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Sustainability Strategies: What's in a Name?

A Conceptual Restatement of Fundamental Mechanisms Toward Sustainability

Eric Hartmann

Leuphana University Lüneburg, School of Sustainability, Institute of Sustainability Governance, Lüneburg, Germany

Correspondence: Eric Hartmann (eric.hartmann@leuphana.de)

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ABSTRACT

Efficiency, consistency, and sufficiency are repeatedly discussed under the umbrella term sustainability strategies. However, their use is rather intuitive yet vague, lacking a conceptual foundation. This is particularly problematic as sustainability challenges necessitate effective and fast implementation of all strategies at hand. A deep conceptual understanding of such strategies is necessary but not yet provided by existing research. Therefore, this paper introduces a framework of sustainability strategies, founded on an explicated working conception of sustainability. On this basis, five intergenerational sustainability strategies targeting environmental impacts are discussed (population reduction, sufficiency, efficiency increase, consistency increase, regeneration expansion). Additionally, the paper introduces five intragenerational sustainability strategies targeting the intragenerational dimension of justice inherent in sustainability (capability empowerment, equalization, eco-efficiency increase, impact expansion, population reduction). For each strategy, potential contributions, limitations, and examples for practical implementation are briefly sketched. The main contribution of this paper is the introduction of a conceptually grounded framework of sustainability strategies. The framework may motivate further empirical studies regarding the importance of sustainability strategies in diverse contexts, as well as the practical implementation of all feasible strategies to face recent sustainability crises.

1 | Introduction

Even though sustainable development is well-established as a shared vision in politics, business, academia, and civil society, the world is currently facing multiple sustainability crises. As Richardson et al. (2023) reported, six of nine planetary boundaries are currently transgressed including climate change and biodiversity loss, threatening the safe operating space for humankind. The progress to reach the Sustainable Development Goals (SDGs) is not sufficient or has even regressed for about 80% of the measurable targets since 2015 (DESA 2023). Therefore, concerted efforts to foster sustainable development are necessary.

Here, sustainability strategies enter the stage. Sustainability strategies are often understood as mechanisms to foster sustainable development (Huber 2000a), usually focusing on environmental aspects. Efficiency, consistency, and sufficiency are repeatedly discussed under this label (Grunwald and Kopfmüller 2022), promising to tackle pressing sustainability crises. In some cases, they are discussed together in the context of specific challenges or topics (Allievi et al. 2015; Gunarathne and Lee 2021; Brinken et al. 2022; Rudolf and Schmidt 2025). In others, authors are focusing on one particular strategy and trying to demonstrate its potential (Weizsäcker et al. 1998; Huber 2000b; Sandberg 2021). Usually, sustainability strategies are not further defined but used in a seemingly intuitive yet vague way. Often, the work of Huber (2000a, 2000b) from the German sustainability debate is referenced as a starting point. Huber coined the term, presented a joint discussion of efficiency, consistency, and sufficiency, and loosely connected his perspective to the *IPAT* equation (Commoner 1971; Ehrlich and Holdren 1972). However, Huber (2000a, 2000b) does not present a conceptual foundation on what constitutes sustainability strategies. Furthermore, it is unclear what efficiency, consistency, and sufficiency have in common and whether there could be further sustainability strategies yet unknown.

Beyond the umbrella term, each strategy is advocated by a particular school of thought. Efficiency has a history as a central idea of capitalism (Princen 2005). The hope of positive impacts through efficiency increases is prevalent in the report to the club of Rome by Weizsäcker et al. (1998). By increasing the energy and material efficiency in production processes, resulting in increasing eco-efficiency (ibid.; Schaltegger and Sturm 1990), environmental impacts should be reduced without restricting production, consumption, and economic growth. Sufficiency is often presented as the alternative, stressing the necessity to reduce production and consumption. Hence, Princen (2005) elaborated his understanding of sufficiency as a general principle of 'enough' through a manifold critique of efficiency. Today, there is an increasing body of literature regarding sufficiency (Sandberg 2021; Jungell-Michelsson and Heikkurinen 2022) which often lacks conceptual clarity and preciseness (Spengler 2016; Hartmann 2024). Finally, Huber (2000a, 2000b) introduced the term consistency. Hereby, Huber shifts the focus to inconsistencies between industrial and natural metabolisms. He argues that consistency is the most important sustainability strategy, as efficiency and sufficiency are not able to prolong industrial production into the indefinite future. Nowadays, consistency gets ever more attention in the form of a circular economy (e.g., Ghisellini et al. 2016).

The lack of an elaborated conceptual foundation of sustainability strategies is particularly problematic, as they should contribute to solving pressing sustainability challenges. Hereby, a deep understanding of underlying mechanisms, potential contributions, and limitations is necessary but not yet provided by existing research. Exemplarily, efficiency increases dominated the fight against climate change in the past, though they cannot conclusively tackle the climate crisis due to fundamental inconsistencies (Huber 2000b). Therefore, the aim of this article is to found sustainability strategies on a comprehensive conceptual approach, based on the following research question: *Which sustainability strategies can be systematically identified based on an explicated conception of sustainability?* The article will start with the introduction of a working conception of sustainability (Section 2), founded on the capability approach (Nussbaum 2011), strong sustainability (Ott and Döring 2008), planetary boundaries (Richardson et al. 2023), the *IPAT* equation (Commoner 1971; Ehrlich and Holdren 1972) and relations of enoughness (Hartmann 2024). The main approach of the paper is to modify the *IPAT* equation based on basic mathematics and well-established conceptual insights and use the factors of the two resulting *IPSMT* and *SFED* equations as anchor points for respective sustainability strategies. On this foundation, sustainability strategies can be defined, systematically derived, and shortly discussed, forming a conceptually grounded framework of sustainability strategies (Section 3). In addition to efficiency, consistency, and sufficiency, further strategies are identified. Hereby, five intergenerational sustainability strategies targeting environmental impacts are discussed (population reduction, sufficiency, efficiency increase, consistency increase, regeneration expansion). Additionally, the paper introduces intragenerational sustainability strategies targeting the intragenerational dimension of justice inherent in sustainability and discusses five corresponding strategies (capability empowerment, equalization, eco-efficiency increase, impact expansion, population reduction). Hence, the main contribution of this paper is the development of a conceptually grounded framework of sustainability strategies. This framework may motivate empirical research regarding the use of such strategies in diverse contexts such as climate change policy and inform, as well as foster practical implementation to face recent sustainability crises.

2 | A Working Conception of Sustainability

The following discussion will be based on a working conception of sustainability (Figure 1), since an explicated understanding of sustainability is necessary to conceptually derive sustainability strategies. The main purpose of the working conception is the modification of the well-known *IPAT* equation (Commoner 1971; Ehrlich and Holdren 1972), based on well-established conceptual insights from the sustainability debate such as the capability approach (Nussbaum 2011), strong sustainability (Ott and Döring 2008) and planetary boundaries (Richardson et al. 2023). This will lead to two novel modified versions of the *IPAT* equation, namely, the *IPSMT* and the *SFED* equation. These two novel equations then can be used to define and systematically identify sustainability strategies by investigating the factors of the equations as anchor points.

Note that the working conception is based on normative assumptions that are the foundation for the resulting framework of sustainability strategies. The working conception will be explicated through relations of enoughness, which have been used to discuss diverse uses of sufficiency (Hartmann 2024). Generally, relations of enoughness have the form 'enough/too much/too little of X regarding Y', where X is called the object and Y is called the point of reference. The object causally influences the point of reference, while the point of reference defines how much of the object is 'enough', respectively 'too little' or 'too much'. Exemplarily, one can say that right now for an average person in Germany, there is too much individual consumption (object) regarding limited individual carbon budgets (point of reference). Furthermore, single relations of enoughness can be combined into chains of enoughness. The established structure and visual representations (Hartmann 2024) will be used in this paper to reflect on sustainability strategies.

