Horizon 2020 Societal challenge 5:
Climate action, environment, resource efficiency and raw materials

Deliverable 7.5

Educational Nexus Game

Contributors:

J.F. Schyns (UT), J. Oprel (UT), B. Holmatov (UT), C.C.A. Verburg (UT), M.S. Krol (UT), A.Y. Hoekstra (UT)

August, 2020

www.magic-nexus.eu

Please cite as:

Schyns, J.F., Oprel, J., Holmatov, B., Verburg, C.C.A., Krol, M.S. & Hoekstra, A.Y. (2020) Educational Nexus Game. MAGIC (H2020–GA 689669) Project Deliverable 7.5.

Date: August 2020

Contents

List of tables

Summary

Consolidation of the United Nations Agenda for Sustainable Development and ambitious directives by the European Commission have put the European Union (EU) up for a challenge: the EU needs to reconcile its food and energy security goals with goals of climate adaptation and sustainable and efficient use of water and land resources. Tackling this challenge requires that measures are taken in several sectors or policy domains (food, energy, climate, water, land). However, measures taken in one domain have implications across other domains. These interlinkages in the so-called “nexus” complicate the development of coherent and effective policy.

To get a better grasp on the complexity of policy development in the nexus domain, we have designed a game with an educational character. The target audience is educated laymen with an interest in policy development in the domain of the water-land-carbon-food-energy nexus, such as the EU and national policy makers as well as MSc and BSc level students. The purpose of the game is to experience the challenges and solutions for member states – as part of a larger economic block – to achieve food and energy security within safe environmental boundaries. The game conveys the main trade-offs and synergies in the nexus using a quantitative framework of relations between the nexus elements based on environmental footprint indicators. This framework is made accessible to players by means of an interactive dashboard, which they can use to explore the effects of choices regarding the consumption and production of food and energy, on the food & energy dependency of the EU as well as carbon, land and water footprints.

The game is available in single player and multiplayer variants. The single player version offers an individual online learning experience at two different levels of complexity. The multiplayer version enables collaborative learning and requires a minimum of four players and one facilitator, preferably all present in one venue.

This report describes the rationale behind the game design and the technical implementation of the framework behind the interactive dashboard. The report is meant for individuals who want to facilitate the game or who have played the game and want to further deepen their understanding of the game and its learning objectives. This report is not meant for individuals who aim to participate in the game, because it contains information that will weaken their learning experience.

Acknowledgements

We have developed an educational nexus game that has been titled “MAGIC Nexus Game”.

The game including instructions for players and facilitators, and the computational framework behind the interactive dashboard of the game, have been developed at University of Twente, the Netherlands, by the authors of this report.

The interactive dashboard of the game has been translated to a web appliction by the Statistics Technology and Analysis of Data group at University of Naples Federico II, Italy, with executive contributions by Eligesoft and advisory contributions by University of Twente.

We thank the teams at University of Naples Federico II and Eligesoft for the effective collaboration. We also thank all people at University of Twente and Universitat Autònoma de Barcelona who have been involved in testing previous versions of the game.

1. Introduction

1.1. The context

Consolidation of the United Nations Agenda for Sustainable Development and ambitious directives by the European Commission have put the European Union (EU) up for a challenge: the EU needs to reconcile its food and energy security goals with goals of climate adaptation and sustainable and efficient use of water and land resources. The main challenge here arises from the two main reasons. First, measures will be required that ask for a change of current practices by the EU consumers and producers. The focus and impact of these measures vary from place to place, since member states (MS) vary widely in current practices and natural resource endowments. Yet, cooperation between the MS is essential to achieve targets of the EU as a whole. Second, measures taken in the several sectors or policy domains (food, energy, climate, water, land) have implications across other domains. These interlinkages in the so-called "nexus" complicate the development of coherent and effective policy (Carmona-Moreno et al., 2018; Giampietro, 2018).

1.2. The game

To get a better grasp on the complexity of policy development in the nexus domain, we have designed a game with an educational character. The target audience is educated laymen with an interest in policy development in the domain of the water-land-carbon-food-energy nexus, such as the EU and national policy makers as well as MSc and BSc level students. The purpose of the game is to experience the challenges and solutions for MS – as part of a larger economic block – to achieve food and energy security within safe environmental boundaries. The game conveys the main trade-offs and synergies in the nexus using a quantitative framework of relations between the nexus elements based on environmental footprint indicators (see Box 1). This framework is made accessible to players by means on an interactive dashboard, which they can use to explore the effects of choices regarding the consumption and production of food and energy, on the food & energy dependency of the EU as well as carbon, land and water footprints. The framework is a hugely simplified representation of the real world and should therefore not be used as a tool to inform decision making outside the context of this serious game. The game is available in single player and multiplayer variants. The single player version offers an individual online learning experience at two different levels of complexity. The multiplayer version enables collaborative learning and requires a minimum of four players and one facilitator, preferably all present in one venue. The game is available online:

On the MAGIC-Nexus Knowlegde Hub: https://magic-nexus.eu/magic-nexus-game

Direct link to web application: https://game.magic-nexus.eu/

Box 1. The environmental footprint concept explained.

The environmental footprint (EF) can be expressed for several entities, such as a product, a group of consumers or a certain geographic area (Hoekstra and Wiedman, 2014). The EF of a product refers to the resource appropriation (water and land) or emissions (carbon) per unit of product produced (e.g. kilocalorie of food or a gigajoule of energy). The EF of a group of consumers (e.g. EU citizens) relates to the resource use and emissions associated with all goods and services (e.g. food and energy) consumed by this group, which can also be expressed per unit of product consumed. In short, this is referred to as the EF *of consumption*. The EF *of production* within a certain geographic area (e.g. the entire EU, or a single MS) relates to the resource use and emissions associated with all goods and services produced within the borders of that area. Note that the EF of consumption can be partially outside the area in which the group of consumers resides, i.e., the EF is externalized. Also note that the EF of production may partially be related to good and services produced for export, i.e., not intended for final use by consumers in the same area.

1.3. About this report

This report describes the rationale behind the game design (Chapter 2) and the technical implementation of the framework behind the interactive dashboard (Chapter 3). The annexes to this report include the player (Annex I) and facilitator (Annex II) instructions. This report is meant for individuals who want to facilitate the game or who have played the game and want to further deepen their understanding of the game and its learning objectives. This report is not meant for individuals who aim to participate in the game, because it contains information that will weaken their learning experience. Game participants should turn to the player instructions in Annex I.

2. Game design

Here we report on the choices made in the game design, specifically addressing the setting & scope (2.1), the purpose & learning objectives (2.2) and the gameplay of the three game versions (2.3). The game has been designed with two main principles in mind (Lepper and Cordova, 1992):

- The learning task should be set in the context of a story, to increase intrinsic motivation, which in many cases leads to increased learning as well.
- Learning should be an integral part of winning the game, because if people can win a game in a rapid way without learning, they are likely to do so.

2.1. Setting & scope

The EU needs to secure its future food and energy supply while keeping environmental impacts within safe boundaries: reduce carbon emissions while staying within the sustainable limits to land and water use. Reconciling the policy targets on food and energy security, sustainable and efficient resource use, and climate adaptation is a major challenge due to the many feedbacks in terms of the water-land-carbon-food-energy nexus. Tackling this challenge requires changes in the current food and energy production and consumption patterns. Moreover, many of the related choices are not made at the EU level, but at the level of individual member states (MS). Natural resource endowments, consumption habits, and production practices vary widely among the MS. As a consequence each of the MS need to focus on taking different measures, and inter-regional cooperation between the MS is essential to achieve the goals of the economic block.

This setting and scope is quantitatively reflected in the game by means of indicators reflecting the state of food and energy security, and environmental footprint indicators reflecting pressure on the environment. The game includes carbon, land, green water (rainwater) and blue water (surface water and groundwater) footprints. There are physical and sustainable limits to the size of land and water footprint. Physical limits refer to all of the resource available in a MS. Sustainable limits are set as a fraction of the physical limit, reserving part of the resource for biodiversity protection.

2.2. Purpose & learning objectives

The purpose of the game is to experience the challenges and solutions for MS – as part of a larger economic block – to achieve food and energy security within the safe environmental boundaries.

The EU is schematized into four regions based on the degree of land and water scarcity and the resource-intensity of consumption patterns, in such a way that they face different challenges and have different learning points (Table 1). There are also universal learning points for all regions:

+ Less meat (& dairy in second instance) and less food waste reduces the LF & WF of consumption.

+ Energy use reduction is always a good starting point to lower the CF.

+ Switching from fossil to renewable sources of energy lowers the CF of consumption, but choosing biofuels increases the LF & WF and choosing hydropower increases the WF.

Table 1. Learning objectives for each of the four EU regions in the game.

Region A – Relatively high water availability per capita[a] & densely populated[b] (average meat & fish) *Austria, Croatia, Greece, Ireland, Netherlands, Portugal, Slovakia, Slovenia*	**Region B – Relatively high water availability per capita[a] & sparsely populated[b] (average meat & fish)** *Bulgaria, Estonia, Finland, Hungary, Latvia, Lithuania, Sweden*
Learning points (do's & don'ts): + Challenge: reduce LF & CF + More food import reduces land scarcity + Increasing crop yields reduces LF and thus land scarcity - Irrigation measures & mulching make little difference - Increasing biofuels increases LF to unacceptable levels	Learning points (do's & don'ts): + Challenge: reduce CF + Increasing crop yields reduces LF, but land scarcity is not a concern - More food import makes little sense - Irrigation measures & mulching make little difference - Increasing biofuels increases LF but seems no problem, although producing export food is better?
Region C – Relatively low water availability per capita[a] & densely populated[b] (high meat & fish) *Belgium, Cyprus, Czech Republic, Germany, Italy, Luxembourg, Malta, United Kingdom*	**Region D – Relatively low water availability per capita[a] & sparsely populated[b] (high meat & fish)** *Denmark, France, Poland, Romania, Spain*
Learning points (do's & don'ts): + Challenge: reduce all three footprints! + More food import reduces water and land scarcity + Increasing crop yields reduces LF and thus land scarcity + Deficit & drip irrigation & mulching reduces WF of production & consumption - Increasing biofuels increases LF & WF to unacceptable levels	Learning points (do's & don'ts): + Challenge: reduce WF & CF + More food import reduces water scarcity + Increasing crop yields reduces LF, but land scarcity is not a concern + Deficit & drip irrigation & mulching reduces WF of production & consumption - Increasing biofuels increases WF to unacceptable levels

[a] Renewable freshwater resources (m^3/cap/year) from EUROSTAT (2019a): high: >5000; low: <5000.

