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Identifying gaps in social and ethical foresight methodology for nano-enabled advanced technologies

Session 34 @ STS Graz 2026

Chairs: Ineke Malsch, Carlos E. Gómez-Camacho, Fernand Doridot, Andreas Falk

Summary

Partners of the International Network Initiative on Safe and Sustainable Nanotechnologies (INISS-nano) are joining forces in developing and testing methodologies for Safe, Sustainable and Responsible by Design of nano-enabled advanced technologies.

The aims of this session at the annual STS Conference Graz, entitled „*Critical Issues in Science, Technology and Society Studies*“ 2026 were:

To refine social and ethical foresight with respect to “nano-enabled advanced technologies”. The scope of this topic included among others Ethical Impact Assessment (e.g. CEN CWA 17145-2, 2017, Malsch et al. 2024, UNESCO, 2023), Ethics by Design (e.g. Francis et al, 2023), Scenario Exploration Systems (e.g. European Commission, 2024), and Narrative ethics (e.g. Baldwin, C. (2015).

We invited participants in STS-Graz to submit papers demonstrating state-of-the-art social and ethical foresight methodology on key enabling technologies and advanced materials (AdMa), highlighting methodological weaknesses and opportunities for improvement of the methodology and its relevance to real-world impacts of AdMa and advanced technologies.

The aim was to focus the future research agenda in Safe, Sustainable and Responsible by Design (SSRbD) of nano-enabled advanced technologies on addressing these identified weaknesses and opportunities for improvement.

Presentations & discussions

Jesse de Pagter (CSI) reflected on ontological, epistemic and socio-economic challenges for STS foresight in Safe & Sustainable by Design (SSbD), inspired by his experience as STS-partner in the Bio-Sushy project: <https://www.bio-sushy.eu/>.

Andreas Falk (BNN) presented strengths and weaknesses of the establishment of a European and international ecosystem for Safe & Sustainable by Design of AdMa in the current InnoMatSyn project: <https://www.innomatsyn.eu/> and longer term INISS-nano initiative, including a pillar on ethics and RRI, coordinated by Ineke Malsch and Fernand Doridot:

<https://nsc-community.eu/cooperation/> inviting STS-researchers to join these networks as stakeholders.

Ineke Malsch (Malsch TechnoValuation) recalled recommendations for incorporating ethics in a professional SSbD training programme for professionals and researchers at STS-Graz 2025, to

stimulate anticipation by taking dreamed outcomes of research as starting point to reflect on ethical and societal implications. This approach was tested in two courses on ethics and RRI of nanomedicine. Three challenges were raised: Understanding what young researchers know and what they want to learn, Engaging Principal Investigators in dialogue about ethics together with young researchers, Balancing the role of Ethics expert and facilitator of mutual learning by participants.

Carlos Gomez (EMPA) explored ways to translate ethical principles and values into the hundreds of social indicators in current LCA databases, as a way to integrate ethics and responsibility in the quantitative SSbD methodology.

Fernand Doridot (ICAM) built on this by advocating the integration of responsibility in the SSbD framework, towards SSRbD. He also gave an overview of relevant ethical and philosophical approaches including ethics by design, ethical impact assessment, RRI and governance of use of technology.

Conclusion: SSbD was new to most STS-colleagues who participated in the session, and a key issue in the discussions was how to integrate STS and ethics and responsible research and innovation into the emerging SSbD framework, and more in general, to bring the STS and Ethics research communities closer to the SSbD community. To be continued.

Impression of the five talks and Q&A

Negotiating “Good Chemicals” through Safe and Sustainable by Design

Jesse De Pagter, Centre for Social Innovation, AT

JdP reports on the Bio-Sushy project, aiming for SSbD of PFAS substitutes. In this project, SSbD, based on the EU/JRC framework (2022, 2025/26) is combined with STS. A reviewer asked what 'negotiating' in the title means. This refers to technology and society co-shaping each other. What challenges can be identified? Combining SSbD and STS offers new possibilities for social and ethical foresight, as a next step in the history of chemical foresight, going back to the Alkali act (1863) addressing the severe impact on health & environment of industrialisation. After WW II, public awareness of impacts of chemicals increased, leading to institutionalisation of environmental regulations and the precautionary principle. In the 2000's the EU regulated governance of chemicals (REACH, ECHA: 'no data, no market'). followed by the formulation of SSbD in the 2020s, introducing anticipatory safety and sustainability in the design phase of chemicals. This is relevant for STS-researchers, because it opens a conceptual space enabling reflexive participation in the chemicals & materials domain. It also makes it possible to discuss socio-technical controversies. Negotiating new realities is possible in iterative assessment cycles where different types of toxicologists negotiate about exposure limits and hazard characterisations. Challenges for STS: foresight as part of design activities:

- Ontological: what is the object of anticipation? What is SSbD or tox-free?
- Epistemic: what can we credibly anticipate? Uncertainty and unpredictability
- Socio-economic challenges: context-adapted design, geopolitical and socio-economic constraints

Q: How does SSbD relate to ethics in chemistry. How well is it developed? I had not heard of it. Is STS involved in developing SSbD?