As already argued (Hartmann 2024), the concept of sustainability can be understood as the application of the concept of justice to two dimensions: (1) intragenerational justice, targeting persons who already live on Earth today and (2) intergenerational justice, targeting persons who will live in the future, including future generations. However, different persons can have different ideas about what principles should be seen as just, leading to different conceptions of justice and sustainability (Rawls 1971; Hopwood et al. 2005). Following Princen (2005) and Huber (2000b), sustainability as a concept is concerned with the indefinite future.

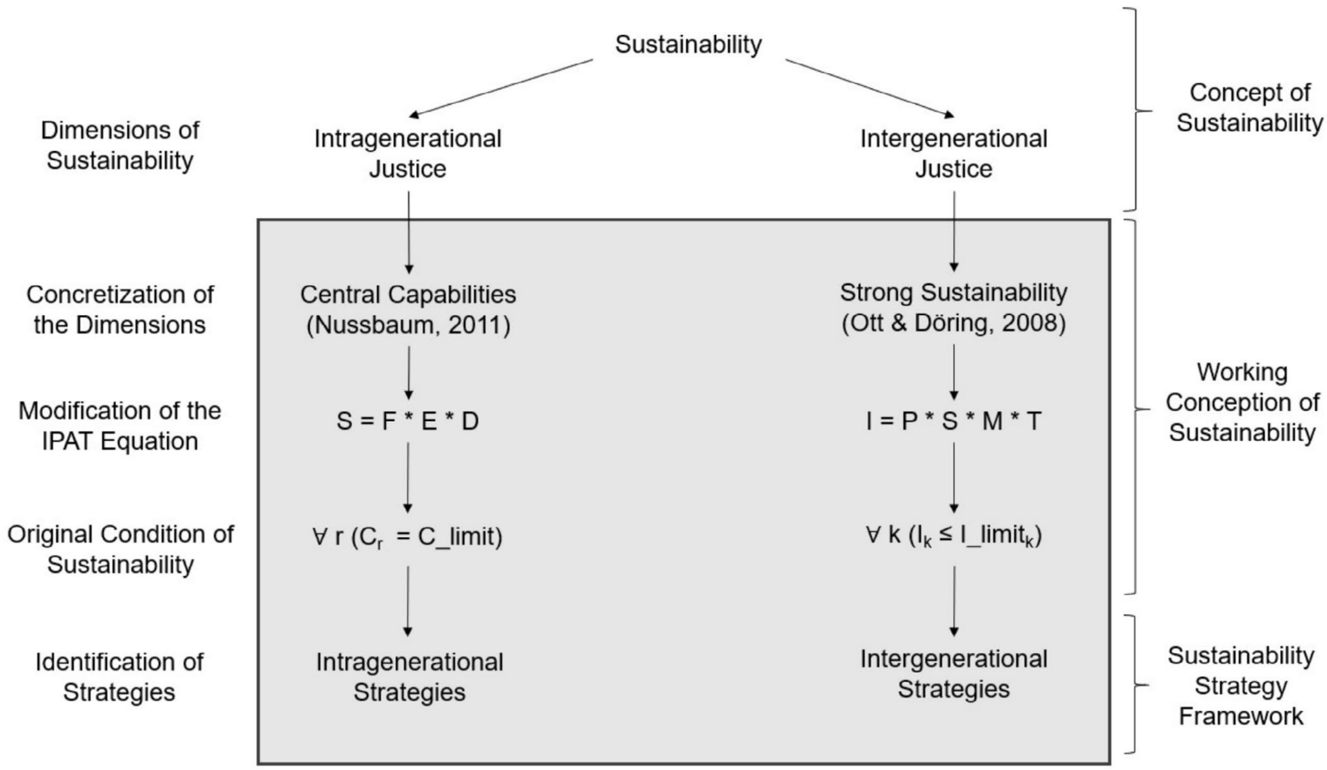

FIGURE 1 | The working conception of sustainability. Own illustration.

Let us explicate the assumptions of the working conception (Figure 1). Following the seminal work of Sen (1988) and Nussbaum (2011), a minimally just society can be defined as a society with institutions that guarantee a sufficient level of central capabilities to everyone. Capabilities are the possibilities to choose out of different functionings, representing options of human beings and doings. Nussbaum (ibid.) identifies 10 central capabilities which allow a life worth living with human dignity (regarding intragenerational justice), namely: life; bodily health; bodily integrity; senses, imagination and thought; emotions; practical reason; affiliation; other species; play; and control over one's environment. Derivable from this abstract list is—beyond political and social requirements—the access to fundamental goods such as shelter, energy, water, food, education, and medicine. As these central capabilities must also be guaranteed for persons living in the future and future generations, necessary natural capital and intact planetary processes must be maintained. The working conception of sustainability follows this assumption of strong sustainability that natural capital is essential in many cases, cannot per se be substituted through manufactured capital, and must not be destroyed (Ott and Döring 2008). The planetary boundaries framework serves as a starting point for considering different kinds of environmental processes and corresponding impacts (Richardson et al. 2023). Exemplarily, greenhouse gas emissions causing climate change can be conceptualized as environmental impacts that must be limited. Furthermore, the working conception of sustainability is anthropocentric and does not consider intelligent and sentient animals as beings with dignity and ends in themselves. Finally, the scope of the working conception is the global level, including all persons on earth living today and all relevant kinds of environmental impacts. Note that the difference between inter- and intragenerational justice is not congruent with the distinction between the ecological and social dimension of sustainability. Exemplarily, climate change as an environmental crisis threatens both, inter- and intragenerational justice.

In a next step, the working conception of sustainability is extended by the *IPAT* equation (Commoner 1971; Ehrlich and Holdren 1972). Through modification, two new equations will be introduced, namely the *IPSMT* and the *SFED* equation. In Section 3, the former is used to systematically identify sustainability strategies focusing on intergenerational justice, while the latter serves the identification of sustainability strategies concerning intragenerational justice. As argued by Chertow (2000), there are many versions of the *IPAT* equation, which cannot be discussed in detail. The fundamental idea is that environmental Impacts I can be calculated as the product of population P, affluence A, and technology T:

$$I = P^{*} A^{*} T \tag{1}$$

Following Ehrlich and Holdren (1972), it is assumed that this equation is true by definition as a mathematical identity:

$$I = P^{*} G / P^{*} I / G \tag{2}$$

Here, affluence A is explicated as economic goods per size of the population (G/P) representing mean levels of consumption. Furthermore, technology T is explicated as the impact caused by economic goods per amount or monetary value (I/G) representing eco-intensity, the inversion of eco-efficiency (Ehrenfeld 2005).

The *IPAT* equation enriches the working conception as it explicates that environmental impacts I produced by humans must be limited to conserve natural capital and fundamental environmental processes constituting planetary boundaries (Ott and Döring 2008; Richardson et al. 2023). This results in the first original condition of sustainability, as one can say that every environmental impact I must stay within a certain limit I_limit. These limits should be chosen following the precautionary principle, leaving adequate buffer before fundamental damage is caused and tipping points might be reached (Princen 2005; Rockström et al. 2009). As there are many different kinds of fundamental natural capitals, planetary processes, and environmental impacts, impacts of all relevant kinds k must be limited in such a way:

$$\forall k \left(I_k \leq I\_limit_k\right); \tag{3}$$

This first condition of sustainability targets the intergenerational dimension of justice inherent in sustainability. It can be interpreted as a relation of enoughness (Hartmann 2024), stating that there must be enough but not too much environmental impacts (object) regarding intergenerational justice (point of reference). Therefore, all relevant kinds k of impacts I must be smaller than or equal to their respective limits I_limit to allow the guarantee of central capabilities in the future.

