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[Giovanni Ferri wrote Section 3. Habib Sedehi wrote Section 2. The rest was jointly written]

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Abstract

The 2030 UN Agenda provides a list of 17 Sustainable Development Goals (SDGs). Typically, SDGs are viewed as non-hierarchical, if not standalone, objectives. Our main aim is to try to represent the structure of multilayered relationships among the SDGs, where possible assigning influence links in order to configure a Systems Thinking view. We achieve that by sketching a Causal Loop Diagram (CLD) which allows drawing the multiple linkages on qualitative grounds disregarding the individual SDGs measurement issues. To close the system and conform it to quantitative analysis, we propose adding three other goals and using Systems Dynamics (SD) modeling analysis. Our approach is twofold. First, it is entirely deductive based on our a priori. Secondly, however, we draw references to the relevant literature to provide support to our initial conjectures.

Our main result is to confirm that SDGs constitute a highly-interconnected network. Therefore, though acknowledging that SDGs have been themselves a major step forward, we posit that considering their systemic interconnectedness will be indispensable to raise the chances of sustainability on planet earth.

Keywords: Sustainable, System Thinking, System Dynamics, Modelling, SDGs, 2030 UN Agenda

While the peoples of the world were becoming more and more aware of the challenge that social and environmental stress pose to sustainability on planet earth, a major global political event contributed to restore hope since 2015. Indeed, the approval by nearly all countries of its constituency of the United Nations' 2030 Agenda for Sustainable Development marked a strong and promising discontinuity with previous policies. Differently from prior approaches – e.g., the United Nations' Millennium Development Goals – that were timid and piecemeal, sustainability became the open aim of world policies with the formulation of the Agenda's Sustainable Development Goals (SDGs). The seventeen SDGs which were agreed upon span from social inclusion/improvement to environmental safeguard/repairing action.

It is too soon to try assess whether and how much SDGs may effectively be achieved by 2030. After just three years since they were launched we can perceive that sustainability related issues have gained higher ranks in the political discussion, in the way businesses shape their image to customers, in growingly frequent and vocal public advocacy. The coupled reshaping of the economy and society is multifaceted. Generally, each sector affected by the sustainability discourse identifies one or a few SDGs as vital to its future strategies. In some cases, national and supranational sectoral institutions preside the compliance to an individual SDG: e.g., healthy lives at all ages (SDG-3) or education & lifelong learning (SDG-4), as if we were talking of different ministries. This is oblivious of the complexity of the 2030 Agenda, which embraces a holistic approach. Indeed, single SDGs cannot be considered in isolation. Their total outcome will be more or less than their mere summation. This is due to the manifold intrinsic interactions among the various sectors and dimensions of the socio-

economic structure. We seem to have a gap between the micro dimension – the individual SDGs targets – and the macro dimension – the 2030 Agenda as a whole.

This paper contributes to fill that gap. We use a Systems Thinking Approach to configure a map of the many inner interactions among the SDGs. To do that, we rely on priors derived in various ways, including from our own deduction. Our map of SDG interconnections – derived as a Causal Loop Diagram (CLD) – provides a dashboard which can be valuable to experts and policy makers. First, moving beyond a partial equilibrium view, it can help assess the general equilibrium effects of any achievement on a specific SDG. Second, our modeling identifies areas on the map where interlinkages among a few SDGs are denser, configuring those few SDGs as a relatively self-contained subsystem. Third, our CLD map strengthens the 17 SDGs approach by embodying three additional sustainable goals – population growth; migration; security – which didn't become part of the 2030 Agenda, perhaps because of being politically sensitive, but cannot be ignored since they are deep drivers affecting the environmental and social balance. We are aware that our effort is just an initial, amply perfectible attempt. However, we moved from one explicit consideration: The fact that the interconnections are difficult to draw doesn't justify not even trying to figure them out.

The remainder of the paper is organized as follows. Section 2 offers a background on SDGs documenting how non-systemic views are common among scholars and how the 2030 Agenda remains in some ways incomplete because of consensus constraints affecting the negotiating table where it was agreed upon. Section 3 hosts our main contribution which consists in fitting the SDGs+3 within a CLD based on priors. In Section 4 we gather and comment relevant contributions supporting our priors. Finally, in concluding, Section 5 draws the main implications of our SDG+3 map while stressing some caveats as well as proposals of further research avenues to be explored in the future.