[b] Arable land (m^2/cap) from World Bank (2020): sparsely populated: <0.25; densely populated: >0.25.

2.3. Game versions

Three versions of the game can be played:

- **Single Player Level 1** focuses on the challenges within an individual MS to achieve environmental sustainability by changing the consumption habits and the production practices. The player controls one EU region, and there is no trade in food and energy. This version is recommended for anyone with limited experience regarding the water-land-carbon-food-energy nexus.
- **Single Player Level 2** focuses on the challenge to achieve food and energy security for the EU as a whole, while also achieving sustainability targets in each of the MS (i.e. corresponding to one of the four EU region's in the game). The player controls all four EU regions and has full flexibility in changing practices and closing trade agreements. This version is recommended for anyone with more experience regarding the water-land-carbon-food-energy nexus, and people who have mastered Single Player Level 1. This version of the game ends with a multiple choice test that serves as a multiplier for the final score. This

encourages the player to make informed choices and understand their effects (as evaluated in the test), because the score can be nullified if the test is made unsuccessfully. After finishing the test, the player receives explanation for wrong answers (Box 2).

- **Multiplayer** focuses on the cooperation and policy alignment between the MS to attain the EU level targets. This version requires a facilitator and a minimum of four players: each controlling one of the EU regions in the game. Players do not earn any points when EU targets for food & energy security and carbon emissions are not achieved. This forces players to cooperate and make intra-EU trade agreements, because if they do not, they all lose. When these pre-conditions have been met, every player can earn points for its MS by reducing the land and water footprints of production (within the MS) below sustainable limits. Thus, each player has a stake to minimize the land and water footprints within its MS, and therefore needs to reduce its footprint of consumption or externalize its footprint to other MS (to meet the pre-condition of security at the EU level). This creates a tension field in the negotiations among players.

Version specific gameplay, player roles, objectives and score-taking are described in full in Annex I.

Box 2. Multiple choice test with key messages to the President of the European Commission. Correct answers in green. Wrong answers in red with explanation in brackets.

Select the three correct key messages:

(a) Applying deficit & drip irrigation & mulching reduces the water footprint significantly [no, not if you have very little irrigated area]
(b) Less meat (& dairy in second instance) and less food waste reduce the land & water footprint of consumption
(c) Choosing biofuels increases the land and water footprint
(d) All EU regions can attain self-sufficiency in food and energy supply, trade is not necessary. [no, it depends on consumption levels, but regions low in (both) water and land availability will have a hard time to achieve this]
(e) Whatever electricity mix we have, electrification of the transport sector helps to reduce the carbon footprint a lot [no, not if fossil energy is used to generate electricity]
(f) Switching from fossil to renewable energy has two positive effects: it reduces both the carbon and the water footprint [no not if you switch to biofuels and hydropower]
(g) Switching from fossil to renewable energy has two positive effects: it reduces the carbon footprint & it increases energy security of the EU
(h) Saving energy barely reduces the footprints of consumptions [no, saving energy always good starting point to reduce the (carbon) footprint]

3. Technical implementation of the interactive dashboard

The game makes use of an interactive dashboard that allows the players to experiment with choices regarding the production and consumption of food & energy, and to see the effects of these choices in terms of environmental sustainability, food & energy security and desirability. The players can make choices regarding food consumption (e.g. diet, intake, food waste), energy consumption (e.g. saving energy, switching away from the use of gas and gasoline), agricultural productivity (e.g. water-saving practices), energy production technology (e.g. share of renewables in the energy mix) and import and export of food and energy. All specific choices are explained the player instructions (Annex I). This set of choices is the result of internal discussions and literature (De Olde et al. 2018; Di Felice et al., 2018; Krol et al., 2018; Matthews et al., 2018; Holmatov et al., 2019; Holmatov & Hoekstra, 2020; Vargas-Farías et al., 2020;) about what are the main questions in society that play a role in the domain of the water-land-carbon-food-energy nexus.

In the following sections, we describe the technical implementation of choices and their effects (sections 3.1 to 3.6), EU-level targets for food & energy security and carbon footprint reduction (section 3.7) and region-level limits to land and water footprints (section 3.8). Generally, input data per region are derived by averaging statistical data from the MS within a region (Table 1, section 2.2). In some cases the data was subsequently abstracted to create challenges in the game and emphasize differences between the regions. The goal was to create an interesting educational game, which roots in real data. We re-iterate the interactive dashboard and the quantitative framework behind it is a hugely simplified model of reality which should not be used for analysis beyond the scope of this game.

3.1. Food consumption

The players' choices regarding food consumption are converted into a per capita consumption (in kcal/cap/year) of the three food categories (plant-based products, dairy and eggs, and meat & fish). The amount of calories consumed (per capita per day) and the percentage of food waste, are user inputs. The total supply per capita is calculated as:

$$Supply = Consumption \times (1 + waste)$$

The supply is built up from different food categories. The consumption pattern of the three diets is shown in Table 2. The flexitarian diet (x days per week meat) is a linear combination of the reference- and vegetarian diet in the table:

$$f_{flex} = \frac{x}{7} f_{ref} + \frac{(7-x)}{7} f_{vega}$$

Where f denotes the fraction of a certain food category in the specified diet.

Table 2. Consumption patterns of the three diets. The consumption values for the reference diet differ in different regions, this is indicated by the superscripts.

	Reference diet	**Vegetarian**	**Vegan**
Plant-based	70%^{AB} / 65%^{CD}	85%	100%
Dairy and eggs	15%	15%	0%
Meat and fish	15%^{AB} / 20%^{CD}	0%	0%

The fraction that a food category has in the average diet is calculated by multiplying the f-fractions with the diet fractions, denoted by d (user input):

$$F = f_{flex} \times d_{flex} + f_{vega} \times d_{flex} + f_{vegan} \times d_{vegan}$$

The value *F* is calculated for each food category. The total supply in a category is calculated by multiplying the total supply with the F-fraction of the category.

3.2. Food production

The footprint of production for a certain food category can be influenced by the player by applying efficiency measures on rainfed and/or irrigated land. The footprint of production of a certain food type is based on an initial footprint FP_0. These footprints are shown in Table 3.

Green and blue water footprints of plant-based food are derived from country- and crop product-specific water footprint estimates from Mekonnen and Hoekstra (2010). Based on Hoekstra (2020; Table 6.2) we assumed that water footprints (in liter/kcal) of dairy & eggs and meat & fish are 2.5 and 5 times larger than for plant-based products, respectively.

Land footprints of food products have been taken from Poore & Nemecek (2018) (mean values). This dataset covers millions of diverse producers worldwide, but does not provide country- or region-specific data. Therefore, some assumptions were made. For plant-based products we assumed the densely-populated (A, C) to have double the output per unit of land compared to the sparsely populated regions (B, D). Still, we assumed the EU regions B and D to be slightly more productive than the world-average. For animal products, first, we assumed that the densely-populated regions A and C are 20% more productive (i.e. more output per unit of land) than the sparsely populated regions B and D. Second, we assumed that all EU regions A-D are roughly twice as productive compared to the world-average productivity (with a wide range) reported by Poore & Nemecek (2018). Carbon footprint values were also taken from Poore & Nemecek (2018) (mean values).

Table 3. Initial footprints to produce different food categories.

	Region A				Region B			
Units/kcal	**WF green (L/kcal)**	**WF blue (L/kcal)**	**LF (m2/kcal)**	**CF (kg CO2eq /kcal)**	**WF green (L/kcal)**	**WF blue (L/kcal)**	**LF (m2/kcal)**	**CF (kg CO2eq /kcal)**
Plant-based products	0.61	0.15	0.0005	0.0008	0.73	0.18	0.001	0.0008
Meat & Fish	3.61	0.19	0.014	0.0129	4.35	0.23	0.02	0.0129
Diary & eggs	1.71	0.19	0.007	0.0064	2.06	0.23	0.01	0.0064

	Region C				Region D			
Units/kcal	**WF green (L/kcal)**	**WF blue (L/kcal)**	**LF (m2/kcal)**	**CF (kg CO2eq /kcal)**	**WF green (L/kcal)**	**WF blue (L/kcal)**	**LF (m2/kcal)**	**CF (kg CO2eq /kcal)**
Plant-based products	0.32	0.08	0.0005	0.0008	0.44	0.11	0.001	0.0008
Meat & Fish	1.9	0.1	0.0140	0.0129	2.61	0.14	0.014	0.0129
Diary & eggs	0.9	0.1	0.007	0.0064	1.24	0.14	0.007	0.0064

	World average			
Units/kcal	**WF green (L/kcal)**	**WF blue (L/kcal)**	**LF (m2/kcal)**	**CF (kg CO2eq /kcal)**
Plant-based products	0.58	0.14	0.0011	0.0008
Meat & Fish	3.42	0.18	0.0344	0.0129
Diary & eggs	1.30	0.14	0.0172	0.0064

The influence of certain measures on the footprints is expressed as a relative increase or decrease with respect to the initial footprints. In Table 4, these relative changes depict the situation when a measure is applied to 100% of the land in a category (rainfed or irrigated). It is assumed that these changes apply to each food category.

Table 4. Relative effect of efficiency measures on the footprints. Effect of yield gap closure based on data from the Global Yield Gap and Water Productivity Atlas (2020). Other effects are based on Chukalla et al. (2015).