Unfortunately, the intragenerational dimension of justice inherent in sustainability cannot be explicated by the *IPAT* Equation (1) as it does not provide an appropriate connection to central capabilities. Therefore, a modification of the *IPAT* equation is necessary. In a similar context, Kurz (2019) modifies the *IPAT* equation to include a factor for happiness. However, happiness and well-being are not adequate foundations for matters of social justice as, following Nussbaum (2011), justice is founded on central capabilities. The guarantee of central capabilities may not per se increase or maximize well-being or happiness, rendering them insufficient representatives of intragenerational justice. Instead, the *IPAT* equation can be modified with a metric representing the portion of guaranteed central capabilities, as Nussbaum (2011) presented an elaborated attempt to connect capabilities to matters of justice. Nussbaum introduces 10 central capabilities, which are incommensurable and must all be guaranteed above a threshold level to allow a life worth living. Inspired by Kurz (2019) and Nussbaum (2011), the *IPAT* equation can be modified in such a way to include guaranteed central capabilities:

$$I = P^* S^* M^* T; \tag{4}$$

This modification results in the novel *IPSMT* Equation (4), in which environmental impacts I are defined as the product of population P, the level of social, intragenerational justice S, the materiality of central capabilities M, and technology T. Therefore, the former affluence A is split into two new terms, social justice S and materiality M, to adequately represent the distinction between the consumption of economic goods and the guarantee of central capabilities. Again, Equation (4) is true by definition, as the terms can be explicated as follows:

$$I = P^* C/P^* G/C^* I/G; \tag{5}$$

This explicates that the level of social justice S is equal to the mean number of guaranteed central capabilities per person (C/P), while materiality M is equal to the consumption intensity of central capabilities (G/C), indicating how much consumption is caused per guaranteed central capabilities. The main contribution of this modification is to introduce guaranteed central capabilities C to the equation, allowing the application of the *IPSMT* equation to matters of intragenerational justice. As there are 10 central capabilities that all must be guaranteed beyond a minimal level for every person r (Nussbaum 2011), the individual level of guaranteed central capabilities C_r and overall social justice S can have values between zero and 10, where zero represents no guaranteed central capabilities beyond the minimal level and 10 is equal to all central capabilities guaranteed at least at the minimal level.

In the *IPSMT* equation, a second original condition of sustainability can be derived. To reach intragenerational justice, every person r must reach a minimal level of guaranteed central capabilities C_limit, equal to 10 out of 10 central capabilities guaranteed:

$$\forall r \left(C_r = C\_limit = 10\right); \tag{6}$$

The second condition of sustainability (6) can again be reformulated as a relation of enoughness (Hartmann 2024): If and only if the condition is fulfilled, there are enough but not too little guaranteed central capabilities for every person living today (object) regarding intragenerational justice (point of reference). Note that the capabilities approach (Nussbaum 2011) necessitates that the capabilities of one person do not compensate for the lacking capabilities of another person, which is adequately considered by Equations (4–6).

Given the interest in guaranteed central capabilities, it is useful to mathematically rearrange formula (5) to determine guaranteed central capabilities per person (C/P). This new arrangement (8) leads to the novel SFED Equation (7), which represents a further modification of the IPAT equation.

$$S = F^* E^* D; \tag{7}$$

$$C/P = C/G^* G/I^* I/P; \tag{8}$$

The *SFED* equation states that the general level of social, intragenerational justice S is the product of capability focus F, eco-efficiency E, and environmental degradation D. Again, the general level of social, intragenerational justice S can be explicated as the mean guaranteed central capabilities per person (C/P), where a value of 10 can be interpreted as a minimally just society, guaranteeing central capabilities to every person at least on a minimal level. Furthermore, capability focus F is explicated as the sum of all guaranteed central capabilities of all persons per economic goods (C/G), as a higher focus on capabilities leads to more capabilities with less consumption. Eco-efficiency E is used in the established sense as economic goods per impact (G/I), representing the inversion of technology T. Finally, environmental degradation D is explicated as the mean personal level of environmental impacts (I/P), as higher average environmental impacts foster degradation of the environment.

In circumstances in which (1) the production and use of economic goods usually causes environmental impacts of a certain kind, (2) these impacts are threatening to transgress the respective environmental limit, and (3) central capabilities are not guaranteed to everyone adequately, it is unjustified for a person to claim more environmental impacts of such kind than every person would get assigned through equal distribution. This results in a third, combined condition of sustainability (9), intertwining inter- and intragenerational justice, sharing fundamental assumptions with the environmental and climate debt approach (Warlenius 2018):

$$\forall r\ \left(I_{kr} \leq I\_acc_k / P\right); \tag{9}$$

$$I\_acc_k = I\_limit_k — I\_curr_k; \tag{10}$$

This third, combined condition (9) states that for every person r currently living, all environmental impacts of the relevant kind caused by her way of life I_{kr} must be kept smaller than or equal to the level of equally distributed maximally still acceptable environmental impacts I_acc_k/P. As explicated in Equation (10), the still acceptable environmental impacts I_acc_k are equal to the environmental limit I_limit_k minus the current level of environmental impacts I_curr_k. Exemplarily in the realm of climate change, the IPCC calculates I_acc as the remaining carbon budget from the beginning of 2020 (1.5°C, 50% likelihood) to be 500 $GtCO_2$ (IPCC 2023), which can be used to derive yearly individual lifestyle carbon footprints (IGES et al. 2019). If condition (9) is not fulfilled for an expanding timeframe, it results in historical responsibilities of polluters (e.g., of CO_2), resulting in environmental and climate debts (Warlenius 2018).

The *IPSMT* and *SFED* equations operate with accumulated variables such as environmental impacts, economic goods, and mean capabilities. It is not explicated yet how these accumulated variables result from the ways of life and the modes of production in given societies. This is a problem, as sustainability strategies should be connected to the global level and the working conception of sustainability, while also being applicable to concrete consumption and production processes.

Therefore, a micro-foundation of the *IPSMT* and *SFED* equations is necessary. This endeavor builds on the connection of the capabilities approach to social practice theory (Walker 2013). Walker discusses the capability of a person to keep warm. This capability references the ability of a person to execute concrete functionings of keeping warm, which can be acquired through different social practices. Social practices are founded on particular materials, competences, and meanings. One possible social practice contributing to keeping warm could be a person using a gas boiler to heat her flat. This practice builds on the existence of a working gas boiler (material), the knowledge of how to operate the boiler (competence), and gas boilers being an easy and independent way to heat a flat (meaning). Additionally, it necessitates the consumption of particular goods, which beforehand have to be produced. Following Marx (1989), the production process of the gas boiler can be disintegrated into a collection of acts of productive consumption, in which goods (metal, energy, labor force) are consumed to produce products (gas boilers). Beyond individual consumption, all these acts of productive consumption are necessitated by the practice of using a gas boiler. This perspective is in line with sustainable consumption literature which subsumes production into the acquisition phase (Geiger et al. 2017). Both individual and productive consumption might cause environmental impacts (greenhouse gas emissions) which can be connected to the social practice of using a gas boiler and the functioning of keeping warm. The case of capabilities as possibilities to choose out of different functionings is more complicated, as a person who benefits from the capability to keep warm does not necessarily decide to execute it. Therefore, it must be distinguished between the acts of consumption caused by the provision of the capability (e.g., the existence of gas infrastructure) and the acts of consumption caused by particular functionings (e.g., the used gas). The former can be equally distributed to all persons who can choose to execute the capability, while the latter can be connected to the person benefiting from executed functionings. Based on the capabilities and executed functionings of a single person r, it is possible to conclude if the minimal level of central capabilities is guaranteed for this person, based on her possibilities to perform respective practices. Though a challenge (Nussbaum 2011), operationalization and measurement of capabilities have been investigated recently (Comim 2009; Lorgelly et al. 2015; Ubels et al. 2022). However, these are rather problems of empirical research which is not the focus here. In conclusion, social practices contribute to guaranteeing central capabilities of individuals at the cost of necessitating environmental impacts. Hence, one can identify all the functionings, capabilities, necessitated economic goods in both individual and productive consumption, and caused environmental impacts for a single person r. The values used in the *IPSMT* and *SFED* equations are the result of global accumulation of these individual values for population P.

