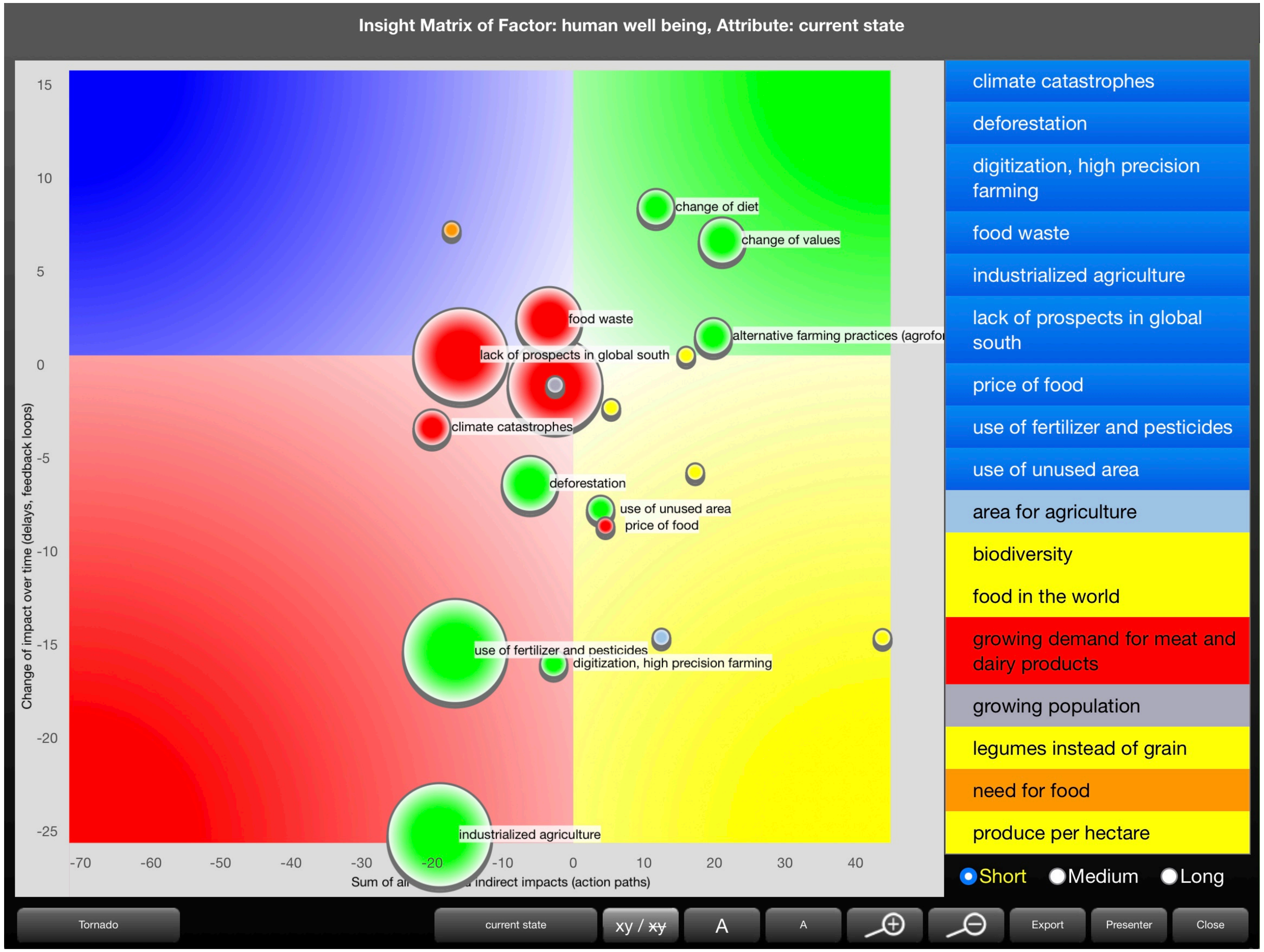
The GLU Model
Can we feed the world and survive it?

Consideo - Kai Neumann, Franc Grimm



Insight matrix from the model "Feed the world" published on KNOW-WHY.net: https://www.know-why.net/present/CwkbdEOEOd_qe9xzKk9Q90Q.

CONSIDEO

The GLU Model

CAN WE FEED THE WORLD AND SURVIVE IT?

Summary

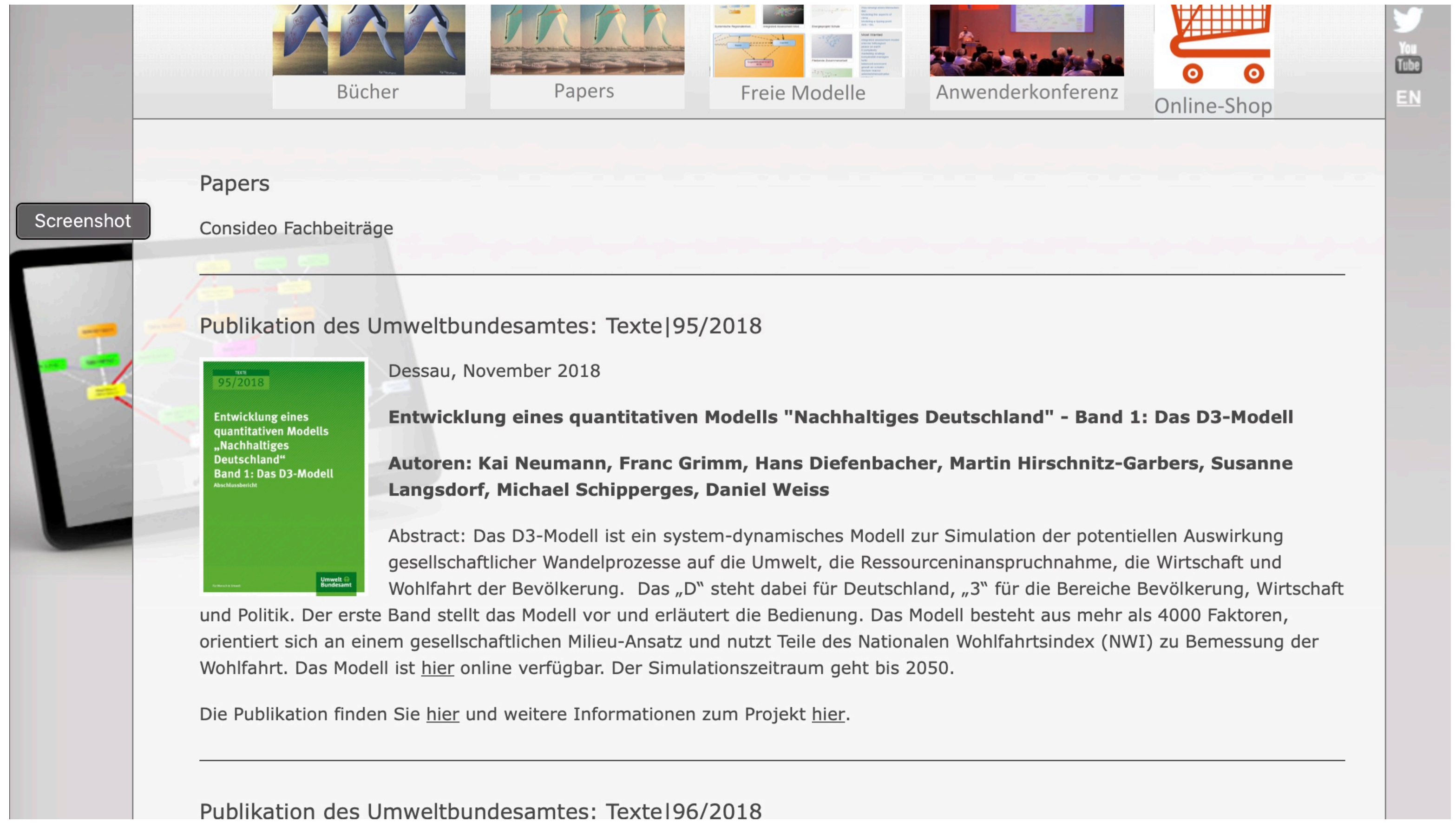
The Global Land Use Model developed for a project for the German Environment Agency explores the potentials for biotic resources - food/non-food, material/energetic - being a system dynamics model using data from the FAO and the World Energy Outlook. It looks at the land use for forests, extensive or intensive agriculture, and for infrastructure, the development of the population and its plant and animal based diet, the waste of food and the use of both wood and non-wood biomass for materials and energy generation. The GLU Model also calculates the relative impacts of the global land use on greenhouse gases in the atmosphere. The simulations indicate that the current trajectories even without the assumption of major yield losses as a result from climate catastrophe would not allow us to further feed the world. Unless the world takes concerted action the logic would be a continued deforestation. However, a combination of moderate changes in diet, food waste, energetic use of biomass, and the utilization of extensively used land would allow for afforestation substituting steel and concrete with an end of life energetic use of biotic materials for a significant contribution to tackling climate change as would the shift towards organic farming that, too, would help to capture carbon from the atmosphere plus its additional benefits for biodiversity and resilience to extreme weather.