Land	**Measure**	**CF**	**LF**	**WFg**	**WFb**
Rainfed	Yield gap closure	0%	-17%	-17%	0%
	Organic mulching	0%	-25%	-25%	0%
Irrigated	Deficit irrigation	0%	+10%	+8%	-15%
	Deficit irrigation + organic mulching	0%	+10%	-2%	-30%
	Deficit irrigation + organic mulching + drip technology	0%	+2%	-5%	-35%

The actual relative change depends on the percentage of land on which the measure is applied (user input). The actual change is the relative change multiplied with the fraction of land applied.

$$\frac{\Delta FP}{FP_0} = Rainfed \times \sum \left(\frac{\Delta FP_{max\,Meas}}{FP_0} \times f_{meas\,applied} \right) \times f_{meas\,applied} + Irrigated \times \frac{\Delta FP_{max\,Meas}}{FP_0}$$

Where $\frac{\Delta FP_{max\,Meas}}{FP}$ is the relative change of the footprint when a certain measure is applied on 100% of the rainfed/irrigated land, $f_{meas\,applied}$ is the fraction of land on which this measure is applied, and $Rainfed$ and $Irrigated$ are the fractions of land which are rainfed and irrigated. Note that only one measure at a time can be applied on irrigated land, therefore there is no sum in the irrigated term. The rainfed/irrigated fractions differs for different regions and are shown in Table 5.

The footprint per kcal after measures applied to agricultural land is calculated as:

$$FP = FP_0 + \frac{\Delta FP}{FP_0} FP_0$$

Table 5. Rainfed and irrigated agricultural land in the 4 regions. Source: EUROSTAT (2019b).

% of total agricultural land	Irrigated	Rainfed
Region A	16%	84%
Region B	4%	96%
Region C	11%	89%
Region D	9%	91%

3.3. Food trade

The total footprint of food production is influenced by the mix of food that is actually produced. As values are expressed in per capita values, the demanded import per capita (of the importing region) is not the same as the export per capita (of the exporting region). If region X imports $k_{import,\ Y \to X}$ kcal/cap/day from region Y, then $k_{export,Y \to X}$ can be calculated by multiplying with the inhabitants ratio:

$$k_{export,Y \to X} = \frac{c_X}{c_Y} k_{import,Y \to X} = \frac{c_X}{c_Y} \times S_X \times i_X$$

Where c_X is the number of inhabitants of region X. $k_{import,Y \to X}$can also be written $S_X \times i_X$ the supply in region X times the import fraction i_X.

The total quantity of food produced in a food category is calculated by adding the locally produced consumption and the exports:

$$Production_Y = S_Y \times (1 - i_Y) + \sum_{x=A}^{D} k_{export,Y \to x}$$

The total footprint is found by multiplying the footprint per kcal with the production per capita per day:

$$FP_{prod,Y} = Production_Y \times FP_Y$$

The footprint of consumption does not only depend on the footprint of food production on the region itself, but also on the regions from which food is imported. The total footprint of consumption is:

$$FP_{cons,Y} = S_Y \times (1 - i_Y) \times FP_Y + S_Y \times i_Y \times FP_X$$

Where FP_X is the footprint per kcal produced in country X. The total footprint of food consumption is the sum of all footprints of consumption for the different food categories.

3.4. Energy consumption

The player has seven choices that shape the total energy consumption for the three energy categories distinguished in this game: fossil (*F)*, electricity (*E*) and biofuels (*B*). The choices affect the initial energy consumption ($C_0 = F_0 + E_0 + B_0$; EUROSTAT (2020b)) and the energy mix in the different sectors:

- Choices 1-4 relate to reduction in energy consumption four sectors: industry (r_{ind}), transport (r_{trans}), services (r_{serv}) and households (r_{house}).
- The electrification of the transport sector e. This directly determines the percentage of electricity that is used, but also the energy consumption is reduced (by a factor ~3.3), because electricity is more efficiently transformed into motion than regular fuels: 0.7 MJ/km for an electric vehicle vs. 2.3 MJ/km for gasoline (Holmatov & Hoekstra, 2020).
- The reduction of gas and coal usage in households (g) decreases fossil/biofuel consumption while increasing the electricity use. The total consumption is assumed to remain the same.
- The fraction of biofuels b applies to all four sectors and changes the fraction fossil/biofuel such that $b = \frac{B}{F+B}$ in all sectors.

Here we give an example for the transport sector (as this sector is the most complex). The total consumption on the transport sector is:

$$C = C_0 \times (1 - r_{trans}) \times (1 - 0.7e)$$

The consumption is split into the three energy types:

$$E = C \times e \qquad B = C \times b \qquad F = C \times (1 - b)(1 - e)$$

3.5. Energy production

The user can adjust the electricity mix. The initial mix has been obtained from IEA (2020). The footprint of all electricity production is the same in each region and the values are shown in Table 6.

Table 6. Footprints to produce different energy types (equal in each region).

		WF green[a] (L/GJ)	WF blue[a] (L/GJ)	LF[b] (m2/GJ)	CF[c] (kg CO2eq/GJ)
Electricity	Wind	0	1.3	0.194	6.1
	Solar	0	140	2.417	28.2
	Hydro	0	9114	0.972	3.1
	Bioelectricity	90000	10000	125	19.2
	Nuclear	0	567	0.278	5.3
	Fossil	0	388	0.028	219.1
Fossil fuels		0	97	0.0	54.8
Biofuels		24300	2700	33.8	5.2

[a] Source: Vanham et al. (2019); Schyns & Vanham (2019)

[b] Source: Fritsche et al. (2017)

[c] Source: Turconi et al. (2013)

The total footprint of production depends again on the exports of a region, where the calculation is equivalent to the food footprints of production. Note that the electricity mix of the producing region is applied, so the electricity mix of the importing country does not play a role.

In the energy footprint of consumption, again the calculation is analogue to the food footprint of consumption where again the electricity mix of the exporting country plays a role. As the footprints do not differ between countries here, this is the only factor that changes the footprint of consumption when a country switches to import.

3.6. Desirability

Not all choices are evenly easy to implement due to societal resistance or costs. Therefore each choice comes with a desirability penalty in the game (details in Annex I: section 5.4). The purpose of these penalties is to have the players think twice about the potential consequences of their choices, which are alluded to in the players' instructions where choices are explained. The quantitative values have been set such that changes in diets are 'penalized' more than other choices. Further, the values have no physical meaning and are quite arbitrary.

3.7. EU-level targets for food & energy security and carbon footprint reduction

The both food and energy security are expressed as follows:

$$Security = 1 - \frac{Import}{Total\ consumption}$$

The security depends on the import policy of different regions. The players can specify a fraction of the total consumption that they want to import, and a region from which it is imported.

The initial values for import are based upon trade data from FAOSTAT (2020) (for food) and IEA (2020) (for energy). The initial import (%) value is:

$$Import_{initial}\ (\%) = \frac{\max[import - export, 0]}{supply}$$

Where the numerator is the net import reported for a region.

In the initial situation we assume that all food imports come from outside the EU, resulting in a food security ratio of 92% for the EU. This roughly reflects the, more complicated, actual food security situation of the EU, which is more complicated: food imports from extra-EU slightly exceed export from the EU to non-EU countries (which is not considered in the game) (EUROSTAT, 2020a).

Also all energy imports are assumed to come from outside the EU in the initial situation, resulting in an energy security ratio of 52% for the EU. This is close to the actual energy security of the EU in 2017; 55% (EUROSTAT, 2020c).

Concrete quantitative targets of the EU for food and energy security are not available. We have set these targets to 95% for food and 70% for energy to create a significant challenge in the game.

Note that, for the sake of simplicity, we express, compare and add energy output from different sources all in MJ. We acknowledge this is a simplification, since there are qualitative differences among different energy forms, e.g. a joule of electricity has more “value” than a joule of coal (Giampietro & Sorman, 2012).

3.8. Region-level limits to land and water footprints

The regions differ in land and water availability, and differences in population size make that regions have different weights in the EU-average footprints per capita (Table 7).

Table 7. Key characteristics of the regions.

	Region A	Region B	Region C	Region D
Inhabitants[a] (mln)	63.7	38.6	234.1	177.1
Land physical limit[a] (m^2/cap)	10.4	72.1	8.2	17.9
Land sustainable limit[b] (m^2/cap)	21.4	21.9	14.1	29.9
Green water physical limit[c] (L/cap/y)	8 834	32 746	5 923	12 947
Blue water physical limit[d] (L/cap/y)	5 710	12 749	873	1 146

[a] Sum of cropland, grassland, bareland, woodland and scrubland. Source: EUROSTAT (2020d).

[b] Sum of cropland, grassland and bareland. Source: EUROSTAT (2020d).

[c] Initial data: Actual evaporation from Eurostat. Adjusted to emphasize differences between countries. Sustainable limit set at 40% of the physical limit (loosely based on data from Schyns et al. (2019) for the EU28).

[d] Initial data: Internal flow from Eurostat. Adjusted to emphasize differences between countries. Sustainable limit set at 30% of the physical limit (loosely based on the variable monthly flow method (Pastor et al., 2014) which sets apart environmental flow requirements based on high, intermediate, and low flow regimes, at which between 30% and 60% of runoff is allocated to the environment).

4. Final remarks

The game is available online:

On the MAGIC-Nexus Knowlegde Hub: https://magic-nexus.eu/magic-nexus-game

Direct link to web application: https://game.magic-nexus.eu/

We hope this serious game will help players understand – in an enjoyable way – the complexity of policy making in the water-land-carbon-food-energy nexus domain, while conveying the main trade-offs and synergies that exist in the nexus.

References

De Olde EM, Ripoll Bosch R, Kok A, De Boer IJM, Giampietro M and Pereira A (2019). Report on Narratives behind Directives Protecting the Environment (Revision). MAGIC (H2020–GA 689669) Project Deliverable 5.6. First version 30 November 2018, revision 30 June 2019

Di Felice L, Dunlop T, Giampietro M, Kovacic Z, Renner A, Ripa M and Velasco-Fernández R. Report on the Quality Check of the Robustness of the Narrative behind Energy Directives. MAGIC (H2020–GA 689669) Project Deliverable 5.4, 30 November 2018

Carmona-Moreno C, Dondeynaz C & Biedler M (Eds) (2018) Position Paper on Water, Energy, Food and Ecosystems (WEFE) Nexus and Sustainable development Goals (SDGs), EUR 29509 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-00159-1, doi:10.2760/31812, JRC114177

Chukalla AD, Krol MS & Hoekstra AY (2015) Green and blue water footprint reduction in irrigated agriculture: Effect of irrigation techniques, irrigation strategies and mulching. *Hydrology and Earth System Science*s, 19(12): 4877-4891

EUROSTAT (2020a) Extra-EU trade in agricultural goods, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Extra-EU_trade_in_agricultural_goods&stable=0&redirect=no#EU_trade_in_agricultural_products:_slight_deficit (accessed on: 31-1-2020)

EUROSTAT (2020b) Final energy consumption, https://ec.europa.eu/eurostat/data/database (accessed on: 18-1-2020)

EUROSTAT (2020c) From where do we import energy and how dependent are we?, https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-2c.html (accessed on: 31-1-2020).