Finally, the two original conditions of sustainability can be located in a two-dimensional coordinate system, constituting an enoughness corridor (Figure 2). Here, the y-axis represents environmental impacts I, and the x-axis represents guaranteed central capabilities C. The two original conditions of sustainability generate four areas, joining the relations of enoughness of both dimensions of justice inherent in sustainability. Hence, sustainability is reached if and only if both conditions are fulfilled, meaning there is enough but not too much environmental impact I for all kinds of impacts k, as well as enough but not too little guaranteed central capabilities C for each person r. This intersection in which both dimensions are in the area of 'enough' can be called the enoughness corridor of sustainability. Hence, efforts toward sustainability can be understood as the co-management of the two dimensions of justice, represented by environmental impacts and central capabilities, connected and entangled by the *IPSMT* and *SFED* equations.

This section aimed at introducing a working conception of sustainability and discussing its conceptual foundations, consisting of an understanding of sustainability as enoughness, central capabilities, strong sustainability, and planetary boundaries, the *IPSMT* and *SFED* equations, and the two original conditions of sustainability. As will be shown, sustainability strategies are connected in a systematic way to the factors of the *IPSMT* and *SFED* equations and contribute to the fulfillment of the two original conditions of sustainability. This allows the definition and systematic identification of sustainability strategies in the following section.

3 | Defining and Identifying Sustainability Strategies

Sustainability strategies can be defined as original mechanisms that contribute to the satisfaction of the formerly introduced conditions of sustainability. The goal of sustainability strategies is to reach the enoughness corridor of sustainability. As there are two original conditions of sustainability, one for each dimension of justice (intragenerational and intergenerational), there are two resulting sets of sustainability strategies. Until now, sustainability strategies have been discussed primarily in an environmental context, yet sometimes considering implications on welfare (e.g., Weizsäcker et al. 1998). Hence, the idea of intragenerational sustainability strategies is newly introduced here.

In the following two subsections, sustainability strategies will be identified, and existing knowledge and examples for practical implementation will be outlined. Hereby, recurrent sustainability challenges will be covered, such as climate change mitigation (SDGs 7 and 13), no hunger (SDG 2), health (SDG 3), education (SDG 4), and inequality (SDG 10). By doing so, the transfer of the conceptual work into sustainability practice is promoted.

3.1 | Intergenerational Sustainability Strategies

Intergenerational sustainability strategies aim at reducing environmental impacts *I* and satisfying the intergenerational condition of sustainability (3): $\forall k \ (I_k \leq I\_limit_k)$. Based on the *IPSMT* Equation (4), explicated in formula (5): $I = P * C/P * G/C * I/G$, intergenerational sustainability strategies will be systematically derived by looking at the particular factors of the equation, from left to right. Intergenerational sustainability strategies contribute to sustainability by limiting or reducing environmental impacts *I* through targeting exactly one of the factors of the *IPSMT* equation (Figure 3 and Table 1).

The first intergenerational sustainability strategy with the goal to reduce environmental impacts *I* is population reduction, meaning to reduce the size of the population *P*. This argument has a strong history of thought: First articulated by Thomas Malthus (1998), targeting population growth was recommended by the Brundtland report (WCED 1987) and the focus of the original introduction of the *IPAT* equation (Ehrlich and Holdren 1972; Chertow 2000). As Bergaglio (2017) criticized, there is only little recent focus on the size and growth of the population in the context of sustainability. This might be due to the arguments that, first, countries of the Global North have been identified as being responsible for vast amounts of environmental impacts while having moderate population sizes and fertility; second, a stabilization of the global population is predicted during the twenty-first century; and third, there are moral and practical doubts if population control is ethically justifiable, appropriate, and feasible (Schmelzer and Vetter 2021; Grunwald and Kopfmüller 2022). Also, it must be mentioned that many countries in the Global North, such as Germany, are already affected by low fertility rates and aging, stagnating, or declining populations. This can challenge societies and their economies due to changing workforce and increasing demands of elderly care and pension payments (Brussig 2015; Ragnitz 2021; Blüher and Kuhlmey 2023). Yet, there are continuing voices stressing the importance of the size of the global population for sustainability

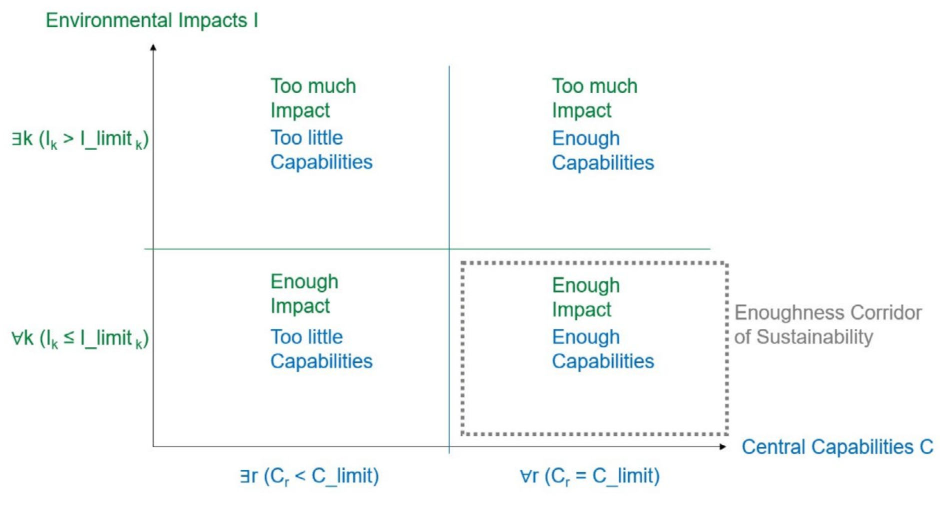

FIGURE 2 | The enoughness corridor of sustainability. Own illustration.

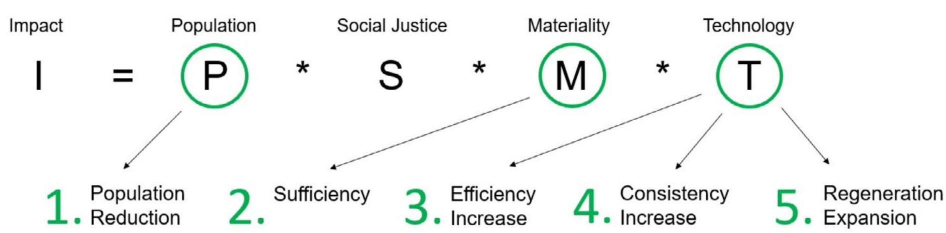

FIGURE 3 | The Conceptual Foundation of Intergenerational Sustainability Strategies. Own illustration.

TABLE 1 | The Five Intergenerational Sustainability Strategies.

Sustainability strategy	Relation of enoughness	Potential external limitations
Population reduction	Too much population regarding environmental impacts.	Individual choices.
Sufficiency	Too much consumption regarding environmental impacts.	Consumption necessary to guarantee central capabilities.
Efficiency increase	Too little efficiency regarding environmental impacts.	Knowledge-related and physical limits.
Consistency increase	Too little consistency regarding environmental impacts.	Knowledge-related and physical limits.
Regeneration expansion	Too little regeneration regarding environmental impacts.	Trade-offs due to limited resources.

(Ehrlich and Ehrlich 2009; Bergaglio 2017). Examples of practical implementations are measures supporting sexual and reproductive health care and allowing self-determined and voluntary family planning through access to modern contraceptive methods (Gaffikin and Engelman 2018), which are also founded in the SDGs and supported by the United Nations (DESA 2019). It must be stressed that sexual and reproductive healthcare and individual choices on reproduction are strongly connected to central capabilities following Nussbaum (2011), which therefore should be guaranteed in their own rights and must not be forced.