Agro-PV, legumes, permaculture, terra preta … a resilient and productive garden

The 'grey series'

Studies do not seem to reach the political arena at all, are usually too specific for the general public, and are all too often perceived by other scientists as competition or are not taken up.

We can reach policymakers through the public and we will continue to write official project reports and peer-reviewed articles for the scientific community. But for the public, we want to offer an attractive format that is easy to read and that sums up the findings and the action that can be derived from them - our 'grey series' based on the term 'grey literature'.



Screenshot of the Consideo website with the project reports and scientific publications linked there (www.consideo.de/papers.html)

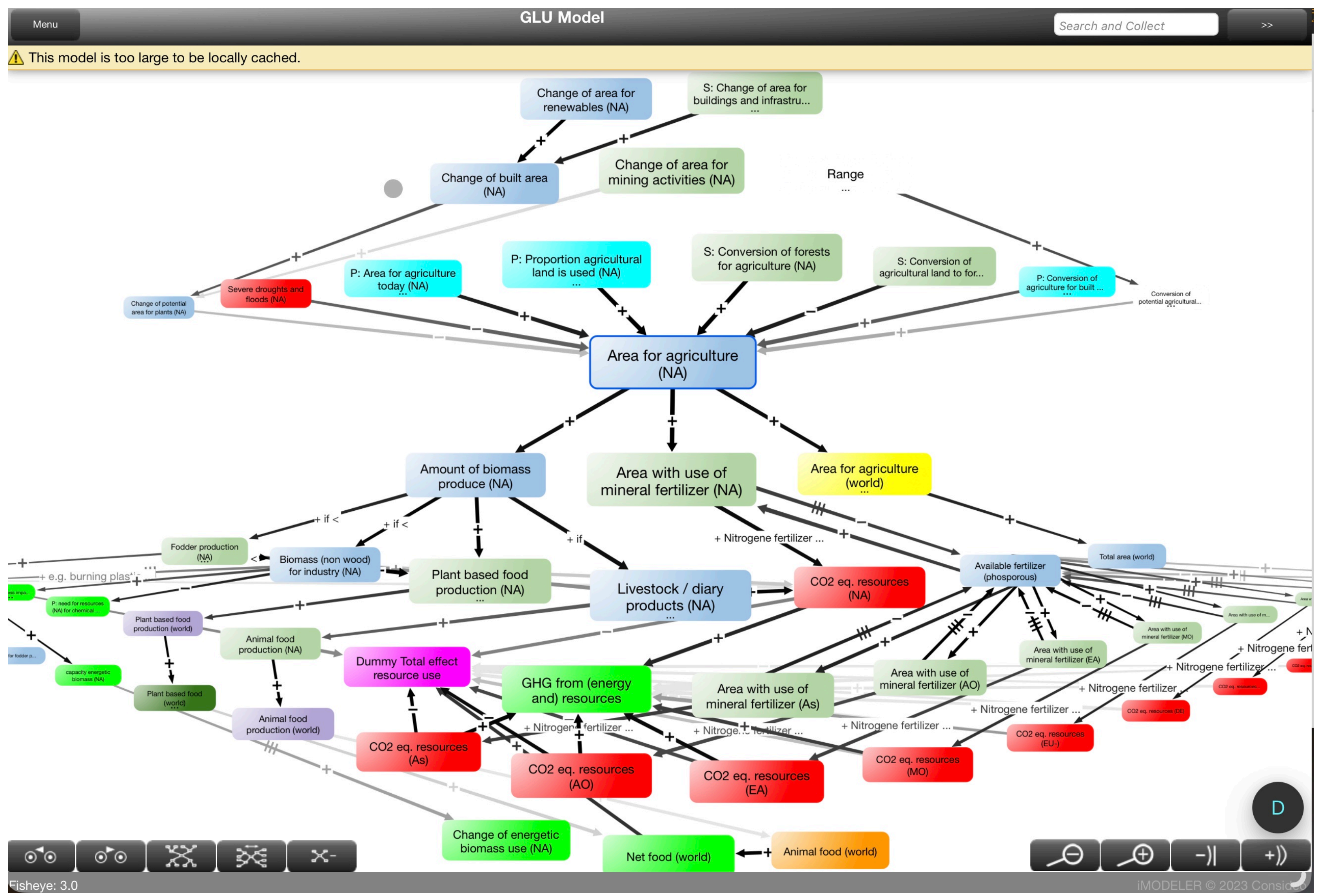
Our findings from the GLU Model which was only a side product of another project actually looking for the potentials for material use of biotic resources are a revelation. Just looking at the FAO data on available agricultural land, the projections of the global population and its diet by the OECD, the FAO's and the agricultural industry's forecast of potential yields from use of fertilizer and chemicals also in developing countries, reveals that we will not be able to feed the growing population. We would be forced to cut more forests even if there weren't major losses from extreme weather due to climate catastrophe.