1. Background on SDGs: The Diffusion of Non-Systemic Views and Three More SDGs

It is possible to document that non-systemic views of sustainable development are common among scholars who at times are oblivious of interlinks among SDGs or even view individual SDGs in isolation from the rest of the 2030 Agenda (Subsection 2.1). We also infer that, likely due to political constraints, three obvious SDG candidates were dismissed from the 2030 Agenda (Subsection 2.2).

1.1 The Diffusion of Non-Systemic Views

Although some scholars show awareness that SDGs are interdependent, many others seem to underplay interconnections or even look at individual SDGs as standalone objectives. Examples of this limit – excluding SDG17 (Partnerships for the goals) on means to implement the Agenda – may be: Cimadamore (2016) on SDG1 – Less poverty everywhere; Laborde et al. (2016) on SDG2 – End hunger / improve nutrition & sustainable agriculture; Kickbusch (2016) on SDG3 – Healthy lives at all ages; Rambla & Langthaler (2016) on SDG4 – Education & lifelong learning; Rosche (2016) on SDG5 – Gender equality; Hutton & Varughese (2016) on SDG6 – Water & sanitation; Pahle et al. (2016) on SDG7 – Reliable & modern energy for all; Frey (2017) on SDG8 – Economic growth & jobs; Vinzamuri et al. (2017) on SDG9 – Resilient infrastructure, industrialization & innovation; Kabeer (2016) on SDG10 – Inequality reduction among countries; McPhearson et al. (2016) on SDG11 – Inclusive & safe cities; Schuster & Torero (2016) on SDG12 – Sustainable production & consumption; Arndt & Tarp (2017) on SDG13 – Climate change & impacts; Cormier & Elliott (2017) on SDG14 – Conserve oceans – seas & marine resources; Andrew (2017) on SDG15 – Forest preservation & combact desrtitfication & biodiversity loss; Whaites (2016) on SDG16 – Peaceful & inclusive societies.

1.2 Three More SDGs

The process of consensus building made it difficult for negotiators of the 2030 UN Agenda to venture into politically sensitive terrain (see, e.g., Costanza et al., 2016). Perhaps the greatest fragility

of the 2030 Agenda is that the 17 SDGs lack a scale dimension. This is tantamount holding that resources were unlimited, which – as exemplified from the sustainability debate since the Club of Rome (Meadows et al., 1972) – would contradict in an exemplary way why we need a sustainable approach to nature, society, and the economy. The most obvious and neutral scale dimension can be found in the size and dynamics of the world's population. Thus, it is not by chance that some scholars advocate ways to abate population growth as key to achieving sustainable balance (see, e.g., Schneider et al., 2010) or even the SDGs themselves (see, e.g., Starbird et al., 2016).

The extent of migration is also a crucial omitted driver interacting in various ways with a system's sustainability. First, massive and costly migration may result from climate change related degradation (see, e.g., Warner et al., 2010) or loss of habitat (Sassen, 2016) or even from open conflict (Fiddian-Qasmiyeh et al., 2014). Also, displaced migrants may aggravate sustainability problems by over exploiting resources (Ratha et al., 2011). Finally, big migratory waves upset receiving countries' societies because of the challenge to integrate the migrants (Collier, 2013) and by seeding nationalist and populist political reaction which might destabilize democracy in those societies (Dunn, 2015).

The third and last additional SDG we propose regards security. The issue of overall security has become crucial and critical to any country in the planet. Some scholars draw a link between security and sustainable development (Hettne, 2010) while others stress the need to use the paradigm of complex dynamic systems which allows grasping global chaotic phenomena (Endrijaitis & Alonderis, 2015) that might follow the passage from single-U.S. to multipolar leadership (Acharya, 2018).

2. Fitting the SDGs to the CLD Method

A Causal Loop Diagram (CLD) represents the behavior of a system by showing a collection of connected nodes and the feedback loops created by the connections. A CLD helps visualize how different variables in a system are interrelated. One or more of the nodes represent the symptoms of the problem. The rest of the nodes are the causal chains causing the effect of the problem. So the diagram consists of a set of nodes and edges; nodes represent the variables and edges are the links that represent a connection or a relation between the two variables. A link marked '**+**' indicates a positive relation and a link marked '**–** ' indicates a negative relation. A positive causal link means the two nodes (variables) change in the same direction, i.e. if the node in which the link starts decreases (increases), the other node also decreases (increases). Similarly, a negative causal link means the two nodes change in opposite directions.