JdP: The connection has not yet been made, but I am trying to make the connection in the Bio-Sushy project.

CG: SSbD is a voluntary approach, it has been tried in few case studies. I hope big companies will adopt it.

Q: For epistemic challenges, refer to uncertainty management literature. Address uncertainty in an appropriate manner.

Societal Impact of the unique Advanced Materials ecosystem

Andreas Falk, Johanna Scheper, BioNanoNet, AT

AF: introduces BNN: <https://www.bnn.at/> and the InnoMatSyn project they coordinate: <https://www.innomatsyn.eu/>. Ecosystem thinking is a potential solution for making the European Advanced Materials (AdMa) ecosystem more sustainable. Challenges include economic borders (e.g., financial, resources, regulatory, policy, protective measures). To overcome them: identify fields of collaboration, agreements, standards, harmonisation, knowledge sharing, joint investments and calls for proposals, to achieve and generate synergy. Collaboration also brings risks, such as the technology leakage risk, where competitors use your technology against you.

InnoMatSyn establishes an AI-based knowledge repository for a Safe & Sustainable materials ecosystem. STS-researchers are invited to become stakeholders in InnoMatSyn and influence the policies.

Via the network INISS-nano we engage in cross-border collaboration, addressing regional and European differences, setting a common ground for industrial development. INISS-nano organised a session at STS-Graz 2025, on “*Ethical challenges & role of societal stakeholders for building a pan-European training partnership for (R&I) on safe and sustainable nano- and advanced materials*”. Now, via InnoMatSyn, BNN aims to *connect the dots* in governance of the allocation of resources, including best possible alignment of funding initiatives across borders. Accepting the identity of each individual stakeholder is important, and each level of the ecosystem must be involved. Defragmentation is critical; thus, it is important to reduce barriers and connect stakeholders to maximise impacts.

Q: What are advanced materials and why do you need a specific assessment methodology?

AF: AdMa are not yet defined as an ISO-standard, despite the fact that we have been working on such a definition already for 7 years, which is expected to be published next year. At the moment, to make clear what AdMa are the OECD working description is referred to. It covers amongst others nano-, bio- and biobased materials, and it is cross-sectoral, calling for assessment of safety, sustainability and societal impacts. We need specific assessment methodology (ref. to testing guidelines) to maximise positive impacts and integrate societal impacts in the impact assessment. By building an ecosystem, we create resilience.

Engaging young researchers in Ethical Impact Assessment of nanomedicine

Ineke Malsch, Malsch TechnoValuation, NL

In this presentation, experiences were shared in engaging young researchers in ethical impact assessment of nanomedicine in the VISION course on ethics of biomedical research (17 March 2022): <http://vision.sav.sk/index.html>, and in the workshop on ethics and RRI of nanomedicine in the MELOMANES MSCA doctoral network: <https://melomanes.eu/>. Methodological weaknesses and opportunities for improvement of the methodology were highlighted, as well as its relevance to real-world impacts of advanced materials and technologies. Feedback from the audience was explicitly invited. A key issue was how to balance stimulating the students to share their dreams and facilitating discussions, with bringing in your ethical expertise.

Q: How to institutionalise education of young researchers in Ethics? I teach ethics to engineering students in an elected course. I include anticipation in RRI, but in practice, it often becomes very speculative.

IM: engineering students have expertise in the technology, but not in the societal context. You could engage social science students, or stakeholder representatives in your course. Theatre workshops with professional actors are also used, in MELOMANES this was done by Frank Kupper, and here at STS-Graz 2026, there are also some presentations reporting on such theatre workshops.

From Social Indicators to Decision-Making: Overcoming the Integration Gap through MCDA and Monetization in Safe and Sustainable by Design (SsbD)

Carlos E. Gómez-Camacho, Roland Hischier, Swiss Federal Laboratories for Materials Science and Technology, CH

Life Cycle Assessment includes environmental and social LCA and Life Cycle Costing, but there is no common thread connecting the parts. LCA makes use of several indicators and databases, including the social hotspots database, PsiLCA, SoCQ, and UNEP methodological sheets. For social impacts and s-LCA, there are databases with hundreds of indicators. To select relevant indicators, you must first identify stakeholders and potential impacts, and then choose the indicators. Are these indicators linked to ethical or normative values? Which ethical values and which indicators can I find to assess the impacts in a quantitative manner? There are different approaches to quantify societal impacts. Monetization approaches (CE Delft) translate environmental and social impacts in monetary terms. Another approach is True pricing. You identify the midpoint impact, translate this to the related endpoint, and monetize. Indicators include welfare and human and environmental well-being, human health in DALY, ecosystem integrity in biodiversity loss, social well-being in labour and inequality. The MF-GDP uses valuation logics in GDP per capita, estimating the value of life impacts and societal importance. MCDA is used to combine the different criteria.