But, if we push 50 percent of the available levers for change we could even grow more forests and feed the world through organic farming. Fascinating!

The GLU Model

The GLU Model (Global Land Use Model) was developed to support the ICARE Simulation Model (Neumann, Hirschnitz-Gabers, 2022) for the German Environment Agency to explore the role of resource efficiency for the global energy transition and greenhouse gas emissions. Next to the classic materials like copper or neodymium the study looked at the potentials to substitute greenhouse gas intensive steel and concrete through biotic resources. For that question we wanted to know what potential for biotic materials as well as for their energetic use there will remain after feeding the growing population and what that would imply for greenhouse gas emissions and sequestration.

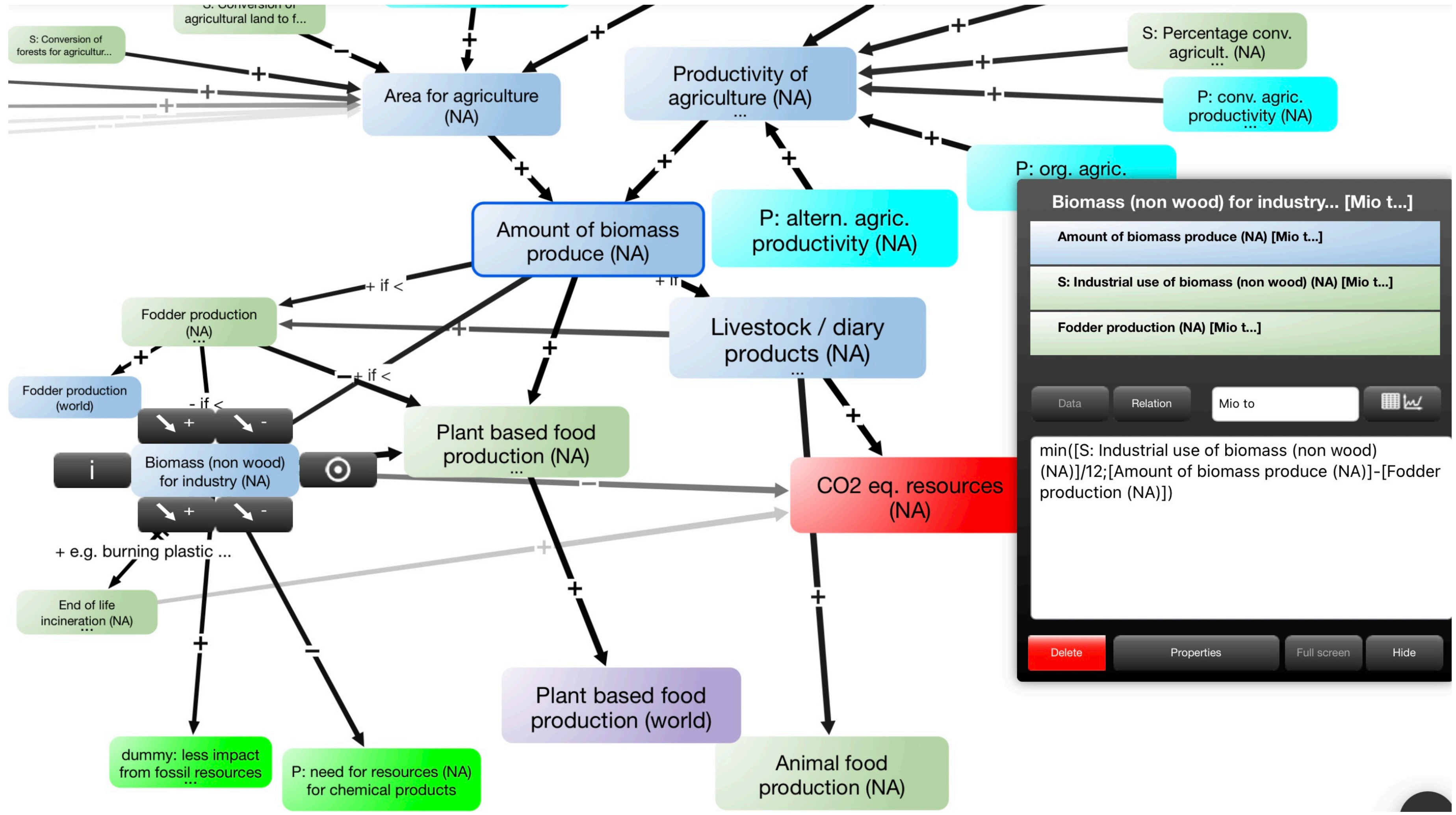
The model has a huge potential to explore many more aspects, like the role of extreme weather, the differentiation of regions in the world, the potential for even more afforestation etc.. This paper only roughly describes the model and some selected scenarios and conclusions that should contribute some valuable memes to the public discussion.



The GLU Model looking at the scenarios of Global Land Use

Model structure

The GLU Model uses 529 factors and runs in monthly steps from 1990 to 2100. The Model looks at the same regions of the world as the ICARE model that is based on the data from the World Energy Outlook (WEO) by the International Energy Agency (IEA, 2015). Model wise the regions were just cloned, connected, and their data adopted accordingly. To differentiate the regions of the world allows for further elaborated scenarios considering varying farming practices and diets in the world. Nevertheless, the GLU Model also features factors for a world market for food and biotic materials.