Closed cycles (loops) in the diagram are very important features of CLDs. A closed cycle (loop) is either defined as a reinforcing (amplifying – positive loop) or balancing (stabilizing – negative loop). A positive loop is a cycle in which the effect of a variation in the causal variable propagates through the loop and returns to the variable reinforcing the initial deviation i.e. if a variable increases in a reinforcing loop the effect through the cycle will return an increase to the same variable and vice versa. A balancing loop is the cycle in which the effect of a variation in the causal variable propagates through the loop and returns to the variable a deviation opposite to the initial one i.e. if a variable increases in a balancing loop the effect through the cycle will return a decrease to the same variable and vice versa. If a variable varies in a reinforcing loop the effect of the change reinforces the initial variation. The effect of the variation will then create another reinforcing effect. Without breaking the loop, the system will be caught in a vicious cycle of circular chain reactions. For this reason, closed loops are considered "decisional" critical features in CLDs.

Figure 1 depicts a possible overall SDGs Systemic View Causal Loop Diagram (including the three SDGs we added). In the map, by each different SDGs group color, named SDG subsystem, we consider the most interconnected set of goals having a common specific broad aim. For example, the SDG subsystem ***Natural Environment Impact*** (the green color goals) represents the set of SDGs which are mainly connected one to the other with the specific objective tackling Climate Change: Clean Water

and Sanitation (SDG6), Climate Action (SDG13), Life below Water (SDG14), and Life on Land (SDG15). In passing, this subsystem overlaps with the set of goals that Costanza (2014) labels Sustainable Scale: Staying within Planetary Boundaries, one of the Overarching Goals of the Sustainable Wellbeing Index (SWI) identified as Natural Capital/Ecosystem Services Contribution (Costanza et al., 2016).
Once the colored subdivision in Figure 1 is shared and provided the overall systemic view is agreed upon, one could (if necessary) analyze each subsystem with the strict consideration that the other connected SDGs are defined as external input or output variables for the subsystem under analysis.

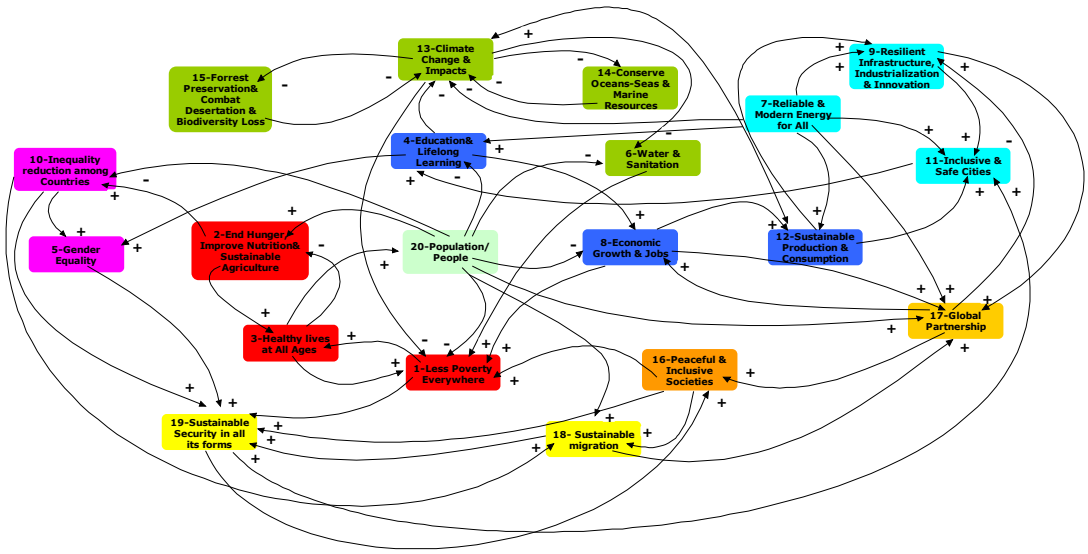

Figure 1 – A Systemic View of overall Sustainable Development Goals

The analysis depicts, from overall systems view, the reinforcing (+ve loops) and balancing (-ve loops) cycles. This will afford to better understand and evaluate alternative decisions in managing possible levers in order to proceed in the direction of reaching different goals linked together.