In general, the potential contribution of sustainability strategies can be explicated through relations of enoughness. Reconceptualizing population reduction (Figure 4), there is too much population *P* (object) regarding environmental impacts *I* (point of reference). Population reduction as a sustainability strategy contributes to sustainability by reducing the size of the population, ceteris paribus, resulting in reduced environmental impacts. All further relations of enoughness for intergenerational sustainability strategies are noted in Table 1.

The next candidate for an intergenerational sustainability strategy following the *IPSMT* equation would be to reduce social, intragenerational justice *S* in the form of mean guaranteed central capabilities (*C/P*). However, as guaranteed central capabilities per person are the central subject of intragenerational justice, this part of the *IPSMT* equation cannot be utilized to benefit intergenerational justice.

The second intergenerational sustainability strategy is based on the reduction of materiality *M*. Materiality *M* represents the consumption intensity of central capabilities (*G/C*) which indicates how much consumption is caused in relation to guaranteed central capabilities. This strategy to reduce materiality *M* can be referred to as sufficiency (Sandberg 2021; Hartmann 2024), meaning the change and reduction of consumption to reduce environmental impacts. As central capabilities must be satisfied for all persons due to intragenerational justice, consumption must be changed and reduced in such way as to not harm central capabilities. Hereby, it does not matter whether acts of consumption are executed by individuals (e.g., driving a fossil-fuel car) or as productive consumption by companies (e.g., using fossil resources in production processes). Therefore, sufficiency as a sustainability strategy does include changes and reductions in both individual consumption patterns (e.g., Sandberg 2021) and production processes (e.g., Jungell-Michelsson and Heikkurinen 2022). Sufficiency is a natural ally and serves as the preferred sustainability strategy of the degrowth paradigm (e.g., Schmelzer and Vetter 2021; Lage 2022). Lots of literature discusses measures implementing sufficiency, including changes initiated by consumers (like reducing air travel; Sandberg 2021), but also options for companies (Schneidewind 2012; Niessen and Bocken 2021) and politics (Schneidewind and Zahrnt 2014; Best et al. 2022). However, empirical research implies limits in the effectiveness of sufficiency measures that must be considered (Sorrell et al. 2020).

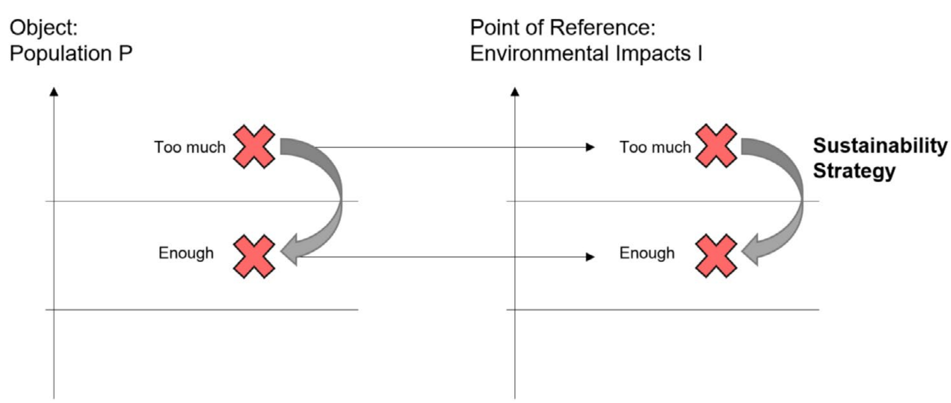

FIGURE 4 | Population reduction, reconceptualized as a relation of enoughness. Own illustration.

The last part of the *IPSMT* equation is the familiar term for technology *T*, representing eco-intensity (*I/G*). By reducing eco-intensity, environmental impacts can be reduced ceteris paribus. However, eco-intensity can be reduced in different ways: by (1) increasing efficiency in established acts of individual and productive consumption, (2) introducing more consistent acts, and (3) expanding regeneration, meaning to introduce acts of individual and productive consumption with net-negative environmental impacts. Efficiency and consistency are well-established as sustainability strategies in their own rights, which is convincing due to their different nature. Exemplarily, the CO_2 emissions per unit of produced energy (eco-intensity) can be reduced by (1) increasing the energy conversion efficiency of a coal-fired power plant (efficiency increase), as well as by (2) switching to renewable energy (consistency increase). Regeneration expansion, as a newly introduced strategy, is also based on a specific functionality and interaction with technology *T*. Therefore, efficiency increase, consistency increase, and regeneration expansion will be treated as separate strategies.

Efficiency increase represents the third intergenerational sustainability strategy. Princen (2005) identifies the nature of efficiency as a ratio between something good (e.g., produced commodities or economic value) and something bad (e.g., work, resource use, energy use, or pollution). The typical argument in favor of efficiency in the context of sustainability is that by increasing efficiency (e.g., produced units per pollution, material use or energy use), environmental impacts are reduced in relation to the produced goods. Thus, advocates as Weizsäcker et al. (1998) argue that efficiency must be increased. Efficiency increases through innovation and technology play an important role in the hegemonic green growth paradigm (Hickel and Kallis 2020). However, studies show that often an increase in efficiency does not lead to the promised reduction of environmental impacts as efficiency gains are compensated by rebound mechanisms (Lange et al. 2021). Additionally, some authors argue that there might be limitations to efficiency increases (Hickel and Kallis 2020), based on physical or knowledge-related limits. Princen (2005) states that efficiency is usually not increased ceteris paribus, but other entities such as production and consumption increase as a consequence. Though, measures targeting efficiency increases are widely discussed, also in the context of corporate sustainability (e.g., Bocken et al. 2014). The European Union has implemented energy efficiency policy (such as regulation, subsidies, and information) for more than 50 years and declared 'efficiency first' as a guiding principle (e.g., in the building sector, Economidou et al. 2020).

The fourth intergenerational sustainability strategy is consistency increase. As Huber (2000b) argues, consistency 'aims at an industrial metabolism that is consistent with nature's metabolism' (Huber 2000b, 269–270). Following Huber, efficiency increases happen within a given industrial metabolism through technological improvements, while consistency increases include fundamental changes in the mode of industrial production. Consistency is discussed with much attention as circular economy (Ghisellini et al. 2016; Grunwald and Kopfmüller 2022), though the link between both terms is often not explicated. Huber argues that consistency increases are superior to efficiency increases and sufficiency: If overall efficiency is doubled and consumption halved, it would take four times as long to cross environmental limits (like carbon budgets), but they would still be crossed eventually. In contrast, consistency increases can enable the expansion of sustainability into the indefinite future (Huber 2000b). In their comparison of consistency, efficiency, and sufficiency, Rudolf and Schmidt (2025) similarly conclude that consistency increases in the form of shifts to potential green technology corridors are of utter importance. Additionally, consistency has a definite goal in which natural and industrial metabolisms are entirely synched. Nevertheless, the potentials of consistency increases are limited, too. Following Hickel and Kallis (2020), even an entirely consistent economy powered by the sun, without greenhouse gas emissions and founded on circular design, will still occupy the natural environment such as material resources and land, thus forced to operate within environmental limits. In addition to regular, demand driven rebound effects, Figge and Thorpe (2019) identify a 'symbiotic rebound effect' based on opportunity costs in circular production regimes. Recently, consistency increases become ever more important. Renewable energies are central for tackling climate change as highlighted by the COP28 in 2023 (UNFCCC 2023), manifold supported through renewable energy policies such as feed-in-tariffs (Kilinc-Ata 2016). Focusing on closing material loops, corporate approaches like cradle to cradle (McDonough and Braungart 2002), as well as circular economy policy in the European Union and China (McDowall et al. 2017) are examples of practical implementations.