Perspective of biomass produce in North America

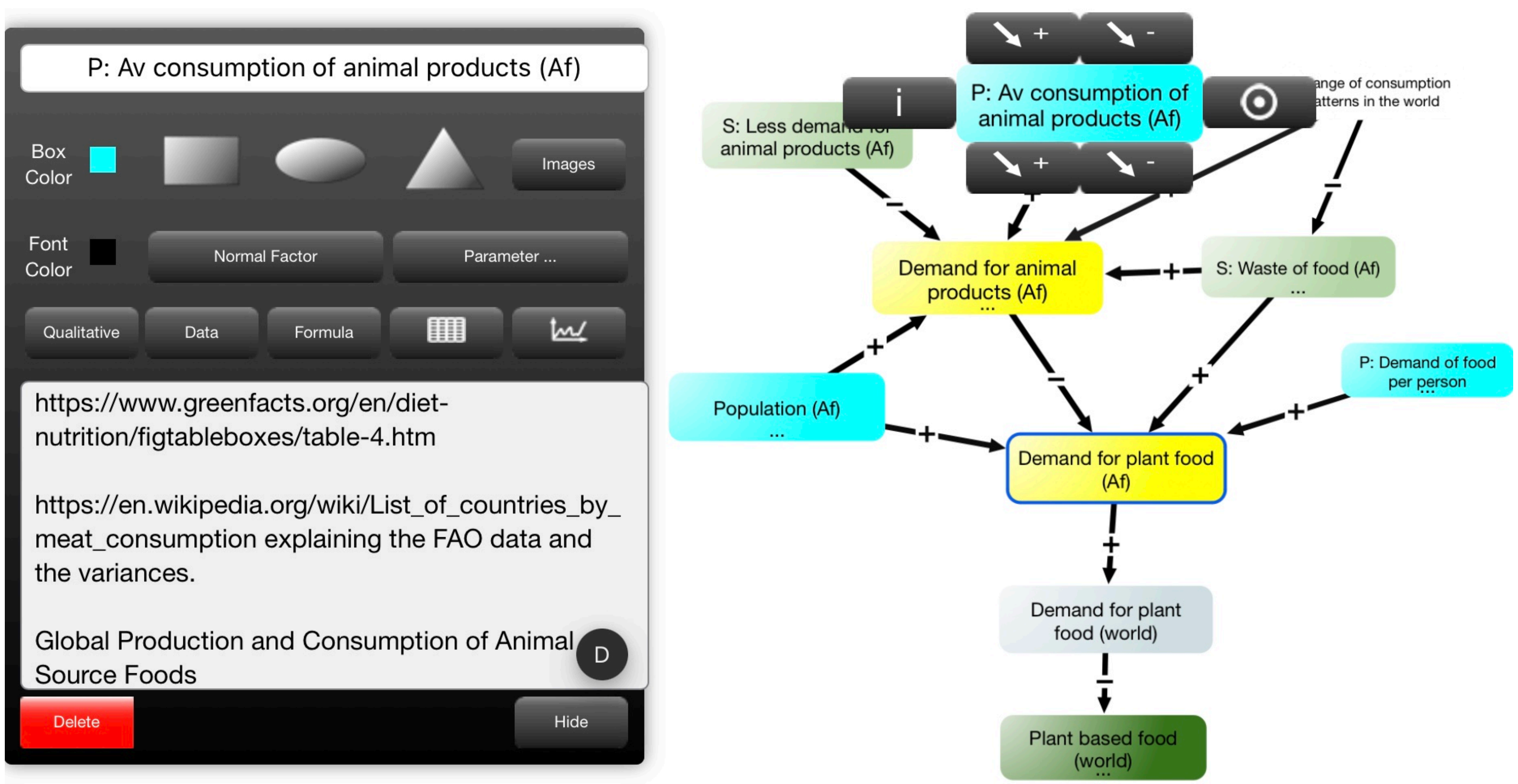
For each region the model looks at the available area for agriculture resulting from the conversions to agricultural area from forests and underutilized areas and the conversions from agricultural area to forests or built area. The area for agriculture is further differentiated into conventional and organic farming practices as well as alternative farming practices like permaculture, terra preta or agroforestry.

The use of the produce from agricultural land starts with the need for fodder production, continues with the amount dedicated for non-food industrial use and as a result leaves the rest for plant based food.

...

The GLU Model looks at the people's diet distinguishing just the amount of animal products as a combination of meat, eggs, milk, and cheese per person starting with the United Nations (UN) Food and Agriculture Organization's (FAO) projections. Food waste described by just one factor per region represents the waste all along the chain from field to the consumer and adds to the demand per person. Since the factor to describe the shift to alternative farming practices summarizes agroforestry, permaculture, terra preta and the use of legumes the model looks just at change from the supply side offering more legumes based products. It doesn't consider a change of diet towards the use of more legumes to change the production by demand from the consumer side. Legumes come with four major benefits: unlike grain they offer the same yield from organic farming practices as from conventional farming practices and they are healthier than the consumption of grain like wheat (see e.g. Harrari's "Sapiens"). Also they enrich the soils and are great for bees (pollinators) as well.

Forests result from the allocation of area and the amount of harvested wood. The wood can either be used as fire wood or for materials. If used for materials there will be an end of life energetic use and the parameter for a life span of material use implies the different applications as well as a possible cascaded use.