In order to illustrate the type of qualitative analysis hereby we present two simple examples:

1. A reinforcing /positive feedback loop (Figure 2) involving four different subsystems
2. A balancing/negative feedback loop (Figure 3) involving three different subsystems

Figure 2 depicts the circular path(cycle), starting from SDG 4 – Education Lifelong Learning which necessarily influences the increase of SDG 5 – Gender Equality which will contribute to Sustain Security in all its forms and hence increases the SDG 11 – Inclusive & Safe Cities that closes the loop by sustaining with positive sign the starting SDG 4.

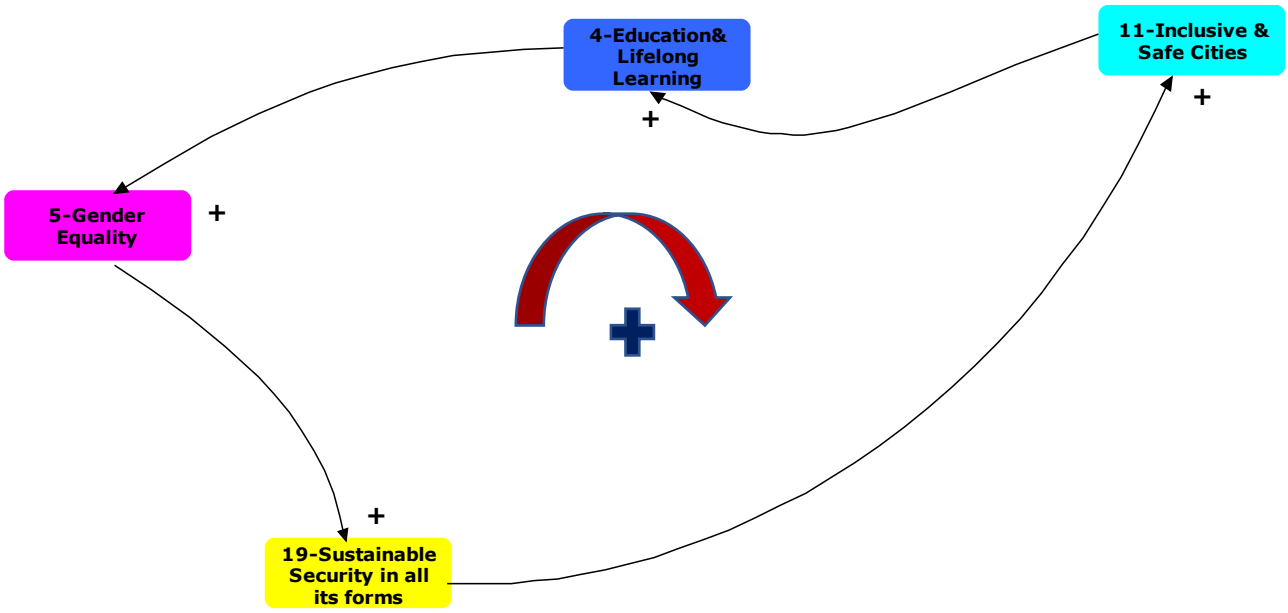

Figure 2 – A reinforcing loop extracted from the Systemic View of overall Sustainable Development Goals

Regarding the second example, Figure 3 points out another cycle, starting from SDG 6 – Water & Sanitation which necessarily influences positively the SDG 1 – Less Poverty Everywhere contributing in increasing SDG 3 – Healthy lives at all Ages which will grow up the Population causing a decrease in SDG 6 – Water & Sanitation, therefore closing the "balancing loop".

