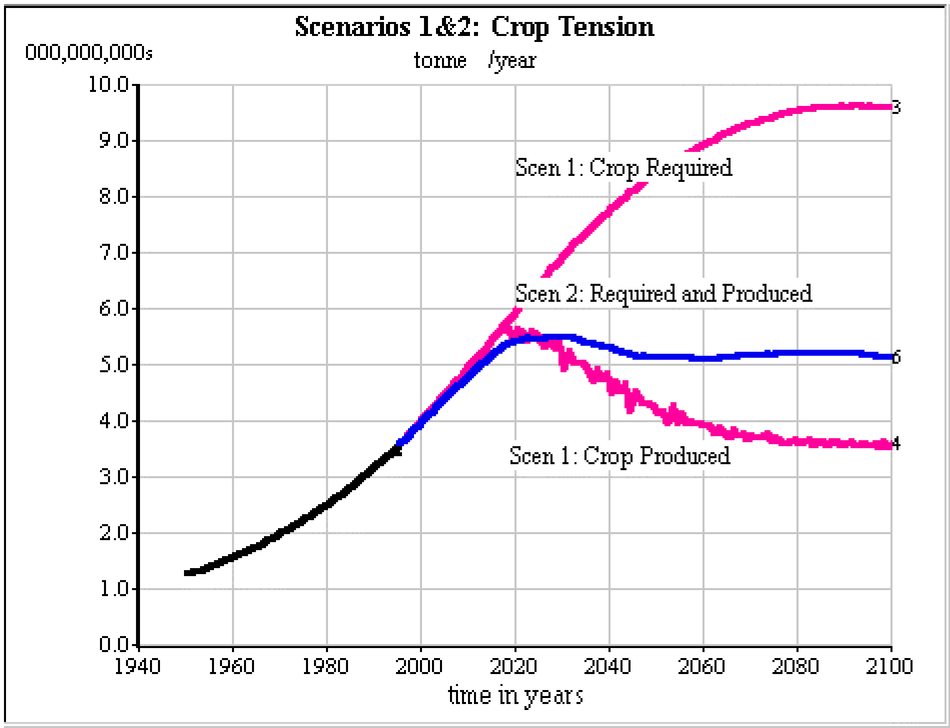


Figure 8

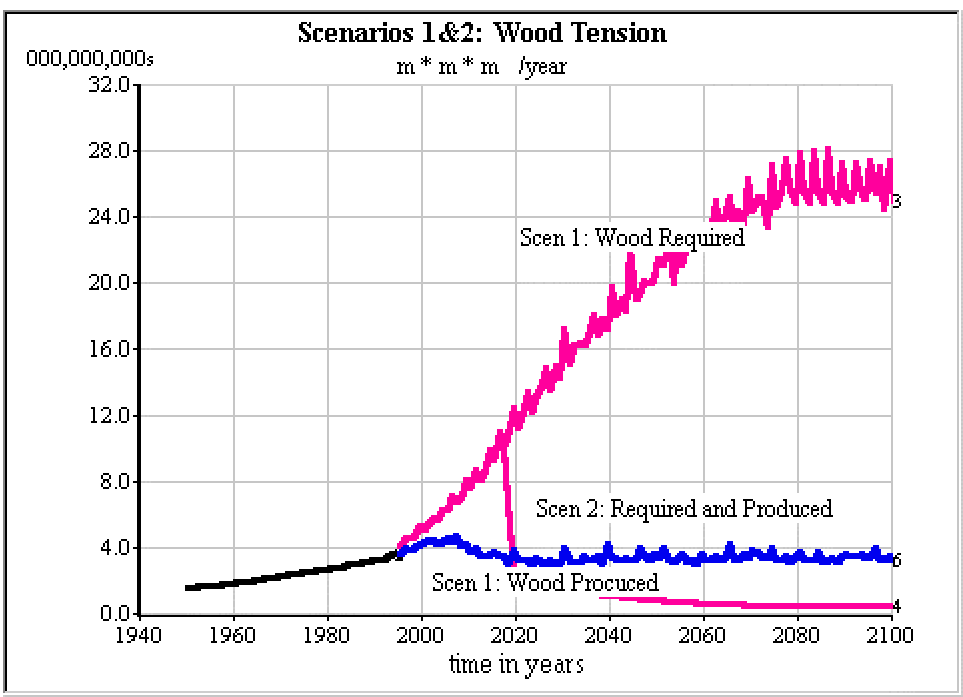
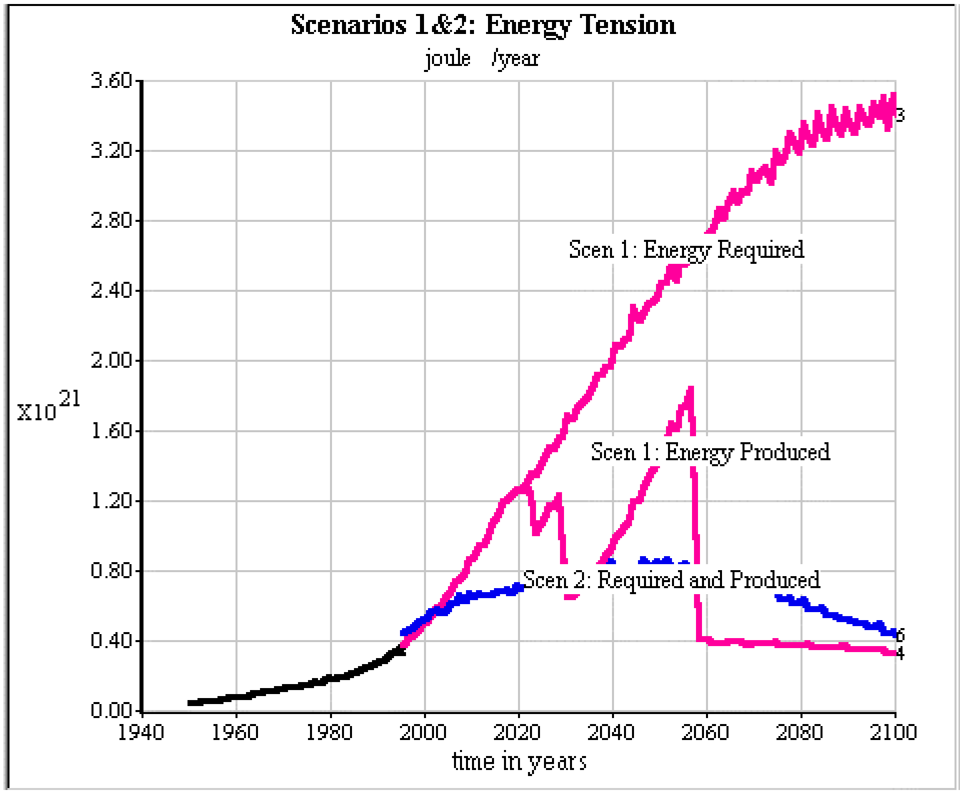


Figure 9


Scenarios 1&2: Energy Tension
joule /year
3.60
3.20
2.80
2.40
2.00
1.60
1.20
0.80
0.40
0.00
X10^21
1940
1960
1980
2000
2020
2040
2060
2080
2100
time in years
Scen 1: Energy Required
Scen 1: Energy Produced
Scen 2: Required and Produced
3
6
4