EUROSTAT (2020d) Land cover overview by NUTS 2 regions, https://ec.europa.eu/eurostat/data/database (accessed on: 28-1-2020)

EUROSTAT (2019a) Renewable freshwater resources, https://ec.europa.eu/eurostat/data/database (accessed on: 20-9-2019)

EUROSTAT (2019b) Share of irrigable and irrigated areas in utilised agricultural area, https://ec.europa.eu/eurostat/data/database (accessed on: 28-11-2019)

FAOSTAT (2020) Food balance sheets: Food Supply - Crops Primary Equivalent, http://www.fao.org/faostat/en/#data/CC (accessed on: 20-1-2020)

Fritsche UR, Berndes G, Cowie AL, Dale VH, Kline KL, Johnson FX, Langeveld H, Sharma N, Watson H & Woods J (2017) Global land outlook working paper: energy and land use. UNCCD and IRENA. Retrieved from: https://knowledge.unccd.int/sites/default/files/2018-06/2.%20Fritsche%2Bet%2Bal%2B%282017%29%2BEnergy%2Band%2BLand%2BUse%2B-%2BGLO%2Bpaper-corr.pdf

Giampietro M (2018) Perception and representation of the resource nexus at the interface between society and the natural environment. *Sustainability* 10(7): 2545

Giampietro M & Sorman AH (2012) Are energy statistics useful for making energy scenarios? *Energy* 37(1): 5-17

Global Yield Gap and Water Productivity Atlas (2020) Available URL: www.yieldgap.org (accessed on: 28-11-2019)

Hoekstra AY (2020) The water footprint of modern consumer society: second edition, Routledge, London, UK. https://www.routledge.com/The-Water-Footprint-of-Modern-Consumer-Society/Hoekstra/p/book/9781138354784

Hoekstra AY & Wiedmann TO (2014) Humanity's unsustainable environmental footprint. *Science*, 344(6188): 1114-1117

Holmatov B & Hoekstra AY (2020) The environmental footprint of transport by car using renewable energy. *Earth's Future*, 8(2):e2019EF001428

Holmatov B, Hoekstra AY & Krol MS (2019) Land, water and carbon footprints of circular bioenergy production systems. *Renewable & Sustainable Energy Reviews*, 111: 224-235.

IEA (2020) Data and statistics, https://www.iea.org/data-and-statistics/data-tables (accessed on: 31-1-2020)

Krol MS, Cabello Villarejo V, Cadillo-Benalcazar J, de Olde E, Di Felice L, Giampietro M, Muscat A, Renner A, Ripa M, Ripoll Bosch R, Serrano-Tovar T and Verburg CCA. Report on exploratory applications of the MuSIASEM Toolbox in Quantitative Story Telling for anticipation. MAGIC (H2020–GA 689669), Project Deliverable 4.3, 31 March 2018

Lepper MR & Cordova DI (1992) A desire to be taught: Instructional consequences of intrinsic motivation. *Motivation and Emotion* 16(3): 187-208

Matthews KB, Blackstock KL, Waylen KA, Juarez-Bourke A, Miller DG, Wardell-Johnson DH and Rivington M. Report on the Quality Check of the Robustness of the Narrative behind the Common Agricultural Policy (CAP). MAGIC (H2020–GA 689669) Project Deliverable 5.5, 29 November 2018

Mekonnen MM & Hoekstra AY (2010) The green, blue and grey water footprint of crops and derived crop products, Value of Water Research Report Series No.47, UNESCO-IHE

Pastor AV, Ludwig F, Biemans H, Hoff H, & Kabat P (2014) Accounting for environmental flow requirements in global water assessments. *Hydrology and Earth System Sciences*, 18(12), 5041-5059

Poore J & Nemecek T (2018) Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392): 987-992

Schyns JF & Vanham D (2019) The water footprint of wood for energy consumed in the European Union. *Water*, 11(2): 206

Schyns JF, Hoekstra AY, Booij MJ, Hogeboom RJ & Mekonnen MM (2019) Limits to the world's green water resources for food, feed, fiber, timber, and bioenergy. *Proceedings of the National Academy of Sciences*, 116(11): 4893-4898

Turconi R, Boldrin A & Astrup T (2013) Life cycle assessment (LCA) of electricity generation technologies: Overview, comparability and limitations. *Renewable & Sustainable Energy Reviews*, 28: 555-565

Vanham D, Medarac H, Schyns JF, Hogeboom RJ & Magagna D (2019) The consumptive water footprint of the European Union energy sector. *Environmental Research Letters*, 14(10): 104016

Vargas-Farías A, Hogeboom RJ, Schyns JF, Verburg CCA & Hoekstra AY (2020) Quality Check of Saving Water in Irrigation. MAGIC (H2020–GA 689669) Project Deliverable 6.8

World Bank (2020) World Bank Data: Arable land (hectares per person), https://data.worldbank.org/ (accessed on 13-1-2020)

Horizon 2020 Societal challenge 5:
Climate action, environment, resource efficiency and raw materials

MAGIC Nexus Game: Player Instructions

August, 2020

Please cite as:

Schyns, J.F., Oprel, J., Holmatov, B., Verburg, C.C.A., Krol, M.S. & Hoekstra, A.Y. (2020) Educational Nexus Game, Annex I: MAGIC Nexus Game: Player Instructions. MAGIC (H2020–GA 689669) Project Deliverable 7.5.

Contents

1. Introduction

This document contains the player instructions for the MAGIC Nexus Game: https://game.magic-nexus.eu/.

1.1. The setting of the game

The European Union (EU) needs to secure its future food and energy supply while keeping environmental impacts within safe boundaries: reduce carbon emissions while staying within the sustainable limits to land and water use. Reconciling the policy targets on food and energy security, sustainable and efficient resource use, and climate adaptation is a major challenge due to the many feedbacks in terms of the water-land-carbon-food-energy nexus. Tackling this challenge requires changes in the current food and energy production and consumption patterns. Moreover, many of the related choices are not made at the EU level, but at the level of individual member states (MS). Natural resource endowments, consumption habits, and production practices vary widely among the MS. As a consequence each of the MS need to focus on taking different measures, and inter-regional cooperation between the MS is essential to achieve the goals of the economic block

1.2. The purpose and focus of the game

The purpose of the game is to experience the challenges and solutions for member states – as part of a larger economic block – to achieve food and energy security within the safe environmental boundaries. The EU is schematized into four regions (Table 1, next page) based on the degree of land and water scarcity and the resource-intensity of consumption patterns, in such a way that they face different challenges and have different learning points. Three versions of the game can be played:

- **Single Player Level 1** focuses on the challenges within an individual member state to achieve environmental sustainability by changing the consumption habits and the production practices. The player controls one EU region, and there is no trade in food and energy. This version is recommended for anyone with limited experience regarding the water-land-carbon-food-energy nexus.
- **Single Player Level 2** focuses on the challenge to achieve food and energy security for the EU as a whole, while also achieving sustainability targets in each of the member states (i.e. corresponding to one of the four EU region's in the game). The player controls all four EU regions and has full flexibility in changing practices and closing trade agreements. This version is recommended for anyone with more experience regarding the water-land-carbon-food-energy nexus, and people who have mastered Single Player Level 1.
- **Multiplayer** focuses on the cooperation and policy alignment between the member states to attain the EU level targets. This version requires a facilitator and a minimum of four players: each controlling one of the EU regions in the game.

Table 1. The four EU regions distinguished in this game.

Region	Typical countries	Population of EU	Land and green water (rain) availability per capita	Blue water (surface and groundwater) availability per capita
A	Austria, Ireland, Netherlands, Slovakia, Slovenia	12%	Low	Medium
B	Bulgaria, Estonia, Finland, Hungary, Latvia, Lithuania, Sweden	8%	High	High
C	Belgium, Cyprus, Czech Republic, Germany, Italy	46%	Medium	Low
D	France, Poland, Romania, Spain	34%	Low	Low

1.3. Theoretical background

The game conveys the main trade-offs and synergies in the nexus using a quantitative framework of relations between the nexus elements based on environmental footprint (EF) indicators. This framework is a hugely simplified representation of the real world and should therefore not be used as a tool to inform decision making outside the context of this serious game.

The environmental footprint (EF) can be expressed for several entities, such as a product, a group of consumers or a certain geographic area[1]. The EF of a product refers to the resource appropriation (water and land) or emissions (carbon) per unit of product produced (e.g. kilocalorie of food or a gigajoule of energy). The EF of a group of consumers (e.g. EU citizens) relates to the resource use and emissions associated with all goods and services (e.g. food and energy) consumed by this group, which can also be expressed per unit of product consumed. In short, this is referred to as the EF *of consumption*. The EF *of production* within a certain geographic area (e.g. the entire EU, or a single member state) relates to the resource use and emissions associated with all goods and services produced within the borders of that area. Note that the EF of consumption can be partially outside the area in which the group of consumers resides, i.e., the EF is externalized. Also note that the EF of production may partially be related to good and services produced for export, i.e., not intended for final use by consumers in the same area.

[1] Hoekstra, A.Y. & Wiedmann, T.O. (2014) Humanity's unsustainable environmental footprint. *Science*, 344(6188): 1114-1117.

1.4. Getting started

Navigate to the MAGIC Nexus Game in your browser: https://game.magic-nexus.eu/

On the welcome screen:

1. Insert a *user name*.
2. Choose a *version*:
   - Single Player Level 1 (SP1)
   - Single Player Level 2 (SP2)
   - Multiplayer (MP)
3. Choose a *role*.
   - For SP1: pick any of the four EU regions (A, B, C or D).
   - For SP2: it does not matter which region you pick now; you can switch between the regions in the interactive dashboard.
   - For MP: follow the instructions from the game facilitator.
4. Click "*Start the game*"!

The interactive dashboard opens.

Proceed to reading the player instructions and exploring the dashboard.