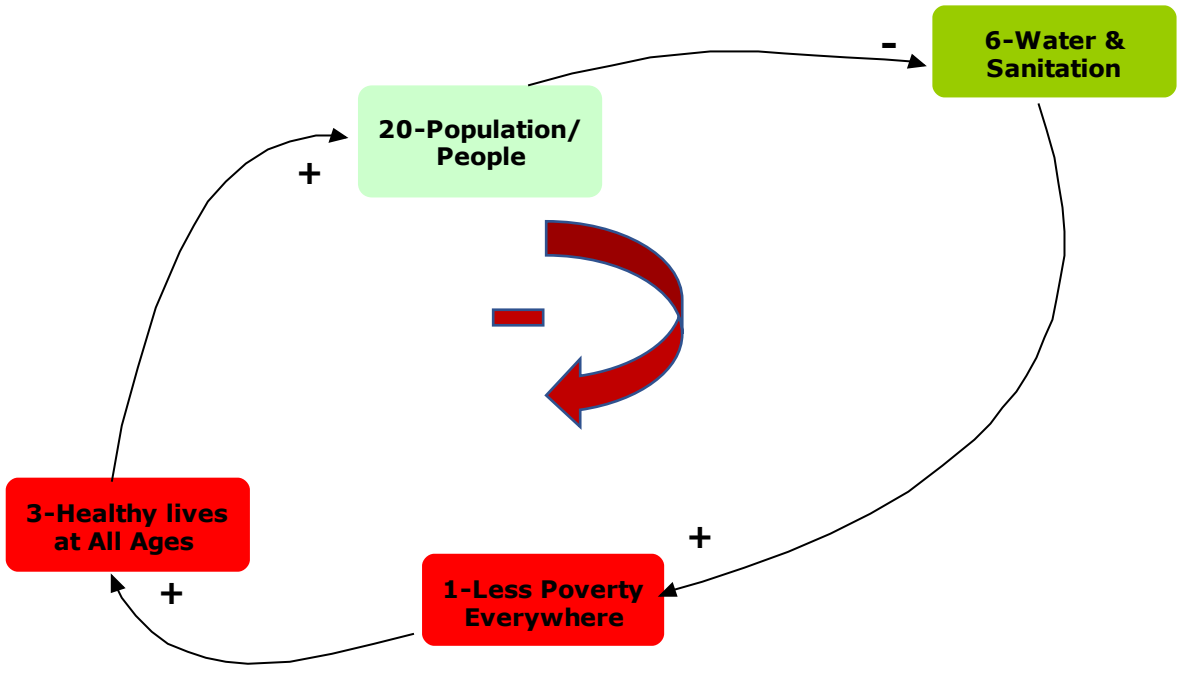

Figure 3 – A balancing loop extracted from the Systemic View of overall Sustainable Development Goals

3. Literature Support

Even though, as we saw in Subsection 2.2, many scholars consider each SDG as a standalone goal or, anyhow, understate the importance of interrelations with other SDGs, a new strand seems to be emerging which addresses the interlinkages among SDGs.

Among the contributions along this line, we note Le Blanc (2015) whose insightful analysis identifies the nodes among the first 16 SDGs. Specifically, excluding the parts of the Agenda relating to means of implementation – SDG17 (Partnerships for the goals) as well as 62 targets (of the total 169 targets associated to the SDGs) – his network analysis focuses on the remaining 107 targets relating to 'thematic areas'. 60 of the 107 targets explicitly refer to at least one other SDG than the one to which they belong. 19 targets link 3 or more SDGs. Such targets create indirect, or "third party" links among SDGs. For example, target 3.8 under SDG3 (Universal health coverage) refers to both inequality and poverty and so is counted as a link between SDG10 and SDG1, even though it does not belong to either SDG. Such indirect links are included in all the counts of links among SDGs. The identified links are: thickest between gender and education (SDGs 4 and 5), and between poverty and inequality (SDGs 1 and 10); strong between SDG10 and SDG16 on peaceful and inclusive societies as well as between SDG10 and SDG12 on sustainable consumption and production. Though this approach is very useful, its chief limit lays in drawing the network but falling short of marking the direction of causality and/or signing the effect and its intensity going through any link, as instead we proposed above.

In a refinement of the previous paper, Le Blanc et al. (2017) take the same approach to assess the linkages between oceans and other SDGs. The main progress here with respect to Le Blanc (2015) – even though the new paper focuses on only a subset of SDGs – is establishing not only the existence of a link but also marking the direction of causality between any two related SDGs. In spite of the methodological progress, even this paper does not venture into providing a sign to the identified causal links and a measure of their intensity, something that we have instead proposed in Section 3.

In turn, ICSU (2017) draws dense target-level interlinks among SDGs. Specifically, it argues that:

- SDG2–Hunger relates to SDG1–Poverty, SDG3–Health, SDG5–Gender, SDG6–Water, SDG7–Energy, SDG13–Climate, and SDG15–Life on land;
- SDG3–Health has main nodes with SDG2–Hunger, SDG8–Jobs, SDG11–Cities, and SDG13–Climate;
- SDG7–Energy links with SDG1–Poverty, SDG2–Hunger, SDG3–Health, SDG6–Water, SDG8–Jobs, and SDG13–Climate;
- SDG14–Life below water relates to SDG1–Poverty, SDG2–Hunger, SDG8–Jobs, SDG11–Cities, SDG12–Consumption, and SDG13–Climate.