Regeneration expansion is the fifth and final intergenerational sustainability strategy. There is increasing attention on regeneration, yet without conceptual clarity. Literature discusses regenerative sustainability (Robinson and Cole 2015; Gibbons 2020; Tàbara 2023), regenerative social-ecological systems (Buckton et al. 2023; Tàbara 2023; Fischer et al. 2024), regenerative development and design (Reed 2007; Robinson and Cole 2015), regeneration and restoration in the circular economy (Morseletto 2020), among others (Gibbons 2020; Buckton et al. 2023; Fischer et al. 2024). Beyond academia, there is increasing interest from economic actors like the World Economic Forum in regeneration in business (van Heel 2023). However, the conceptual foundation of regeneration is quite vague. Overall, there are at least two reappearing components: First, regeneration represents a shift away from reducing environmental impacts to having overall net-positive or renewing impacts on nature (e.g., Reed 2007; Robinson and Cole 2015; Morseletto 2020; Buckton et al. 2023). Second, regeneration is discussed as a conception or even an alternative to sustainability, focusing on a holistic, systemic approach, and the embeddedness of human action in nature (e.g., Reed 2007; Gibbons 2020; Buckton et al. 2023). Following the first component, regeneration expansion as a sustainability strategy is founded in technology *T* of the *IPSMT* equation and understood as acts of individual or productive consumption that do not cause positive but net-negative environmental impacts, striving toward a negative eco-intensity. Here, one can distinguish a narrow and a broad sense. In the narrow sense, regeneration can be implemented through measures that are specifically designed to reduce environmental impacts, such as carbon dioxide removal (Smith et al. 2023) or ecosystem restoration (Yao et al. 2021). Regeneration in this narrow sense is not rooted in regular consumption, but takes up resources, labor force, and financial means, which may produce trade-offs (ibid.). In the broad sense, regeneration is claimed to possibly happen

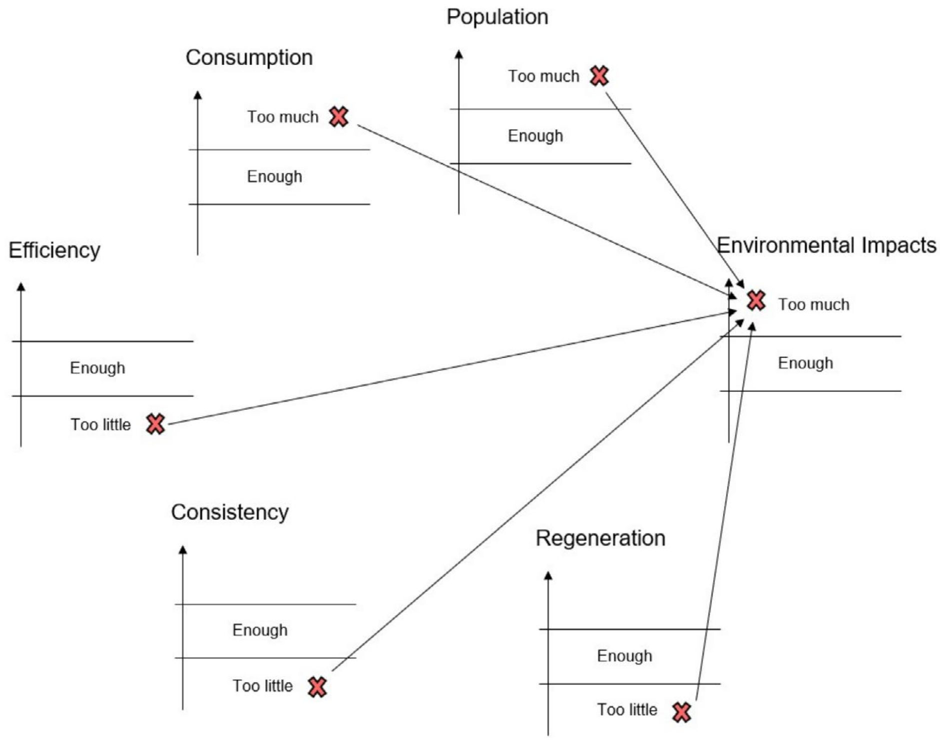

FIGURE 5 | Entanglement of relations of enoughness of population reduction, sufficiency, efficiency increase, consistency increase, and regeneration expansion. Own illustration.

in regular acts of consumption, too. This idea is advocated by McDonough and Braungart (2002) in their cradle-toto-cradle approach, stating that the design of products and services should always benefit people and regenerate the planet. However, such mainstreaming of negative eco-intensity cannot currently be observed empirically (Vadén et al. 2020). Regeneration expansion already plays an important yet underestimated role in climate change mitigation (SDG 13) as most of the paths compatible with the Paris Agreement are expecting extensive use of carbon dioxide removal practices. However, there is a lack of evidence supporting the possibility of a large-scale roll-out. Therefore, the promise of negative eco-intensity through regeneration expansion can indeed be harmful if it leads to less ambitious use of other strategies (Anderson and Peters 2016; McLaren 2020; Anderson et al. 2023; Smith et al. 2023).

The identified intergenerational sustainability strategies can be conceptualized as relations of enoughness (Hartmann 2024). Therefore, the question arises how the areas of 'enough' are respectively constituted. These areas of 'enough' cannot be determined separately, as the *IPSMT* equation connects all intergenerational sustainability strategies in the form of a mathematical product. Therefore, population reduction, sufficiency, efficiency increase, consistency increase, and regeneration expansion are entangled in such way that if and only if there is too much environmental impact, there must be too much size of population, too much consumption, too little efficiency, too little consistency, and too little regeneration simultaneously (Figure 5). As consistently discussed in the paragraphs of the respective strategies, there might be limitations to the potential contributions of each sustainability strategy, external to questions of intergenerational justice (Table 1). Exemplarily, a certain amount of consumption is necessary to guarantee central capabilities, and there might be knowledge-related or physical limitations to efficiency.

3.2 | Intragenerational Sustainability Strategies

Intragenerational sustainability strategies have the goal to guarantee central capabilities to every person and satisfy the intragenerational condition of sustainability (6): $\forall r$ ($C_r = C\_limit = 10$). Based on the *SFED* Equation (7), explicated in formula (8): $C/P = C/G * G/I * I/P$, intragenerational sustainability strategies will be systematically derived by looking at the particular factors of the equation, from left to right. Intergenerational sustainability strategies contribute to sustainability by increasing social, intragenerational justice S through targeting exactly one of the factors of the equation (Figure 6 and Table 2).

The first intragenerational sustainability strategy is capability empowerment, meaning to increase capability focus *F* explicated as the sum of all guaranteed central capabilities per economic goods (*C/G*). Guaranteeing a minimal level of central capabilities such as life, bodily health, and control over one's environment implies quite little consumption and environmental impacts, compared to consumption levels in the Global North. In some sense, capability empowerment is the complementary piece to sufficiency: While sufficiency eliminates acts of consumption not necessary for guaranteeing central capabilities, capability empowerment ensures everything necessary to guarantee central capabilities, including fundamental acts of consumption. By focusing on central capabilities in the production of economic goods, as well as the design of societal institutions and the (global) economy, central capabilities can be fostered through targeted action and policy. Key

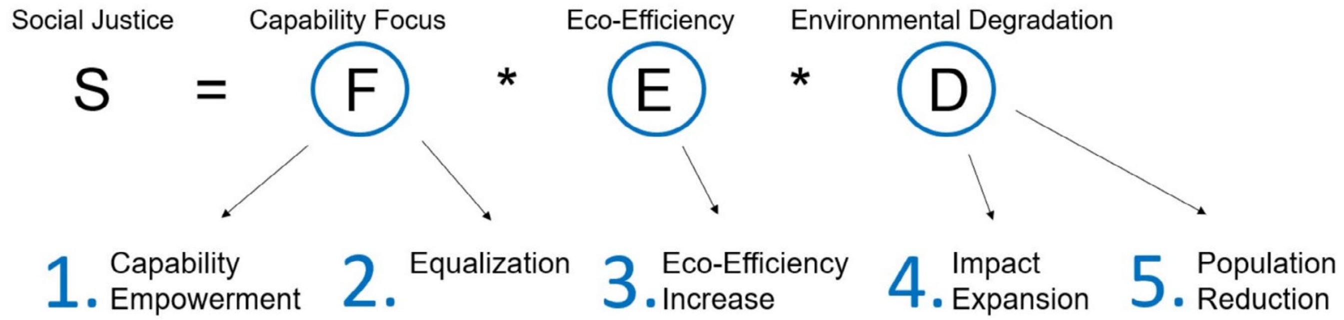

FIGURE 6 | The conceptual foundation of the intragenerational sustainability strategies. Own illustration.