1.5. Readers' guide

Chapter 2 contains the player instructions for Single Player Level 1.

Chapter 3 contains the player instructions for Single Player Level 2.

Chapter 4 contains the player instructions for Multiplayer.

The interactive dashboard is described in Chapter 5.

2. Player instructions: Single Player Level 1

2.1. Introduction

The Prime Minister of an EU member state has been invited by the President of the European Commission together with ministers from other countries to negotiate on what actions should be taken by the member states to achieve the EU goals for food & energy security, climate action, and sustainable resource use. The Prime Minister does not want to make promises (s)he cannot deliver on and wants to understand the possibilities within his/her country to reduce carbon, land and water footprints, and which actions that would require.

Your role and task

You are an advisor to the government led by the Prime Minister. You have been asked to explore the situation and advise the Prime Minister on what to do. Your advice to the will consist of a submitted *interactive dashboard* that contains the actions you advise and their effects on the carbon, land and water footprints in your country.

The interactive dashboard

Your team of geeky specialists has built a simplified model of the water-land-carbon-food-energy nexus in the EU that comes with an interactive dashboard. In this interactive dashboard the EU is divided into four regions of member states based on water availability and population density (Table 1, Chapter 1). You can control you're the dashboard of your region. You can use the dashboard to explore the effect of your choices regarding the consumption and production of food and energy, on the carbon, land and water footprints. The dashboard is explained in Chapter 5.

2.2. Objective and scoring

Your main objective in the game is to:

Adapt production systems and consumption patterns such that
the carbon footprint of consumption is reduced by below the target level (16 kg/cap/day)
and the land and water footprints within the region (i.e. footprint of production) are reduced below the sustainable limits.

Your are challenged to meet these pre-conditions for while keeping the 'desirability penalty' – that reflects societal costs of changing production systems and consumption patterns – to a minimum. Score-taking is summarized in Table 2. Given the differences between the EU regions (Table 1, Chapter 1), the game experience depends on the region that is chosen, and is least challenging for the region with the largest water and land availability per capita (region B).

Table 2. Score-taking in the three versions of the game: single player level I (SP1), single player level 2 (SP2), and multiplayer (MP).

Nexus element	Indicator	Current	Target	Score SP1	Score SP2	Score MP
Food security	% of food supply met by agriculture in the EU	**92%**	≥95%	-	Pre-condition for game completion	Pre-condition for game completion
Energy security	% of energy supply met by energy generation in the EU	**52%**	≥70%	-	Pre-condition for game completion	Pre-condition for game completion
Carbon emissions	EU-average carbon footprint of production (20 % reduction)	**20** kg/cap/day	16 kg/cap/day	-	Pre-condition for game completion	Pre-condition for game completion
Carbon emissions	Carbon footprint of production in region A/B/C/D (20 % reduction)	**20** kg/cap/day	16 kg/cap/day	Pre-condition for game completion	-	-
Land, green water, blue water use	Exceedance of physical limit	≤0%	≤0%	Pre-condition for game completion	Pre-condition for game completion	Pre-condition for game completion
Land use	Exceedance of sustainable limit					
	in region A	**+22.9%**	≤0%	Pre-condition for game completion (for one region only)	1 point	1 point
	in region B	-15.8%	≤0%		1 point	1 point
	in region C	**+70.5%**	≤0%		1 point	1 point
	in region D	-11.7%	≤0%		1 point	1 point
Green water use	Exceedance of sustainable limit					
	in region A	**+39.4%**	≤0%	Pre-condition for game completion (for one region only)	1 point	1 point
	in region B	-67.4%	≤0%		1 point	1 point
	in region C	-7.0%	≤0%		1 point	1 point
	in region D	-35.2%	≤0%		1 point	1 point
Blue water use	Exceedance of sustainable limit					
	in region A	-54.4%	≤0%	Pre-condition for game completion (for one region only)	1 point	1 point
	in region B	-79.6%	≤0%		1 point	1 point
	in region C	**+20.6%**	≤0%		1 point	1 point
	in region D	**+38.6%**	≤0%		1 point	1 point
Total score				Meet pre-conditions with smallest desirability penalty	Score in interactive dashboard (≤12 points) times the number of correct key messages to the President (≤3 points)	Team/player with the highest score (≤3 points) wins. In case of a tie, the team with the smallest 'desirability penalty' (section 5.4) wins.

3. Player instructions: Single Player Level 2

3.1. Introduction

The President of the European Commission is aware of the challenges the EU is facing (section 1.1). The President is stressed out and wonders:

1. Is it possible at all to simultaneously achieve the EU goals for food & energy security, climate action, and sustainable resource use?!
2. what feasible actions should the member states take?!
3. what agreements should be made for trade in food and energy within the EU?!

Your role and task

You are the trusted special advisor to the President. You have been asked to explore the situation and advise the President on what to do. Your advice to the President will consist of a submitted *interactive dashboard* that contains the actions and agreements you advise and their effects on the nexus elements. After you have submitted your interactive dashboard, you need to summarize your advice to the President in *three key messages*. Your team of specialists has prepared 8 messages, but 5 of them are false! They rely on your expertise to select the three correct key messages! Your final score is the number of points scored in the interactive dashboard with your advice times the number of correct key messages to the President.

The interactive dashboard

Your team of geeky specialists has built a simplified model of the water-land-carbon-food-energy nexus in the EU that comes with an interactive dashboard. In this interactive dashboard the EU is divided into four regions (Table 1, Chapter 1). You have full control over the all of them. You can use the dashboard to explore the effect of your choices regarding the consumption and production of food and energy, on the food & energy dependency of the EU as well as carbon, land and water footprints. The dashboard is explained in Chapter 5.

3.2. Objective and scoring

Your main objective in the game is to provide a comprehensive, correct advice to the President of the European Commission on how to:

Achieve EU-level targets for food & energy security and carbon emissions,
while reducing land and water footprints within the four EU regions to below the sustainable limits.

Meeting the EU-level targets for food & energy security and reduced carbon emissions is a pre-condition to complete the game. Also land and water use should be below physical limits in all regions. Once these pre-conditions are met, you can score points by making sure the land and water

footprints in the EU regions remain below sustainable levels of resource use: for each regions, for each footprint that remains below the sustainable level, you get 1 point. When you have met the pre-conditions and you are satisfied with your score, you click the button *Submit Dashboard* on the EU panel. This will freeze your advice (i.e. the choices in all panels) and take you to the final test: select the three correct key messages to the President. Your final score is the number of points scored in your interactive dashboard times the number of correct key messages to the President. Score-taking is summarized in Table 2 (Chapter 2), and the current score can be viewed at all times in the EU panel.

4. Player instructions: Multiplayer

4.1. Introduction

The President of the European Commission has called a meeting with the head of states of all member states to negotiate on what actions should be taken by the countries to achieve the EU goals for food & energy security, climate action, and sustainable resource use. The outcome of the meeting is unmistakably clear: the member states must come to an agreement on a plan that achieves the ambitious EU level targets.

Your role and task

Your team represents one out of four typical member states (Table 1, Chapter 1). You enter the negotiations with a common goal of meeting EU level targets for food & energy security and carbon emissions. However, you also want to reduce land and water footprints within your region to below the sustainable limits to comply with the goals set out in the United Nations' Sustainable Development Agenda and the EU Green Deal and the EU Water Framework Directive. At the same time, you need to consider the social acceptance of the actions you agree upon.

The interactive dashboard

The meeting is supported by a simplified model of the water-land-carbon-food-energy nexus in the EU that comes with an interactive dashboard. In this interactive dashboard, each team/player controls one EU region. You can use the dashboard to explore the effect of your choices regarding the consumption and production of food and energy, on the food & energy dependency of the EU as well as carbon, land and water footprints within your region and for the EU as a whole. Trade agreements are negotiated amongst teams/players and should be formalized in the dashboard during 'trade negotiations rounds' that are announced, opened and closed by the facilitator. The dashboard is explained in Chapter 5.

4.2. Objective and scoring

The objective for each team/player in the game is to:

Achieve EU-level targets for food & energy security and carbon emissions,
while reducing land and water footprints within your region to below the sustainable limits.

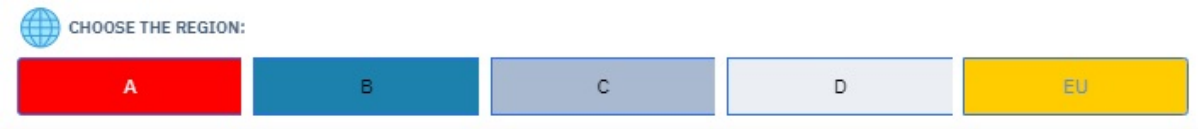
Meeting the EU-level targets for food & energy security and reduced carbon emissions is a pre-condition to complete the game, so you need to cooperate with other players and close agreements for trade within the EU. You can score points by making sure the land and water footprints in your region remain below sustainable levels of resource use. You can decide to exceed the sustainable level of resource (spilling points). However, you will be disqualified if you use more land or water than physically available (you will receive a warning). Score-taking is summarized in Table 2 (Chapter 2).

5. Interactive dashboard

The dashboard contains *five panels* (Section 5.1): four region panels (one for each EU region), and one EU overview panel. In each region panel you can make choices within *six choice categories* on the left hand side (Section 5.2). The effects of those choices are visible within *four effects categories* on the right hand side (Section 5.3). The societal costs of changing production systems and consumption patterns are reflected by means of a 'desirability penalty' (Section 5.4). The EU overview panel (Section 5.5) contains an overview of effects for the EU as a whole. From the EU overview panel you can *Submit Your Dashboard* and proceed to game completion.

