English Summary

The effects of human activities have been shown across all parts of the Earth System. The concern is that the pressures of human activities will push the current Earth System state into a state less suited for humans. To avoid such shift in the Earth System, absolute Planetary Boundaries (PBs) were defined for nine Earth System processes which are considered essential for maintaining the Earth System’s stability. Thus, the PBs delimit a safe operating space for humanity to maneuver within. However, for humanity to govern and act within the safe operating space there is a need for enabling a disaggregation of the various drivers of pressures on the Earth System processes at the relevant scales (e.g. people, companies, industry sector, and countries). Thus, there is a requirement for operational methods that can enable decision-makers in e.g., industry and public policy, to apply PB thinking and take into account the need for staying within the safe operating space as part of strategic planning. In recognition of this requirement, the objective of this PhD-project was to develop operational Absolute Environmental Sustainability Assessment (AESA) methods using Life-cycle assessment (LCA). The intention was to enable decision-makers to apply PB thinking as part of strategic planning by allowing for quantifying impacts of an activity in the metrics of the PBs’ control variables and relate the quantified impacts to an assigned share of the safe operating space. Moreover, this project also sought to develop absolute sustainability references for human health which could be used in combination with the environmentally focused AESAs. This was needed as a one-sided focus on the natural environment could potentially lead to overlooking of important impacts on human health. The thesis summarizes in four core chapters the research that was carried out and described in six scientific articles.

Chapter 2 described the development of an operational Planetary Boundaries based life-cycle impact assessment (PB-LCIA) methodology for charactering results in the metrics of the PBs’ control variables. This included modifying the existing LCA framework to allow estimation of impact scores expressed as environmental states or as annual drivers or pressures. To enable this, it was specified that the functional unit should be defined as continuously providing a specific function. The result is that the life-cycle inventory (LCI) could be constructed to express the annual elementary flows associated with continuously fulfilling the function. The LCI which express annual elementary flows then feeds into the developed characterization models in the PB-LCIA in order to express impact scores in the metrics of the PBs’ control variables. The characterization models in the PB-LCIA were developed for all Earth System processes in the PB-framework, except for ‘Change in biosphere integrity’ and ‘Introduction of novel entities’. The characterization models provide a link between emissions of elementary flows and subsequent impacts expressed in the metrics of the PBs’ control variables. The applicability of the PB-LCIA was shown in a case study. This showed that the PB-LCIA
methodology could be applied in a conventional LCA and results could be expressed in the metrics of
the PBs’ control variables which could be related to the safe operating space.

Chapter 3 investigated how to distribute the safe operating space among anthropogenic activities. A
review of sharing principles used in previous AESA studies using the PBs was conducted. The sharing
principles retrieved from the reviewed studies were categorized according to sharing principle
categories founded in distributional justice theory. The review showed that the most applied sharing
principle for studies at country and person scale was an egalitarian equal per capita sharing principle.
Application of single stand-alone egalitarian sharing principles were from a people-perspective not
sufficient for studies at company and industry sector scale where an additional sharing principle was
needed. This should either be based on value (i.e. utility) or contribution to environmental impacts
(i.e. principles of acquired rights). A case study showed that choice of sharing principle was a large
source of uncertainty to the LCA-result compared to LCI uncertainty and uncertainty in the positioning
of the PB in the zone of uncertainty. Because the choice of sharing principle is subjective, a single
universal sharing principle for use AESAs could not be identified. Instead, transparency in the choice
of sharing principle was recommended and it was recommended to apply different sharing principles
to test the sensitivity of the results to choice of sharing principle. Moreover, it was recommended to
quantify the uncertainty related to choice of sharing principle together with other sources of
uncertainty e.g., by Monte Carlo simulation.

Chapter 4 looked into added value that AESAs using the PBs, such as PB-LCIA, can bring decision-
makers. Key differences between AESAs using the PBs and traditional LCAs were described. Firstly,
this included a new and different area of protection i.e., to protect the Holocene state. Secondly, the
introduction of environmental constraints extends the objective of an AESA using the PBs to seek to
minimize overall impacts while staying within the assigned share of the safe operating space. Thirdly,
a precautionary principle was applied for defining the PBs which is a requirement if the results of an
AESA using the PBs should align with the PB-framework. Added value to decision-makers from
performing AESAs using the PBs was shown in two case studies. The first case study showed that it
was possible to provide results which related impact scores of an activity to an assigned share of the
safe operating space. This allowed for evaluating whether or not impact scores for any of the impact
categories exceeded the assigned share of the safe operating space and whether this was dependent
on the choice of sharing principle. It was found that the choice of sharing principle could influence if
an activity is found to be absolutely sustainable or not. Thus, it was possible to indicate if the assessed
activity could be considered absolutely sustainably and, if this was not the case, indicate the
reductions required for the activity to become absolutely sustainable. This can be used to derive
sufficiently ambitious science-based reduction targets. Moreover, the ability to assess a suite of
impacts can reduce the risk of burden shifting from one impact to another. The second case study
showed how an extended version of the PB-LCIA methodology could be used to express the development in pressures over time which can allow decision-makers to make more informed decisions e.g., on the urgency of taking actions towards reducing pressures for different impact categories.

Chapter 5 described the development of a set of normalization references (NRs) which express tolerable damage levels (TDLs) on human health. The TDLs were derived by identifying socially determined guardrails for impacts on human health for the relevant impact categories in IMPACT World+. Characterization models were used for translating the guardrails into TDLs. The TDLs can be used as NRs to indicate the magnitude of the impacts associated with an activity relative to socially determined guardrails for impacts on human health. This can allow for identifying impact category impact scores which are uncharacteristically large relative to the tolerable damage levels and, thus, should be the focus of reduction to a level which is more in line with the TDLs. The TDL based NRs are intended for use in combination with AESA based NRs to facilitate absolute sustainability assessments (ASAs) which cover both the natural environment and human health.

In conclusion, this PhD-project has contributed to taking major steps towards operationalizing AESAs using the PBs and ASAs in general. This project has helped satisfy the demand for operational methods that make the ‘conceptual’ PB-framework applicable at the relevant levels where decisions occurs and which can enable decision-makers to apply PB thinking. Indeed, the application of AESAs and ASAs appears promising and such assessments can potentially provide an important contribution to science-based sustainability oriented decision-making. Still, further research is required on this topic. Particularly on the distribution of the safe operating space which require inputs from different scientific disciplines and other societal actors. Moreover, the developed PB-LCIA methodology is considered a proof-of-concept methodology. Thus, further development of the characterization models is recommended to increase their validity and predictive accuracy with regards to quantification of environmental impacts.