TABLE 2 | The five intragenerational sustainability strategies.

Sustainability strategy	Relation of enoughness	Potential external limitations
Capability empowerment	Too little capability focus regarding guaranteed central capabilities.	Internal logic of incommensurable central capabilities.
Equalization	Too little equality regarding guaranteed central capabilities.	Societal acceptance; absolute equality.
Eco-efficiency increase	Too little eco-efficiency regarding guaranteed central capabilities.	Knowledge-related and physical limits.
Impact expansion	Too little environmental impacts regarding guaranteed central capabilities.	Limits of environmental impacts due to intergenerational justice.
Population reduction	Too much population regarding guaranteed central capabilities.	Individual choices.

in this endeavor is to not focus on general consumption or indirect benchmarks such as income or gross domestic product, but to consider which specific policies, institutions, and acts of consumption foster central capabilities. As a result of this insight, basic capabilities such as education, nutrition, health, and political participation have been included in international agreements, namely the Universal Declaration of Human Rights (UNGA 1948) and the Sustainable Development Goals (UNGA 2015). Hereby, the internal logics of incommensurable central capabilities (Nussbaum 2011) must be considered as these might limit certain attempts to increase capability focus. Exemplarily, providing more food of better quality might improve nutrition, health, and longevity (SDGs 2 and 3). But giving a person even more fish won't teach her calculus. Hence, the potentials of capability empowerment are limited to measures that particularly target lacking central capabilities. To foster education (SDG 4) through practical measures, the government could exemplarily implement compulsory education with public schools free of charge. For wealthy countries in the Global North, responsibilities go beyond the implementation in their own country and necessitate the support of capability empowerment in the Global South. Additionally, capability empowerment includes the rejection of globalized exploitation (Schmelzer and Vetter 2021) such as imperial modes of living (Brand and Wissen 2017) and ecologically unequal exchange based on disadvantaging trade regimes (Dorninger et al. 2021). An example for policy implementation is the German Supply Chain Act (Lieferkettensorgfaltspflichtengesetz; Grabosch and Schönfelder 2021) and the Corporate Sustainability Due Diligence Directive (CSDDD) of the EU.

The second intragenerational sustainability strategy is equalization. Matters of distribution are only indirectly included in the *SFED* equation, but must be investigated in detail. In a situation in which environmental impacts I must be limited but central capabilities are not yet guaranteed to all persons, claiming the right to cause more than an average share of the acceptable environmental impacts and related consumption is illegitimate. This is expressed through the third, combined condition of sustainability (9): $\forall r\ (I_{kr} \leq I\_acc_k / P)$. In such a situation, equalization of consumption and personal levels of environmental impacts is appropriate. As a result of successful equalization, the same amount of environmental impacts and economic goods will lead to more guaranteed central capabilities, hence increasing capability focus F through a changed societal distribution. While capability empowerment increases capability focus F by focusing on the guarantee of lacking central capabilities, equalization targets the distribution of environmental impacts and economic goods. Potentials of equalization could be limited by reaching absolute equality as well as social acceptance regarding related measures. Despite inequality being included in the SDGs (SDG 10), there seems to be a lack of interest for the connection between sustainability, inequality, and distribution in sustainability science, policy, and practice (Borowy 2019). Most people in the Global North benefit of material and financial wealth and are responsible for vast amounts of environmental impacts, while people in the Global South often suffer from lacking consumption and capabilities and are particularly vulnerable and exposed to the consequences of environmental crises such as climate change (UNDP 2019). Therefore, the material inequalities (consumption, financial means, guaranteed central capabilities), as well as the environmental inequalities (responsibility for impacts, vulnerabilities, exposure) are politicized by global environmental and climate justice movements (Warlenius 2018; Dutta 2022). These movements call for the acknowledgment of environmental and climate debts as countries in the Global North owe restoration and compensation to the Global South (Warlenius 2018). Borowy argues that for sustainable development, 'some form of absolute international redistribution' is necessary, 'in which the rich experience an actual reduction in their material income and wealth, the newly emerging societies accept stagnating levels while those at the bottom improve their standards' (Borowy 2019, 127). However, international redistribution is not strongly institutionalized. First attempts of implementation can be found in development assistance as well as compensation of climate debt, such as the loss and damage fund to support climate change adaptation in the Global South (Warlenius 2018; Borowy 2019; Wyns 2023). Beyond financial transaction, equalization includes ending globalized economic and social exploitation (Brand and Wissen 2017). Therefore, equalization transcends redistribution of financial and material means and includes the reconfiguration of the very social structures which determine the original distribution of money, goods and environmental impacts. However, the international political order is based on sovereign nation states, including both liberal democracies and authoritarian regimes. Therefore, the role of states in creating capabilities and facing ecological crises is crucial (Nussbaum 2011; Heinrichs 2022). Hence, the potentials of international equalization might be influenced by socio-economic foundations of capitalism and the national and global constitution of politics.

The third intragenerational sustainability strategy is to increase eco-efficiency *E*, explicated as economic goods per environmental impacts (*G/I*). In the context of intragenerational justice, the difference between efficiency, consistency, and regeneration is of less importance, therefore they are summarized in one strategy. By increasing eco-efficiency, the amount of consumption that is acceptable regarding environmental limits can be increased which may increase guaranteed central capabilities. This potential of eco-efficiency for welfare is already implied in the title of Weizsäcker et al. (1998) 'Factor Four: Doubling Wealth, Halving Resource Use'. The limitations of efficiency, consistency, and regeneration have already been discussed above and also apply here. Additionally, it must be noted that a mere increase of consumption through increases of eco-efficiency not necessarily benefits persons lacking central capabilities.

The last part of the *SFED* equation consists of environmental degradation *D*, explicated as the mean personal level of environmental impacts (*I*/*P*). An increase in environmental impacts per person ceteris paribus would lead to increased consumption and additional options for guaranteed central capabilities. This can be achieved in two ways, creating two further intragenerational sustainability strategies, namely population reduction and impact expansion. Population reduction has already been discussed in the context of the intergenerational dimension. By reducing the size of the population *P*, the mean personal level of environmental impacts can be increased by distributing the steady level of environmental impacts on a smaller number of persons. In the case of impact expansion, increased environmental impacts are distributed on a steady population, increasing mean personal levels of environmental impacts and leading to more possibilities for acts of consumption, functionings, and capabilities ceteris paribus. Hereby, human welfare is increased at the cost of the environment. This strategy has been extensively used during the industrial revolution and in today's fossil-based economy (Brand and Wissen 2017; Stearns 2021). Historically, in cases of lacking central capabilities and environmental impacts way below their limits, impact expansions might have been appropriate. Note that historically, resulting prosperity was not distributed equally and was based on both environmental and social exploitation. Therefore, mostly privileged parts of the global population benefitted and still benefit from impact expansions (Brand and Wissen 2017). As environmental impacts must be limited due to intergenerational justice and limits are transgressed in many instances (Richardson et al. 2023), this strategy is not acceptable anymore. This may lead to fundamental problems as economic stability seems to rely on continuing economic growth (Jackson 2009), while there is no evidence for fast and strong enough absolute decoupling of environmental impacts and the economy (Hickel and Kallis 2020; Vadén et al. 2020).