5.1. The five panels of the dashboard

The five panels are:



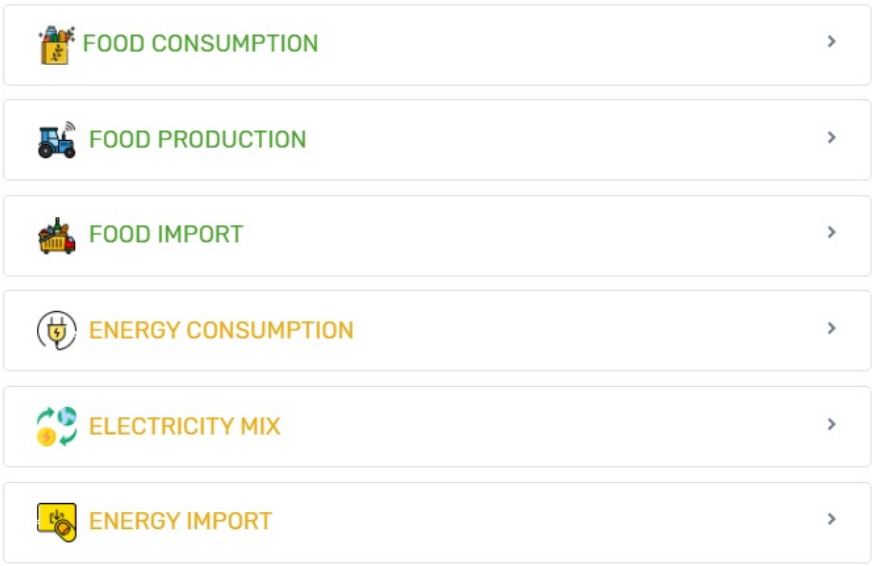
- Panel A: the place to make choices in the nexus for region A
- Panel B: the place to make choices in the nexus for region B.
- Panel C: the place to make choices in the nexus for region C.
- Panel D: the place to make choices in the nexus for region D.
- Panel EU: includes an overview of point scoring the game in as well as graphs comparing the performance of the four regions compared to the EU-average. *Opens is a separate window*. See section 5.4.

In Single Player Level 1 and in Multiplayer, you can only control the panel of the region (role) that you picked (Section 1.4) and view the EU overview panel. In Single Player Level 2 you can switch between and control all panels.

5.2. The six choice categories on panels A-D

You can make choices regarding the consumption and production of food and energy, as well as to international trade in food and energy. It is recommended to start your journey of adaptation by making choices in the domain of food and energy before moving on to trade. Choices are explained per category in sections 5.2.1 to 5.2.6.

The six choice categories are:



5.2.1. Food consumption

Food consumption choices affect the amount and type of food that is grown. You can change the food intake in terms of energy (calories), the fraction of food waste in the chain, and the fraction of your population adhering to a certain diet (Table 3). However, bear in mind that EU citizens do not like being told how to live their lives, so any choices affecting their daily lives will likely be met with resistance.

Table 3. Food consumption choices.

Choice	**Explanation**
Food intake (kilocalories per person per day)	The more food is consumed, the more needs to be produced. You can adjust the average daily food intake of your population. Bear in mind that consuming 2500 kcal per day corresponds to the average energy needs of a 70-kg man aged 30 years and a 60-kg woman aged 30 years whose level of physical activity is moderate to high (Willett et al., 2019). Also consider that deviation from the habit, requires a societal change that is difficult to accomplish.
Food waste (% of food intake)	Wasted food, wasted resources. Cutting down on food waste reduces the need amount of food that needs to be produced and the associated footprints. However, bear in mind that efforts are required to cut down on food waste (see Table 4).
Diets	The fraction of your population that adheres to a vegan (no meat & fish, no dairy & eggs), vegetarian (no meat & fish), or flexitarian (no meat & fish for *x* days a week) diet has a significant effect on the footprint of food production. The footprints of animal products are several factors larger than those of plant-based products, because animals eat plants for energy, and only fraction of that energy ends up in the animal product for human consumption. The footprint of meat is larger than that of dairy & eggs (a cow can give milk multiple times, but meat only once).

Table 4. Food waste/loss categories and typical interventions to reduce them. Adapted from Kummu et al. (2012)[2].

Loss name (top-down from farmer to consumer in the chain)	Definition	Possible interventions in industrialized countries
Agricultural losses	Losses due to mechanical damage and/or spillage during harvest operation, crop sorting etc.	Cooperation among farmers could reduce risk of overproduction that often leads to agricultural losses.
Postharvest losses	Losses due to storage and transportation between farm and distribution, and spillage and degradation during handling.	Improved on-farm facilities.
Processing losses	Losses during industrial or domestic processing.	Develop market for 'sub-standard' products that are eatable; enhanced production line.s
Distribution waste	Losses and waste in the market system, including wholesale markets, supermarkets, retailers, and wet markets.	Lower standards for size, weight, etc.; reduce the diversity of choices requiring a large variety of stocks of different food products.
Consumption waste	Losses and waste at the household level.	Public awareness; smaller packages; better planning in restaurants and households.

5.2.2. Food production

Growing food is associated with land, water and carbon footprints. Agricultural areas leave a land footprint. For several months a year the agricultural land is supplied with rainwater (green water) and irrigation water (blue water) so that the crops can grow. That water evaporates and is no longer available for other uses in that place and moment of time, thus leaving a green and blue water footprint. Fertilizer production and animal husbandry are associated with greenhouse gas emissions, thus contributing to the carbon footprint. A fraction of your agricultural land is rainfed and the rest is irrigated. Dependent on the system (rainfed or irrigated) there are certain agricultural practices that you can change (Table 5).

Table 5. Food production choices.

Choice	Explanation
Closing the water-limited yield gap on rainfed lands	Rainfed croplands solely rely on rainfall for their water supply. These systems are generally low-input and have below-potential crop yields, due to suboptimal management (e.g. nutrient deficiency, weeds, diseases). The difference between the actual yield and the yield under optimal management conditions in the rainfed system, is called the water-limited yield gap.
Applying organic mulching on rainfed lands	The water footprint of rainfed lands can somewhat be reduced by applying organic mulching, i.e. leaving plant-based litter on the field. This causes a so-called vapor shift: water evaporation from the bare soil is reduced, while crop-water uptake is increased. Both the land and water footprint are reduced.

[2] Kummu, M., de Moel, H., Porkka, M., Siebert, S., Varis, O. & Ward, P.J. (2012) Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. *Science of The Total Environment*, 438: 477-489.

Applying alternative irrigation and mulching on irrigated lands	On irrigated croplands, irrigation with surface- or groundwater complements water supply from rainfall. These systems are generally high-input and have near optimal crop yields. The most common system is full irrigation using sprinklers, which means that water stress is avoided by spraying water over the field whenever rainfall alone is not enough. Consequently, the land footprint is small, but the water use is high.
Applying deficit instead of full irrigation	A deficit irrigation strategy seeks a different balance between the land and water footprint: less irrigation water is applied, which increases the land footprint (reduced crop yield). However, relatively, the reduction in water use is larger than the reduction in yield, such that the water footprint does down.
Applying deficit irrigation and organic mulching	Additionally, you can decide to apply organic mulching to reduce the land and water footprint through a vapor shift (see Applying organic mulching on rainfed lands).
Applying deficit irrigation, organic mulching and drip irrigation	On top of that, you can decide to apply the irrigation water to the field by means of a drip irrigation system instead of sprinklers. A drip irrigation system applies droplets of water right where the plant needs it – in the soil next to the stems – so that water is used much more effective than in the case of sprinklers. Drip systems are expensive in terms of investment and operation, though .

5.2.3. Energy consumption

The energy sector is currently responsible for the majority of the carbon footprint, but also water and land are used to produce energy. Think of water that evaporates from reservoirs used for hydropower generation, and the land and water requirements of biofuel crops. You can make choices regarding how much energy is consumed per sector, which type of energy is consumed (fossil fuel, biofuel, electricity), and from which sources electricity is generated. You can choose to reduce the total energy demand of each sector (Table 6). You can also make choices affecting the type of energy consumed (Table 7). Realize that reduction of energy consumption is subject to constraints (not incorporated in this game for sake of simplicity and its educational character) and are accompanied by adaptation costs and time. For example, technological innovations that allow to reduce dramatically the consumption of fossil fuels and the total electrification of all forms of transport will (substantially) affect the material standard of living.

Table 6. Energy consumption choices: total energy demand per sector.

Choice	**Explanation**
Reduction of energy use in industry	Replace machinery/equipment by newer, more energy-efficient models.
Reduction of energy use in transport sector	Replace car park by newer, more energy-efficient models.
Reduction of energy use in services sector	Replace machinery/equipment by newer, more energy-efficient models.
Reduction of energy use in households	Replace appliances and lamps by newer, more energy-efficient models; improved home insulation; public awareness on energy saving (turn thermostat down, laundry with cold water, shorter/colder showers).

Table 7. Energy consumption choices: type of energy consumed.

Choice	Explanation
Electrification of the transport sector	0% means that all transport is driven by fuels. 100% means all transport is electric. Increasing this fraction implies major mid- to long-term adjustments for the automobile industry, transport companies and car owners, as well as companies and government responsible for infrastructure (electricity network and recharge stations).
Reduction of gas and coal usage in households	0% means that all energy use in households is from gas and coal sources. 100% means that all energy use in households is electric. Increasing this fraction implies major mid- to long-term adjustments for real estate owners and for the daily lives of individuals.
Percentage of biofuels in total fuel consumption	Fuels are used in the transport, industry and services sectors. 0% means that all are fossil fuels. 100% means that all are biofuels.

5.2.4. Electricity mix

You can choose the mix of electricity generated in your country (Table 8). Realize changes in the energy mix are subject to constraints (not incorporated in this game for sake of simplicity and its educational character) and are accompanied by adaptation costs and time. Generating a completely different energy matrix, a new fleet of powerplants, a different and much more complex energy grid – something quite expensive both in terms of energy, biophysical resources and emissions – will represent a heroic effort.

Table 8. Electricity mix choices.

Choice	Explanation
Fraction of total electricity production originating from each source	Electricity can be generated from various sources. These sources vary in their efficiency to generate a kWh of electricity and in the footprints they affect, e.g. fossil sources are mainly associated with a carbon footprint; hydropower mainly with blue water; and biofuels mainly with land, green and blue water.

5.2.5. Food import

Import of food (Table 9) is a tempting option to reduce the footprints within your country. However, the flipside is that it increases your dependency on others and therefore reduces your food security. Trade deals will only be effective after acceptance by the exporting region.

Table 9. Food import choices.

Choice	Explanation
Import as fraction of total food demand, per food category (%)	Three food categories are distinguished with varying associated footprints per kilocalorie of food. For each category you can choose the import as a fraction of total demand (both in kcal), and specify the origin of import (world, or one of the other three EU regions). If you import from the world, this reduces food security of the EU. If you import from another EU region, you need their permission: they need to agree to produce what you want to import.