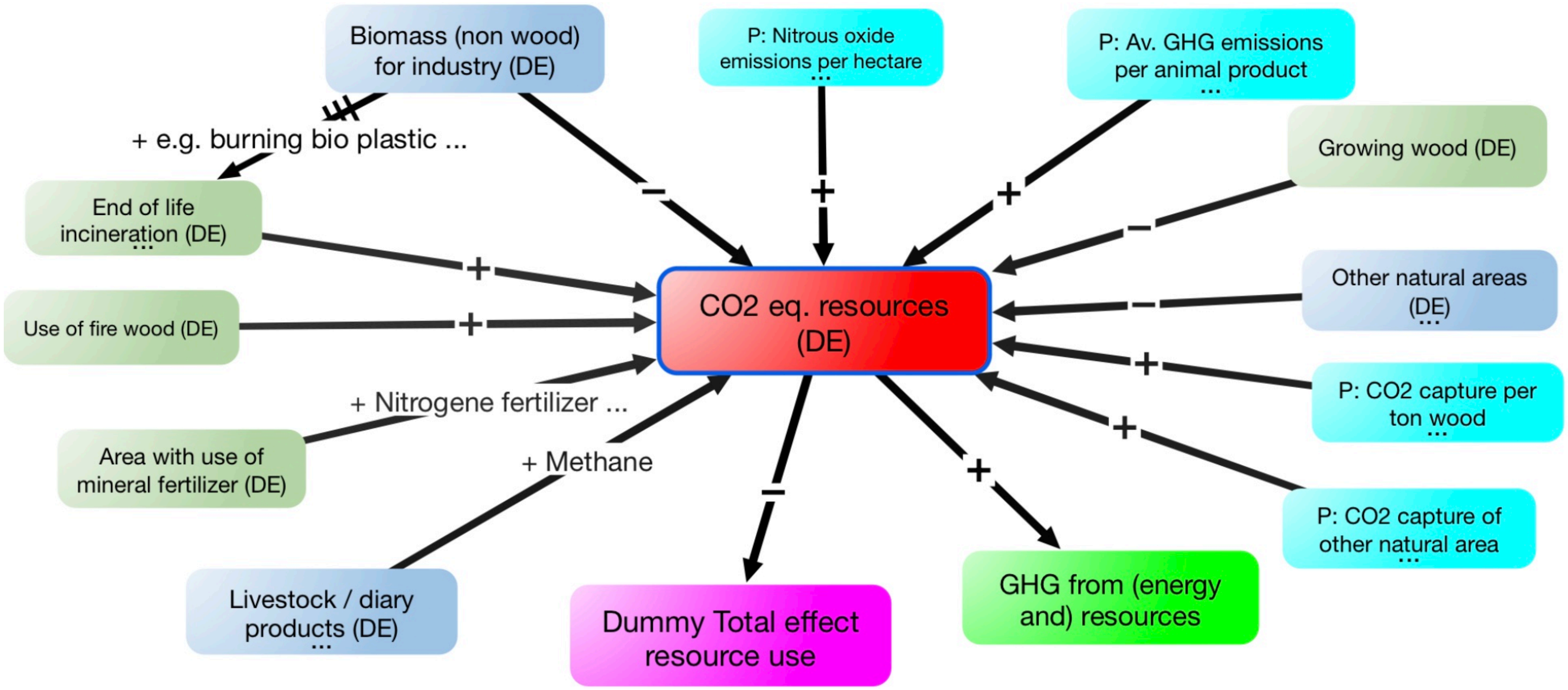
Modeling the demand for food

GHG

The growth of wood minus the energetic use of wood plus the material use as a substitution for greenhouse gas intensive steel and concrete contributes to the total reduction of greenhouse gas in the atmosphere though the effect from material use with the end of life combustion remains relative. The model simplifies the system since it doesn't consider the difference of older forests with physical decomposition of old wood versus the harvesting of mature trees making space for younger trees and their capturing of carbon dioxide (CO_2). The model uses just one parameter for growth of wood per area.

The GLU Model does not try to look endogenously at the choices of production driven by markets and policies. Instead the choices are made by the user of the model and the result is the theoretical surplus or shortage of food in the world.

Next to the potential to feed the world the model looks at the effects from LULUCF (land use and land use change and forestry) on the total of greenhouse gases expressed by carbon dioxide equivalents (CO_{2eq}) also including the methane from cattle or the nitrous oxide from mineral fertilizer for agriculture.



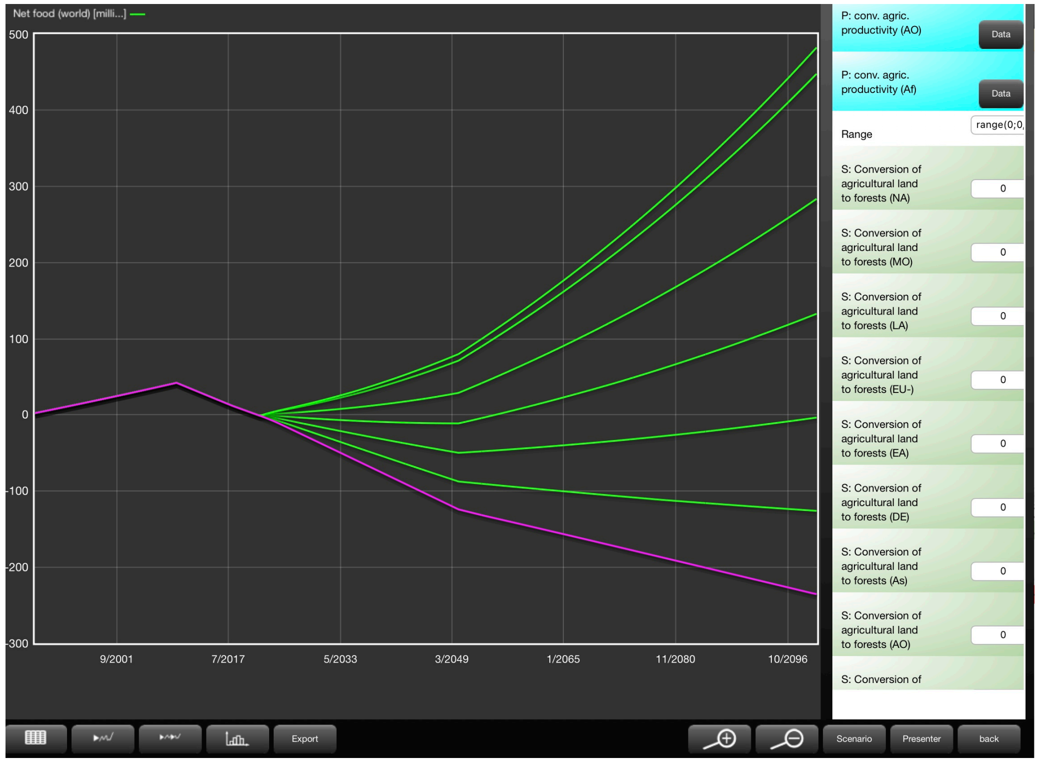
Greenhouse gas emissions from the land use, the livestock, and the burning of biotic resources (including their end-of-live combustion of materials).

Levers

The whole model features about 150 parameters. Here is a list of the parameters that basically can be used to define scenarios. Most of the parameters can be set explicitly for each region. Also, most parameters are not a constant but a time series, e.g. the assumption of a growing proportion of alternative farming practices over time.

- Proportion of alternative farming practices (agroforestry, permaculture, terra preta, legumes etc.
- Amount of harvested wood
- Animal food production
- Cascading use of biotic materials (implying a design for recycling etc.)
- Change of area for buildings and infrastructure
- Conversion of agricultural land to forests
- Conversion of forests for agriculture
- Industrial use of biomass (non wood, e.g. for bioplastics and other chemical products)
- Less demand for animal products (increased proportion of vegan and vegetarian diet)
- Management of bio-waste (manure, wastewater-treatment, etc. to use less mineral fertilizer)
- Percentage of conventional agriculture (the rest would be organic farming practices)
- Proportion of harvested wood that is directly used energetically
- Waste of food (as a percentage along the chain from acre to transport to storage to production to retail to consumer)

For the business as usual scenario the model features time series that describe the continued increase of the proportion of animal products in the diet of people from Asia and Africa and time series that describe the continued conversion of land for infrastructure in all regions, and even a time series that assumes further improvements in yields from the use of fertilizer and optimized crops.