How about areas of 'enough' of intragenerational sustainability strategies? Again, they are mathematically connected by the *SFED* equation and entangled in such a way that if and only if there is too little guarantee of central capabilities, there must be too little capability focus, too little equality, too little eco-efficiency, too little environmental impacts, and too much population simultaneously (Figure 7). Again, the identified sustainability strategies might be limited externally (Table 2). Exemplarily, impact expansion is limited through matters of intergenerational justice, and equalization is limited by absolute equality.

4 | Discussion and Conclusion

This paper contributes twofold to sustainability sciences: (1) it founds a comprehensive understanding of sustainability strategies on an explicated working conception of sustainability to (2) identify and discuss potential sustainability strategies in a systematic manner. For the first time, the paper introduces the idea of intragenerational sustainability strategies and discusses the mechanisms, limitations, and existing implementations of diverse sustainability strategies. By doing so, this paper sets the basis for scientifically informed and targeted sustainability policy and practice.

The author is convinced that the used working conception of sustainability is well-founded as there is a recent convergence of conceptual perspectives. Regarding intergenerational justice, the importance to limit environmental impacts is stressed by approaches like the *IPAT* equation (Commoner 1971; Ehrlich and Holdren 1972), strong sustainability (Ott and Döring 2008) and planetary boundaries (Richardson et al. 2023). Regarding intragenerational justice, the need for an appropriate social foundation is stressed, by Nussbaum (2011) and the human development approach (Stewart 2019). With doughnut economics (Raworth 2018), sustainable consumption corridors (Di Giulio

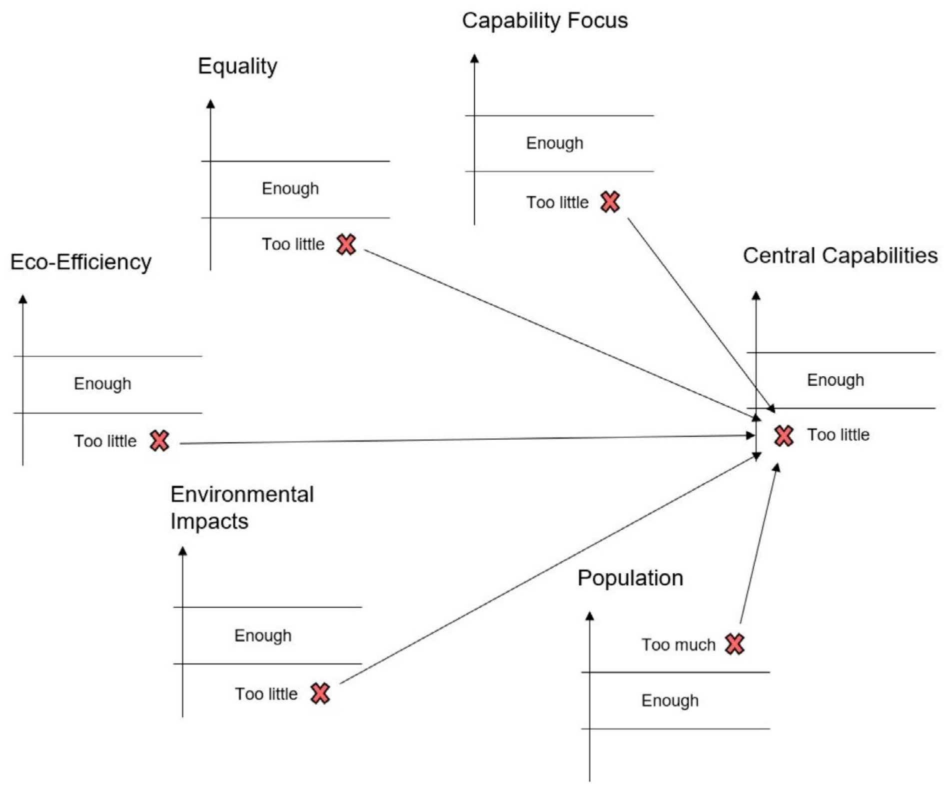

FIGURE 7 | Entanglement of relations of enoughness of capability empowerment, equalization, eco-efficiency increase, impact expansion, and population reduction. Own illustration.

and Fuchs 2014) and Spengler's understanding of sufficiency as minimum and maximum (Spengler 2016), at least three approaches conceptualize matters of sustainability in a similar way to the presented working conception. They all share the insight that certain environmental limits and basic social levels of rights and consumption must not be transgressed. Additionally, the sustainability strategy framework is well-connectable to diverse sustainability topics covered in the SDGs such as climate change, no hunger, health, education, and inequality, allowing fruitful application to sustainability practice and policy. The working conception has been constructed in the given way, as the connection of the work of Rawls (1971), Ott and Döring (2008), and Nussbaum (2011) provides the most elaborated understanding of sustainability as a matter of justice. However, other conceptions of sustainability might lead to other results. This is well-demonstrated by Figge and Thorpe (2023): Their judgment of sufficiency as a regret-option is the result of a different conception of sustainability based on abstract utilities. Conceptions of sustainability with other normative assumptions such as capabilities of animals (Nussbaum 2011) might necessitate an adaptation of the presented framework.

Additionally, the sustainability strategies framework refines the application of the capability approach to environmental sustainability. As Burger and Christen (2011) argued, the capability approach can serve as the foundation for a conception of sustainability, though it lacks considerations regarding environmental aspects. In this paper, the need to complement the capability approach was met through the inclusion of the *IPAT* equation (Commoner 1971; Ehrlich and Holdren 1972), strong sustainability (Ott and Döring 2008) and planetary boundaries (Richardson et al. 2023). Hence, the working conception follows the idea of flourishing within limits (Jackson 2009), embedding capabilities in an ethos of constraint (Peeters et al. 2015). With reference to the liberal tradition of Rawls (1971) and Nussbaum (2011), the presented approach argues that sustainability is a matter of justice. Therefore, guaranteeing central capabilities while limiting environmental impacts through the presented sustainability strategies must not be mistaken as preferences for certain kinds of a good life, but as a manifestation of a certain conception of justice and 'the right' (Peeters et al. 2015).

Furthermore, the modification of the *IPAT* equation in this paper serves conceptual purposes. Beyond conceptual work, the *IPAT* equation has been applied to empirical research through statistical models (Dietz and Rosa 1994; York et al. 2003; Shuai et al. 2017). The feasibility of the developed *IPSMT* and *SFED* equations for empirical research is not the scope of this paper and needs further investigation. Additionally, this paper focuses on the definition and conceptually guided identification of sustainability strategies. The developed framework would strongly benefit from application in empirical research.

Finally, the presented perspective on sustainability strategies does not focus on the socio-economic foundation of capitalist societies. Diverse strategies have connections to this topic, which have been sketched above. Following Laws (2015), the implementation of sustainability strategies can be understood as first-order sustainability policy. However, different authors stress repeatedly that modern capitalism cannot be sustainable without collapsing (Jackson 2009; Brand and Wissen 2017; Schmelzer and Vetter 2021). The question of if and how the socio-economic foundation must be transformed in the sense of a second-order sustainability policy (Laws 2015) requires further investigation. This also applies to the national and global constitution of politics (Nussbaum 2011; Heinrichs 2022) as a precondition of the implementation of sustainability strategies, which could not be covered in detail. Further investigation on the potentials and limitations of sustainability strategies as well as second-order sustainability policy in different national political circumstances, such as liberal market-based democracies, is necessary.

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Conflicts of Interest

The author declares no conflicts of interest.

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