Also, it recommends adopting a systems thinking view to assess the interactions among SDGs, as we tried to do above.

On their part, Singh et al. (2017) propose a 3-step hierarchical framework to characterize the relationships of SDG14-Life under water with the other SDGs' targets (excluding the instrumental Goal SDG17): 1) a relationship is determined (co-benefit, neutral, or trade-off); 2) relationships are considered "prerequisite" or "optional" if progress on the first target is needed to fulfill the second target, or not, respectively; 3) relationships are marked as either "context independent" – i.e., there is high confidence that achieving a specific SDG target contributes to a co-benefit (or trade-off) with another – or "context dependent" – indicating that the compatibility of the relationship is likely to be context-dependent. The authors identify a total of 742 relationships of the 7 SDG14 Ocean targets with the targets of the other SDGs. The vast majority of the relationships are neutral (475 or 64.0%); 96 (or 12.9%) are Co-Benefit / Prerequisite / Context Independent; 32 (4.3%) are Co-Benefit / Optional / Context Independent; 132 (17.8%) are Co-Benefit / Optional / Context Dependent; none is either Trade-off / Prerequisite / Context Independent or Trade-off / Optional / Context Independent; 7 (0.9%) are Trade-off / Optional / Context Dependent.

In another worthy study, Nilsson (2017) addresses the most important interactions between the targets of SDG1–Poverty, SDG2–Hunger, SDG3–Health, SDG5–Gender, SDG9–Innovation, SDG14–Life below water and other SDGs. Pairwise interactions are ranked along a 7-point descending scale:

+3 (Indivisible); +2 (Reinforcing); +1 (Enabling); 0 (Consistent); -1 (Constraining); -2 (Counteracting); -3 (Cancelling). The author reaches insightful conclusions and implications.

With a policy integration focus, Tosun & Leininger (2017) classify the policy coherence and forms of interlinkages between SDGs. In particular, they distinguish the forms of interlinkages between the SDGs into either Intersectoral or Multisectoral and the approaches to policy coherence into either Procedural or Substantive. Then they apply their method to 6 country cases: 3 centralized (Ethiopia, least developed; Turkey, middle income; Qatar, high income) vs 3 decentralized (Benin, least developed; Colombia, middle income; Switzerland, high income). The results are reported in an interesting matrix having SDG1 through SDG15 on the rows and SDG2–Hunger, SDG3–Health, SDG6–Water, SDG7–Energy, and SDG13–Climate on the columns.

Finally, Costanza et al. (2016) suggest clustering the 17 SDGs under the three elements of sustainable wellbeing (SWI): i) Natural Capital/Ecosystem Services Contribution – linked to keeping a Sustainable Scale staying within planetary boundaries (N); ii) Social Capital/Community Contribution – connected with a Fair Distribution protecting capabilities for flourishing (S); iii) Net Economic Contribution – guaranteeing an Efficient Allocation to build a living economy (E). The authors lament that the SDGs lack an overarching goal and an effective aggregate indicator of progress toward that goal and argue that such an aggregate indicator is necessary because SDGs are quite interconnected with each other. Thus, an aggregate indicator can assess the relative contribution of each SDG and the interactions among SDGs in order to gage overall progress. Besides using N, S, and E, they propose developing an underlying systems dynamics model to assess interactions and synergies over space and time, including both stocks and flows, causes and effects. This is exactly the direction we tried to go in Section 3.

4. Conclusions

This short work mainly sketched the systemic view of the 17 SDGs, while proposing to integrate three additional key goals: sustainable growth of the population, sustainable migration, and sustainable security in all its forms. The challenge we tackled was to put a milestone in applying the Systems Thinking approach to an extremely crucial multidisciplinary and complex issue such as managing the planet's sustainable development goals.

Our primary and most important conclusion is confirming and strengthening the conviction that the policy steps that will be taken to pursue any single SDG should always be managed with the awareness of the total effects on the overall SDGs. We are aware this research is in great need of refinements as also revealed by the growing strand of literature it is attracting.

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