Cockpit with range of scenarios from Monte-Carlo simulation

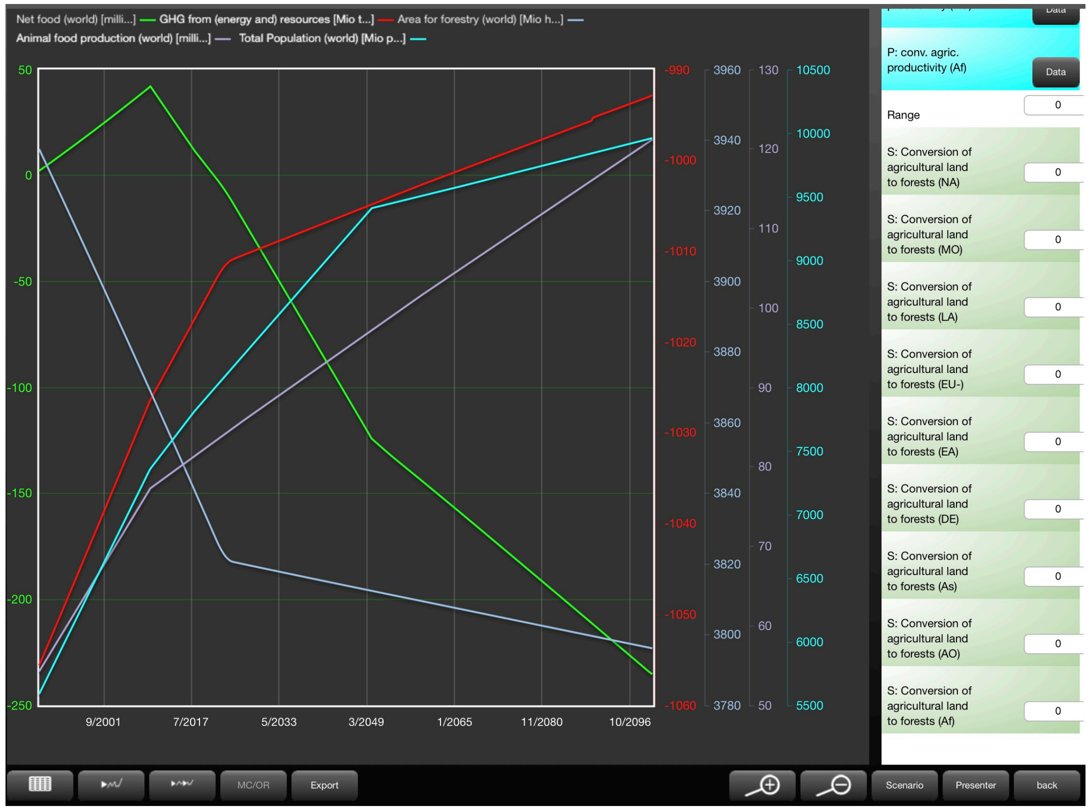
Scenarios

From the seemingly endless number of possible scenarios we describe only three with this paper:

1. a 'business as usual' scenario (b.a.u. scenario) with continued growth in population, further improvements in conventional agriculture (seeds, fertilizer, high precision farming, etc.), further conversion of land for infrastructure, and a continued change in diet in Asia and Africa (more animal products).
2. based on the b.a.u. scenario a 'moderate change for good' scenario regarding food waste, diet (less animal products), afforestation with cascading wood use, and the conversion of parts of underutilized land.
3. based on the 'moderate change for good' scenario a 'consequent shift' scenario towards organic farming combined with change of diet in favor to legumes.

<u>b.a.u. scenario</u>

The b.a.u. scenario basically is the scenario that the economy is heading for. More industrial agriculture with improved seeds, targeted pesticides, use of mineral fertilizer, and the whole prospect of digitized high precision farming on the one hand, and increased demand for processed food including meat and dairy products in all parts of the world on the other hand. With rising demand for fodder there will be growing need for deforestation. Without increased deforestation the simulation of the magnitudes shows (figure of this page) that we face a global shortfall of supply of food (green plot) while the net sink function for greenhouse gases is shrinking (red plot) with the area for forests (blue plot). The turquoise plot shows the development of the global population. This scenario clearly describes that the current trajectory of demand and supply won't work - even without the assumption of major catastrophes from climate change.

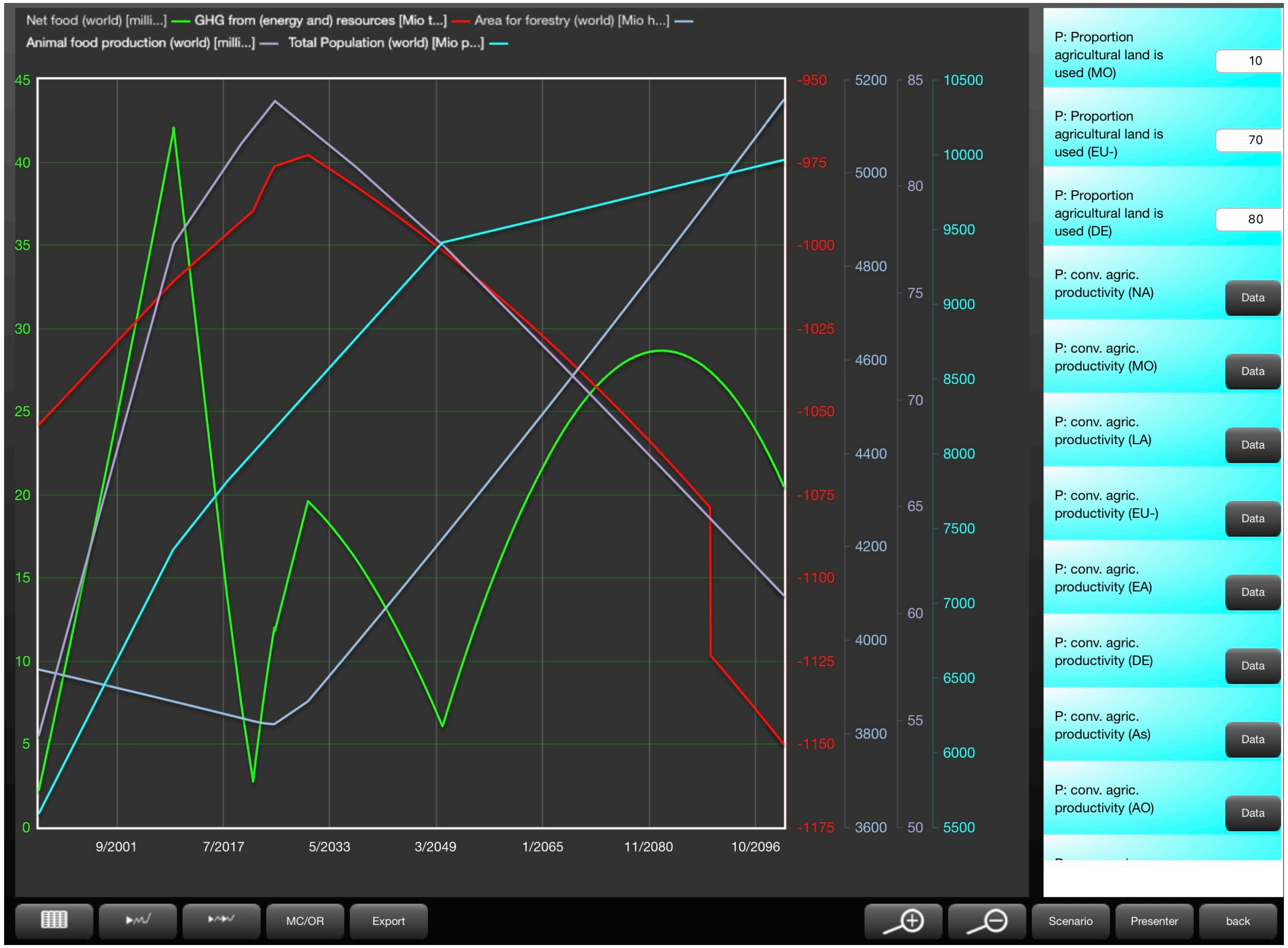


The b.a.u. scenario revealing the upcoming shortage of food in the world (monthly negative values per month - green line)

Scenarios … continued

Different combinations of reduced food waste, less consumption of animal products, more conversion of under- or not utilized potential agricultural area, would lead to scenarios with sufficient surpluses of food for the world's population that would even leave room for afforestation. The 'moderate change for good' scenario assumes that the world decides to eat 50% less animal products, to waste 50% less food and to utilize 50% for the untapped potential for agricultural area.