5.2.6. Energy import

Import of energy (Table 10) is a tempting option to reduce the footprints within your country. However, the flipside is that it increases your dependency on others and therefore reduces your energy security. Trade deals will only be effective after acceptance by the exporting region.

Table 10. Energy import choices.

Choice	Explanation
Import as fraction of total energy demand, per energy source category (%)	Three energy source categories are distinguished with varying associated footprints per Megajoule (MJ) of energy. For each category you can choose the import as a fraction of total demand (both in MJ), and specify the origin of import (world, or one of the other three EU regions). If you import from the world, this reduces energy security of the EU. If you import from another EU region, you need their permission: they need to agree to produce what you want to import.

5.3. The four effects categories on panels A-D

The four effect categories are:

The footprints of consumption indicate resource use and emissions of food and energy consumed by the population in your region. The graphs show which part of the footprint is in your region and which part is externalized, i.e. related to the import of food and energy from other regions.

The footprints of production indicate resource use and emissions of food and energy produced in your region. The graphs show how land and water footprints in your region compare to physical and sustainable limits to land and water use in your regions. Physical limits refer to total resource availability. Sustainable limits refer to total resource availability minus a fraction of the resource that needs to be reserved to maintain healthy ecosystems.

Food and energy security are indicated by charts showing the breakdown of total food (in kcal/cap/day) and energy (in MJ/cap/day) supply in your region by origin. The origin is either local, one of the other three EU regions, or import from the rest of the world. The value in the middle of the chart indicates the fraction of total supply that originates from your region (domestic production).

The efficiency indicators show footprints of food per kilocalorie of food consumed and footprints of energy per megajoule of energy consumed.

5.4. The desirability penalty reflecting societal resistance to change

Not all choices are evenly easy to implement due to societal resistance or costs. Therefore each choice comes with a desirability penalty in the game (Table 11). The purpose of these penalties is to have the players think twice about the potential consequences of their choices, which are alluded to in the explanation of choices in Section 5.2.

Table 11. Desirability penalty per choice.

Choice	**Penalty (no unit/physical meaning)**
Food intake (kilocalories per person per day)	>2500 then per 1 kcal reduction: 0.02 <2500 then per 1 kcal reduction: 0.10
Food waste (% of food intake)	>10% then, per 1% reduction: 0.5 <10% then, per 1% reduction: 2.5
Diets	Per 1% vegan: 3 Per 1% vegetarian: 2
Closing the water-limited yield gap on rainfed lands	<=20% then per 1% of land: 0.1 >20% then per 1% of land: 0.3
Applying organic mulching on rainfed lands	<=20% then per 1% of land: 0.1 >20% then per 1% of land: 0.3
Applying deficit instead of full irrigation	No desirability penalty.
Applying deficit irrigation and organic mulching	<=20% then per 1% of land: 0.1 >20% then per 1% of land: 0.3
Applying deficit irrigation, organic mulching and drip irrigation	<=20% then per 1% of land: 0.2 >20% then per 1% of land: 0.5
Reduction of energy use in industry	<=20% then per 1%: 0.1 >20% then per 1%: 0.3
Reduction of energy use in transport sector	<=20% then per 1%: 0.1 >20% then per 1%: 0.3
Reduction of energy use in services sector	<=20% then per 1%: 0.1 >20% then per 1%: 0.3
Reduction of energy use in households	<=20% then per 1%: 0.1 >20% then per 1%: 0.3
Electrification of the transport sector	<=20% then per 1%: 0.1 >20% then per 1%: 0.3
Reduction of gas and coal usage in households	<=20% then per 1%: 0.1 >20% then per 1%: 0.3
Percentage of biofuels in total fuel consumption	No desirability penalty.
Fraction of total electricity production originating from each source	For increasing the use of nuclear, per 1% increase: 0.3
Import as fraction of total food demand, per food category (%)	No desirability penalty.
Import as fraction of total energy demand, per energy source category (%)	No desirability penalty.

5.5. The EU overview panel

This panel shows the effects of choices made in each of the four EU regions on the EU-average indicators for three categories: footprints of consumption, footprints of production, and security.

The footprints of consumption show the EU-average carbon, land, green water and blue water footprints associated with food and energy consumed by the EU inhabitants. Bars indicate how the footprints in the four EU regions compare to the EU-average.

The footprints of production show the EU-average carbon, land, green water and blue water footprints associated with food and energy produced in the EU. Bars indicate how the footprints in the four EU regions compare to the EU-average. For land and water footprints, physical and sustainable limits to the footprints are indicated as well.

Food and energy security are indicated by charts showing the breakdown of total food (in kcal/cap/day) and energy (in MJ/cap/day) supply in the EU by origin. The origin is one of the other EU regions, or import from the rest of the world. The value in the middle of the chart indicates the fraction of total supply that originates from the EU regions (EU internal production).

Horizon 2020 Societal challenge 5:
Climate action, environment, resource efficiency and raw materials

MAGIC Nexus Game: Facilitator Instructions

August, 2020

Please cite as:

Schyns, J.F., Oprel, J., Holmatov, B., Verburg, C.C.A., Krol, M.S. & Hoekstra, A.Y. (2020) Educational Nexus Game, Annex II: MAGIC Nexus Game: Facilitator Instructions. MAGIC (H2020–GA 689669) Project Deliverable 7.5.

Disclaimer:

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No. 689669. The present work reflects only the authors' view and the funding Agency cannot be held responsible for any use that may be made of the information it contains.

Contents

1. Introduction

This document contains the facilitator instructions for the *multiplayer version* of the MAGIC Nexus Game: https://game.magic-nexus.eu/.

1.1. The setting of the game

The European Union (EU) needs to secure its future food and energy supply while keeping environmental impacts within safe boundaries: reduce carbon emissions while staying within the sustainable limits to land and water use. Reconciling the policy targets on food and energy security, sustainable and efficient resource use, and climate adaptation is a major challenge due to the many feedbacks in terms of the water-land-carbon-food-energy nexus. Tackling this challenge requires changes in the current food and energy production and consumption patterns. Moreover, many of the related choices are not made at the EU level, but at the level of individual member states (MS). Natural resource endowments, consumption habits, and production practices vary widely among the MS. As a consequence each of the MS need to focus on taking different measures, and inter-regional cooperation between the MS is essential to achieve the goals of the economic block

1.2. The purpose and focus of the game

The purpose of the game is to experience the challenges and solutions for member states – as part of a larger economic block – to achieve food and energy security within the safe environmental boundaries. The EU is schematized into four regions (Table 1) based on the degree of land and water scarcity and the resource-intensity of consumption patterns, in such a way that they face different challenges and have different learning points. Three versions of the game can be played:

- **Single Player Level 1**
- **Single Player Level 2**
- **Multiplayer**

Only the multiplayer version requires a facilitator. This version focuses on the cooperation and policy alignment between the member states to attain the EU level targets. It requires a facilitator and a minimum of four players: each controlling one of the EU regions in the game.

Table 1. The four EU regions distinguished in this game.

Region	Typical countries	Population of EU	Land and green water (rain) availability per capita	Blue water (surface and groundwater) availability per capita
A	Austria, Ireland, Netherlands, Slovakia, Slovenia	12%	Low	Medium
B	Bulgaria, Estonia, Finland, Hungary, Latvia, Lithuania, Sweden	8%	High	High
C	Belgium, Cyprus, Czech Republic, Germany, Italy	46%	Medium	Low
D	France, Poland, Romania, Spain	34%	Low	Low

1.3. Theoretical background

The game conveys the main trade-offs and synergies in the nexus using a quantitative framework of relations between the nexus elements based on environmental footprint (EF) indicators. This framework is a hugely simplified representation of the real world and should therefore not be used as a tool to inform decision making outside the context of this serious game.

The environmental footprint (EF) can be expressed for several entities, such as a product, a group of consumers or a certain geographic area[1]. The EF of a product refers to the resource appropriation (water and land) or emissions (carbon) per unit of product produced (e.g. kilocalorie of food or a gigajoule of energy). The EF of a group of consumers (e.g. EU citizens) relates to the resource use and emissions associated with all goods and services (e.g. food and energy) consumed by this group, which can also be expressed per unit of product consumed. In short, this is referred to as the EF *of consumption*. The EF *of production* within a certain geographic area (e.g. the entire EU, or a single member state) relates to the resource use and emissions associated with all goods and services produced within the borders of that area. Note that the EF of consumption can be partially outside the area in which the group of consumers resides, i.e., the EF is externalized. Also note that the EF of production may partially be related to good and services produced for export, i.e., not intended for final use by consumers in the same area.

1.4. Getting started

Navigate to the MAGIC Nexus game (https://game.magic-nexus.eu/) and *apply for a facilitator account*. After you have received login credentials, navigate to the MAGIC Nexus Game and click on "*Facilitator Login*". The facilitator dashboard opens. Proceed to reading the facilitator instructions in Chapter 2.

1.5. Readers' guide

This document contains the facilitator instructions for Multiplayer. Your role as a facilitator is in the first place to make sure that learning takes place. Therefore it is important that you familiarize yourself with the topic, the rationale of the game and the functionalities of the interactive dashboard by consulting the main report that describes the game:

Schyns, J.F., Oprel, J., Holmatov, B., Verburg, C.C.A., Krol, M.S. & Hoekstra, A.Y. (2020) Educational Nexus Game. MAGIC (H2020–GA 689669) Project Deliverable 7.5.

which can be found here: https://magic-nexus.eu/magic-nexus-game.

[1] Hoekstra, A.Y. & Wiedmann, T.O. (2014) Humanity's unsustainable environmental footprint. *Science*, 344(6188): 1114-1117.

2. Facilitator instructions: Multiplayer

2.1. Introduction

The President of the European Commission has called a meeting with the head of states of all member states to negotiate on what actions should be taken by the countries to achieve the EU goals for food & energy security, climate action, and sustainable resource use. The outcome of the meeting is unmistakably clear: the member states must come to an agreement on a plan that achieves the ambitious EU level targets.