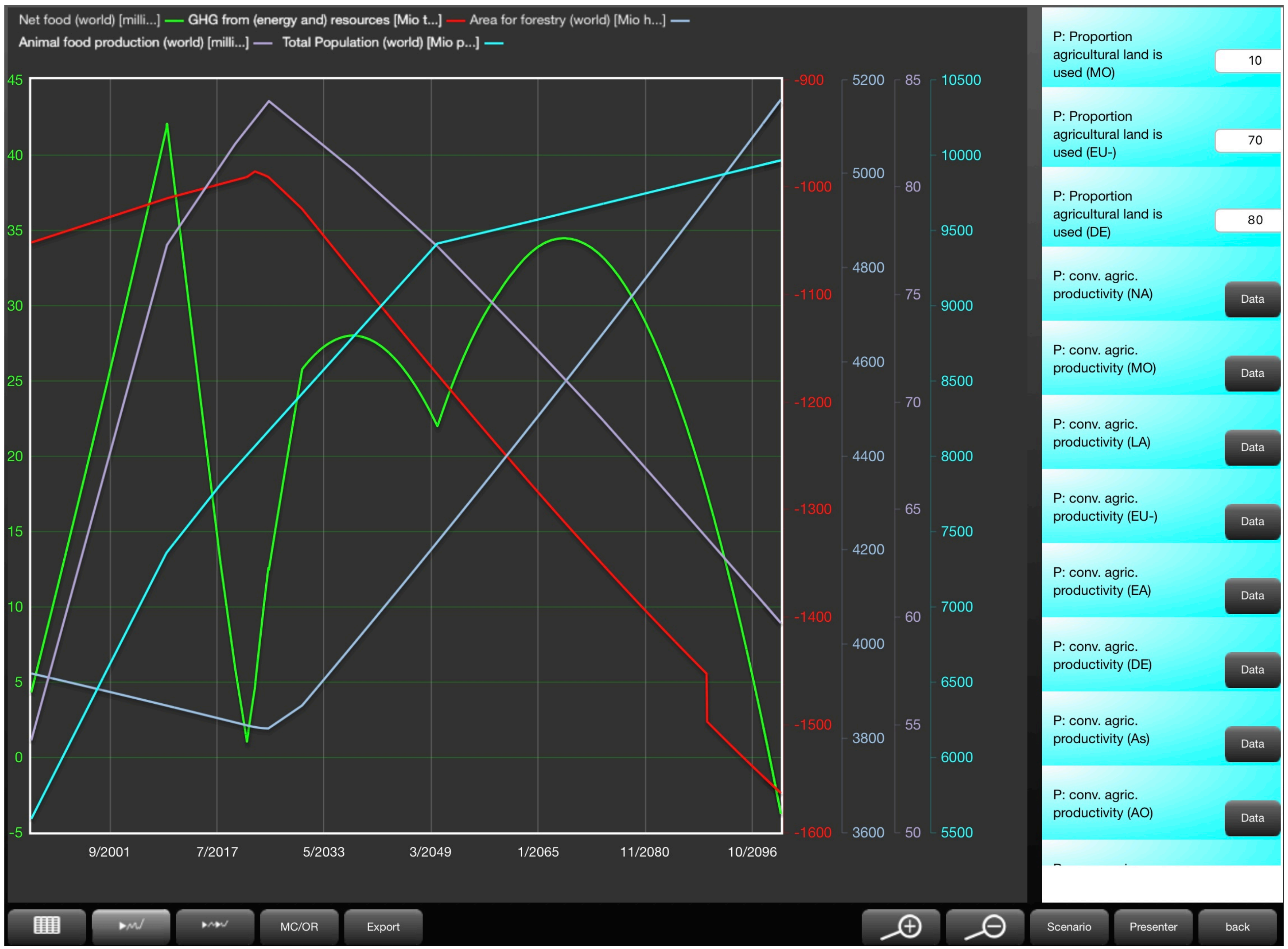
The figure of this page shows how as a consequence the area for forests could be increased and how the net sink function of the system for greenhouse gases could increase. The variances in the green plot for the surplus or shortage of food on the world market are an artifact from the overlapping dynamics from the different regions the GLU-model considers.



If different parts of the world start to change their diet (less animal products), waste of food, use of land, and alternative practices of agriculture….

Consequent shift

The fate of our quality of life on earth not just depends on the supply of food but also on eco system services that come with biodiversity. That's why a lot of people argue for organic food production while the counter argument claims that the productivity of organic agriculture is way lower and thus it would require more deforestation.



If we combine a change of diet (more legumes, less animal products or wheat, maize, or rice) and the other levers with a shift towards organic farming and other resilient farming practices....

The simulations could only confirm that a ceteris paribus diet and variety of crops would require more forest area to be used for agriculture with all the negative implications for greenhouse gases and biodiversity.

However, if we assume a change in diet away from grain like wheat towards healthier legumes that offer high yields without the use of mineral fertilizer and pesticides we could theoretically get to 100 percent organic farming in the world as the figure of this page shows with the 'consequent shift' scenario.

Interpretation

Originally, the GLU-model's purpose was to explore the global potentials to use biotic materials as a substitute for steel and concrete. Realizing, that unlike probably most of us learned at school, feeding the world is not just a matter of distribution - at least not for much longer - inspired us to use the model for further explorations. There have been wheat shortages for some consecutive years due to extreme droughts in Russia and the US, and there is the dramatic loss of biodiversity and the ongoing debate whether we need industrial farming or organic farming - challenges the model helps to understand.

Even without the consideration of prices, patents, and trade barriers the model allows to look at the realistic magnitudes of biotic resources. Of course, there are more levers than just the shift towards more legumes to achieve similar yields from organic farming compared to conventional farming, e.g. more labor intensive permaculture or agroforestry. Organic farming does not just imply less greenhouse gas emissions because of less use of mineral fertilizer, and more biodiversity because of less pesticides. It also has the potential to be more resilient to climate change and if labor intensive it could counter the troublesome mega trend of urbanization without perspective in the so called global south (see our grey paper part 7 on the bio-economy).

The GLU Model also features more details like fish and aquatic cultures that are not mentioned in this paper and yet it is less of a finished work than rather a tool that can be improved by adding more details, updated data, and more elaborated scenarios. Only system dynamics could make these dynamics over time transparent.

So far GLU-model allows to backup three important memes for the public discourse:

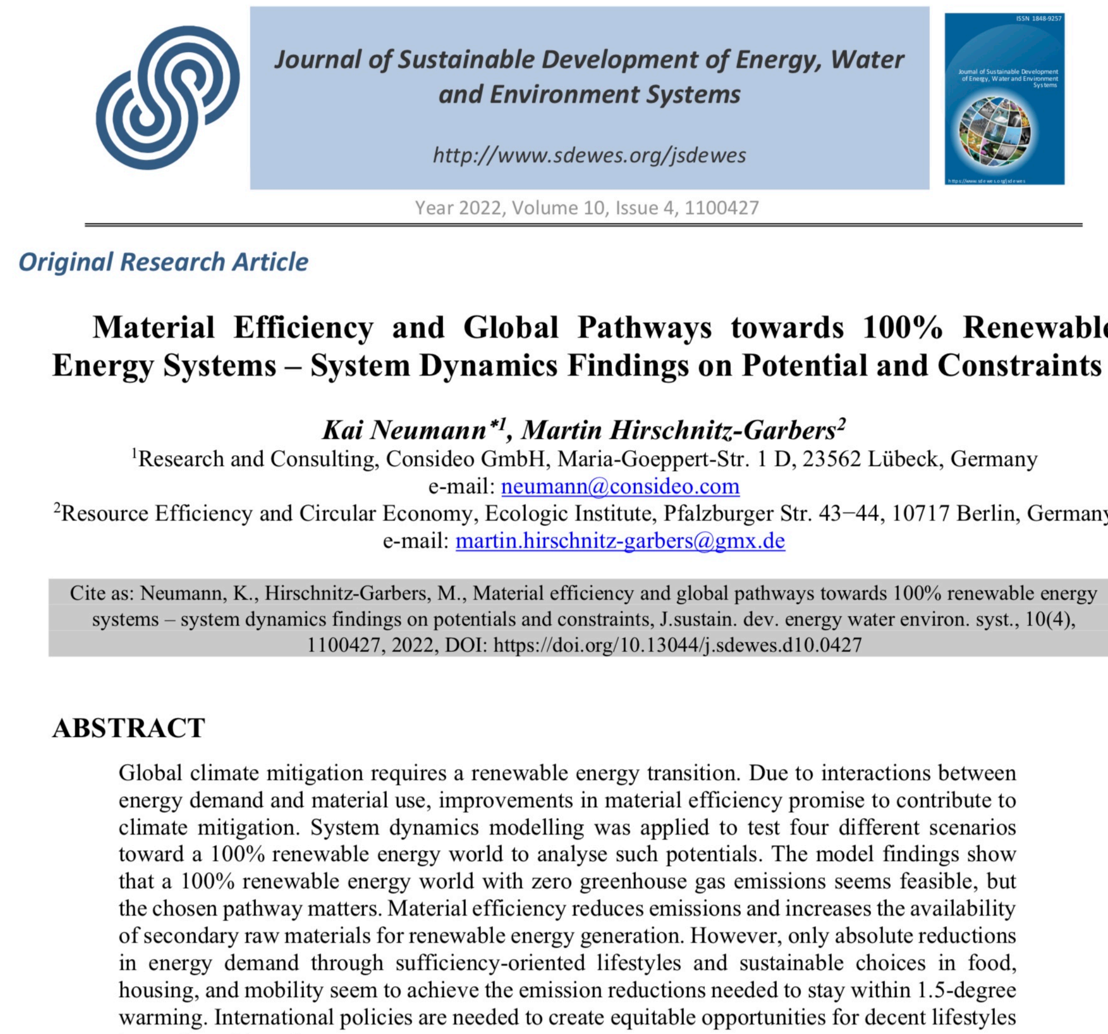
1. On the current trajectory we won't be able to feed the world much longer even if we consider advances in agricultural productivity, neglect the thread from climate change, or consider transforming even more forests into arable land.
2. We would just need to waste less food, eat less animal products, and utilize more agricultural land to even be able to grow more woods.
3. To the extent that we change our diet to more legumes we could feed the world with organic farming with all its benefits for biodiversity, resilience, and reduction of greenhouse gas emissions.

References and link

For the qualitative model and similar models look on KNOW-WHY.NET

A peer reviewed publication:

Neumann, K., Hirschnitz-Garbers, M., Material efficiency and global pathways towards 100% renewable energy systems – system dynamics findings on potentials and constraints, J.sustain. dev. energy water environ. syst., 10(4), 1100427, 2022, doi: https://doi.org/10.13044/j.sdewes.d10.0427


Journal of Sustainable Development of Energy, Water and Environment Systems

http://www.sdewes.org/jsdewes

Year 2022, Volume 10, Issue 4, 1100427

Original Research Article

Material Efficiency and Global Pathways towards 100% Renewable Energy Systems – System Dynamics Findings on Potential and Constraints

Kai Neumann[*1], *Martin Hirschnitz-Garbers*[2]
[1]Research and Consulting, Consideo GmbH, Maria-Goeppert-Str. 1 D, 23562 Lübeck, Germany
e-mail: neumann@consideo.com
[2]Resource Efficiency and Circular Economy, Ecologic Institute, Pfalzburger Str. 43−44, 10717 Berlin, Germany
e-mail: martin.hirschnitz-garbers@gmx.de

Cite as: Neumann, K., Hirschnitz-Garbers, M., Material efficiency and global pathways towards 100% renewable energy systems – system dynamics findings on potentials and constraints, J.sustain. dev. energy water environ. syst., 10(4), 1100427, 2022, DOI: https://doi.org/10.13044/j.sdewes.d10.0427

ABSTRACT

Global climate mitigation requires a renewable energy transition. Due to interactions between energy demand and material use, improvements in material efficiency promise to contribute to climate mitigation. System dynamics modelling was applied to test four different scenarios toward a 100% renewable energy world to analyse such potentials. The model findings show that a 100% renewable energy world with zero greenhouse gas emissions seems feasible, but the chosen pathway matters. Material efficiency reduces emissions and increases the availability of secondary raw materials for renewable energy generation. However, only absolute reductions in energy demand through sufficiency-oriented lifestyles and sustainable choices in food, housing, and mobility seem to achieve the emission reductions needed to stay within 1.5-degree warming. International policies are needed to create equitable opportunities for decent lifestyles

About Consideo

Responsible for the content are the authors (neumann@consideo.com; grimm@consideo.com).

Citation: Neumann, K.; Grimm, F. (2023). The GLU Model - Can we feed the world and survive it? Consideo GmbH, Lübeck
DOI: 10.13140/RG.2.2.28568.16640

Consideo has the vision of a better world. The mission is to help people understand how things are interconnected. We work with the award winning software iMODELER for business, research, politics, and private individuals.

With the platform KNOW-WHY.NET we offer collective connections.

Consideo GmbH
Maria-Goeppert-Str. 1
23562 Lübeck
www.consideo.com