Your role and task in the game

You are the moderator of this high level EU meeting. The (teams of) players represent one out of four typical member states (Table 1, Chapter 1) that enter into the meeting. The players enter the negotiations with a common goal of meeting EU level targets for food & energy security and carbon emissions. However, they also want to reduce land and water footprints within their own region to below the sustainable limits to comply with the goals set out in the United Nations' Sustainable Development Agenda and the EU Green Deal and the EU Water Framework Directive.

The interactive dashboard

The meeting is supported by a simplified model of the water-land-carbon-food-energy nexus in the EU that comes with an interactive dashboard. In this interactive dashboard, each team/player controls one EU region. Players can use the dashboard to explore the effect of choices regarding the consumption and production of food and energy, on the food & energy dependency of the EU as well as carbon, land and water footprints within their region and for the EU as a whole. Trade agreements are negotiated amongst teams/players and should be formalized in the dashboard during 'trade negotiations rounds' that are announced, opened and closed by the facilitator.

2.2. Objective and scoring

The objective for each team/player in the game is to:

Achieve EU-level targets for food & energy security and carbon emissions,
while reducing land and water footprints within your region to below the sustainable limits.

Meeting the EU-level targets for food & energy security and reduced carbon emissions is a pre-condition to complete the game, so you need to cooperate with other players and close agreements for trade within the EU. You can score points by making sure the land and water footprints in your region remain below sustainable levels of resource use. You can decide to exceed the sustainable level of resource (spilling points). However, you will be disqualified if you use more land or water than physically available (you will receive a warning). Score-taking is summarized in Table 2.

Table 2. Score-taking in the multiplayer version of the game.

Nexus element	Indicator	Current	Target	Score
Food security	% of food supply met by agriculture in the EU	**92%**	≥95%	Pre-condition for game completion
Energy security	% of energy supply met by energy generation in the EU	**52%**	≥70%	Pre-condition for game completion
Carbon emissions	EU-average carbon footprint of production (20 % reduction)	**20** kg/cap/day	16 kg/cap/day	Pre-condition for game completion
Carbon emissions	Carbon footprint of production in region A/B/C/D (20 % reduction)	**20** kg/cap/day	16 kg/cap/day	-
Land, green water, blue water use	Exceedance of physical limit	≤0%	≤0%	Pre-condition for game completion
Land use	Exceedance of sustainable limit			
	in region A	**+22.9%**	≤0%	1 point
	in region B	-15.8%	≤0%	1 point
	in region C	**+70.5%**	≤0%	1 point
	in region D	-11.7%	≤0%	1 point
Green water use	Exceedance of sustainable limit			
	in region A	**+39.4%**	≤0%	1 point
	in region B	-67.4%	≤0%	1 point
	in region C	-7.0%	≤0%	1 point
	in region D	-35.2%	≤0%	1 point
Blue water use	Exceedance of sustainable limit			
	in region A	-54.4%	≤0%	1 point
	in region B	-79.6%	≤0%	1 point
	in region C	**+20.6%**	≤0%	1 point
	in region D	**+38.6%**	≤0%	1 point
Total score				Team/player with the highest score (≤3 points) wins. In case of a tie, the team with the smallest 'desirability penalty'* wins.

* Not all choices are evenly easy to implement due to societal resistance or costs. Therefore each choice comes with a desirability penalty in the game. The purpose of these penalties is to have the players think twice about the potential consequences of their choices, which are alluded to in the explanation of choices in the player instructions.

2.3. Monitoring progress during the game

During the game you can monitor the collective progress of the teams towards the game objectives on the *Overview EU* panel.

This panel shows the effects of choices made in each of the four EU regions on the EU-average indicators for three categories: footprints of consumption, footprints of production, and security.

The footprints of consumption show the EU-average carbon, land, green water and blue water footprints associated with food and energy consumed by the EU inhabitants. Bars indicate how the footprints in the four EU regions compare to the EU-average.

The footprints of production show the EU-average carbon, land, green water and blue water footprints associated with food and energy produced in the EU. Bars indicate how the footprints in the four EU regions compare to the EU-average. For land and water footprints, physical and sustainable limits to the footprints are indicated as well.

Food and energy security are indicated by charts showing the breakdown of total food (in kcal/cap/day) and energy (in MJ/cap/day) supply in the EU by origin. The origin is one of the other EU regions, or import from the rest of the world. The value in the middle of the chart indicates the fraction of total supply that originates from the EU regions (EU internal production).

Lastly, you can also see which team(s) took the more drastic measures to meet the targets by viewing the 'desirability penalty' of each team that reflects societal resistance to change or costs.

2.4. Step-by-step guide for facilitating the game

2.4.1. Preparing the game

1. Given the size of the group: decide how the four teams will be made. The advice is to make four teams of maximum four players each. For large classrooms you can opt to host multiple game rooms in parallel. Each team should have a computer with an internet connection.
2. Organize the room such that the four teams can sit apart. Note that you can also host a remote multiplayer session and communicate to the teams (once in the game room) via the DISCORD chat app that can be accessed from the facilitator dashboard.
3. In the facilitator dashboard: create a new game room. Next to the name you give to the game room, the newly created game room gets a unique IDSESSION code assigned, which you need to share with the players later.
4. Given the size of the group and the available time: decide upon how many trade negation rounds there will be. The advice is 2-3 rounds, unless there is less than hour available to play the game (go for 1 round in that case).

2.4.2. Playing the game

1. Introduce the game. Make the four teams and assign each team the role of one of the four EU regions (Table 1, section 1.2).
2. Share the IDSESSION code with the teams, such that they can access the game room.
3. Instruct teams to read the player instructions and familiarize themselves with the interactive dashboard.
4. Dive into your role as moderator of the EU meeting:
5. Welcome the representatives of the member states and announce the desired outcome of the meeting. Sketch the time schedule of the meeting (and manage the time).
6. Ask the teams to first explore which measures in terms of food & energy consumption & production they could take. Give them ample time to explore this in the interactive dashboard. Trade negotiations are to be started somewhat later in the game.
7. Observe teams[2] and help them on their way if needed. Try to intervene as little as possible, give tips if needed, but give them opportunity to figure out things on their own. Remember: your main task is to make sure learning takes place.
8. After a while, if trade negotiations do not start bottom-up: point the teams to the possibility to trade food and energy between their EU regions. By importing less from the rest of the world, EU targets on food and energy security can be achieved. Announce when you will open the first trade negotiation round in the dashboard.
9. Observe teams[2] and monitor progress on the Overview EU panel on the facilitator dashboard.
10. When you feel like the teams are converging to meeting the pre-conditions of the game (Table 2) announce when the final decisions have to be made in order to move the evaluation phase. You can also decide to end the game regardless of whether the pre-conditions have been met.
11. Instruct teams to stop making changes.

[2] With the DISCORD app (accessible from the facilitator dashboard) you can chat with the teams and view their dashboards.

12. Give the teams a break, while you have a look at the dashboards (via the DISCORD app) and prepare the final evaluation.
13. Stick to your role as moderator of the EU meeting:
    a. Thank the teams for attending the meeting and discussing a plan of action to meet the EU targets.
    b. Evaluate the overall success of the meeting: did the teams manage to meet the EU targets?
    c. Evaluate the winners/losers: who scored points by reducing land and water use to below sustainable limits? How drastic where the measures that they took to get there (indicated by the size of the 'desirability penalty')?
14. Dive into your role as educator:
    a. Evaluate whether learning took place: ask questions (in a quiz form) to the participants to test whether the intended learning points (Table 3) came across. Some suggestions for questions:
        i. What was most effective to reduce your land/carbon/water footprint?
        ii. What was your strategy to meet the objectives? What kind of measures did you take?
        iii. What trade-offs did you encounter between food and energy?
        iv. How can you increase food/energy security? What is the flipside of that?
        v. Which region had the most/least challenging task?

Table 3. Learning objectives of the game. Abbreviations: CF = carbon footprint; LF = land footprint; WF = water footprint.

<table>
<tr><td colspan="2">All regions – universal learning points for all regions</td></tr>
<tr><td colspan="2">+ Less meat (& dairy in second instance) and less food waste reduces the LF & WF of consumption.
+ Energy use reduction is always a good starting point to lower the CF.
+ Switching from fossil to renewable sources of energy lowers the CF of consumption, but choosing biofuels increases the LF & WF and choosing hydropower increases the WF.</td></tr>
<tr><td>Region A – Relatively high water availability per capita[a] & densely populated (average meat & fish)
Austria, Croatia, Greece, Ireland, Netherlands, Portugal, Slovakia, Slovenia</td><td>Region B – Relatively high water availability per capita[a] & sparsely populated (average meat & fish)
Bulgaria, Estonia, Finland, Hungary, Latvia, Lithuania, Sweden</td></tr>
<tr><td>Learning points (do’s & don’ts):
+ Challenge: reduce LF & CF
+ More food import reduces land scarcity
+ Increasing crop yields reduces LF and thus land scarcity
- Irrigation measures & mulching make little difference
- Increasing biofuels increases LF to unacceptable levels</td><td>Learning points (do’s & don’ts):
+ Challenge: reduce CF
+ Increasing crop yields reduces LF, but land scarcity is not a concern
- More food import makes little sense
- Irrigation measures & mulching make little difference
- Increasing biofuels increases LF but seems no problem, although producing export food is better?</td></tr>
<tr><td>Region C – Relatively low water availability per capita[a] & densely populated (high meat & fish)
Belgium, Cyprus, Czech Republic, Germany, Italy, Luxembourg, Malta, United Kingdom</td><td>Region D – Relatively low water availability per capita & sparsely populated (high meat & fish)
Denmark, France, Poland, Romania, Spain</td></tr>
<tr><td>Learning points (do’s & don’ts):
+ Challenge: reduce all three footprints!
+ More food import reduces water and land scarcity
+ Increasing crop yields reduces LF and thus land scarcity
+ Deficit & drip irrigation & mulching reduces WF of production & consumption
- Increasing biofuels increases LF & WF to unacceptable levels</td><td>Learning points (do’s & don’ts):
+ Challenge: reduce WF & CF
+ More food import reduces water scarcity
+ Increasing crop yields reduces LF, but land scarcity is not a concern
+ Deficit & drip irrigation & mulching reduces WF of production & consumption
- Increasing biofuels increases WF to unacceptable levels</td></tr>
</table>