How to account for ethics in LCA and SSbD? Should it be separate or integrated? Using MCDA is compared to monetization approaches. It is important to better map ethical values to indicator pathways. Political decisions influence the importance of economic growth.

Q: ethical impacts and ethics by design, what does it contribute in addition to social LCA?

CG: e.g. avoiding child labour, is that an ethical value? It is linked to a social indicator. Identify a core value, such as gender equality. This is linked to indicators including the wage gap and numbers of women working in the sector.

It is possible to add uncertain monetizing factors. Will my assessment be better, or would a descriptive analysis be more appropriate? Approaches to ethics vary from qualitative via semi-quantitative (e.g. through questionnaire surveys), to qualitative. Qualitative assessments can be used in late stages of innovation, when you know your product will be working.

How important are externalities in the impact on the final user price of your product? If they are 10% of the value of your product, increase the price by 10% to cover the costs. If they are 400% of the value, this poses problems for your value proposition.

From Safe and Sustainable by Design to Safe, Sustainable and Responsible by Design: Bridging Sustainability and Ethics in the Governance of Nanotechnologies

Fernand Doridot, ICAM of Lille, FR

SSbD and the social dimension of LCA identify social impacts including Human Rights concerns, supply chain risks, socio-economic issues. It supports decisions and highlights trade-offs and risks. The methodological limits include: there is limited primary data, meaning that proxy indicators are used. Qualitative outputs raise difficulties for aggregation and comparison of alternatives. There are also conceptual limits. It is focused on impacts and risk factors, limited to the purpose of innovation, but weak on governance of the use of the products, and also offers limited insights in long-term trajectories. How to move from impact to responsibility for social and sustainability impacts and risks? In several projects, ethics and responsibility frameworks have been developed, addressing anticipation, reflexivity, inclusion, design for values, ethics by design, governance of use of technology, RRI and ethics by design (e.g. Satori, Sienna, TechEthos). Responsibility should address the purposes, values, governance and trajectories. Contrast acceptability versus legitimacy, perceptions and acceptance versus justification and values. Methodologies include ethical impact assessment, societal readiness tools, codes of conduct and stakeholder engagement. There is currently a fragmented landscape of SSbD and STS researchers focusing on ethics and responsibility. There is limited integration in practice. I call for integrating responsibility as a design parameter in Safe & Sustainable & Responsible by Design. This is complementary to SSbD, not

competing with it. It should include ethical reflection, governance of use, stakeholder involvement and societal expectations. SSRbD integrates SSbD, ethics and values.

Q: Does responsibility fit well in the new JRC SSbD framework, or is it not explicit enough?

Ethics is behind all LCA indicators, but can ethics be operationalised?

FD: we risk losing the context of ethics, but we can also win by integrating responsibility.

Q: Why has the integration of Responsibility in SSbD not yet been implemented? Why did the JRC not integrate the existing ethics concepts in the framework?

FD: this will be done. SSbD has been developed by scientists in cooperation with stakeholders, it must still be operationalised. There are contacts with ethicists, but it is difficult to link ethics and philosophy with different research cultures to the SSbD community. We have to link the communities behind SSbD and STS.

CG: here at STS-Graz, we bring SSbD to STS, but it is necessary to also bring more STS people to the JRC.

References:

Baldwin, C. (2015). Narrative Ethics. In: ten Have, H. (eds) Encyclopedia of Global Bioethics. Springer, Cham. https://doi.org/10.1007/978-3-319-05544-2_302-1

CEN CWA 17145-2: https://www.cencenelec.eu/media/CEN-CENELEC/CWAs/RI/cwa17145-2_2017.pdf

European Commission, Joint Research Centre, Mochan, A., Farinha, J., Bailey, G., Rodriguez, L., Zanca, F. and Polvora, A., Imaging the Future - Horizon scanning for emerging technologies and breakthrough innovations in the field of medical imaging and AI, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/1426669_JRC140099

Francis, B; Brey, P; Richardson, R; Umbrello, S; Porcari, A; Schepers, T (2023). D5.6 Ethical sensitivity tools: societal readiness tool and ethical role-playing tool. TechEthos Project Deliverable. Available at: www.techethos.eu

Malsch, I. Isigonis, Bouman, E. et al. Testing ethical impact assessment for nano risk governance [version 3; peer review: 3 approved, 1 approved with reservations]. Open Research Europe 2024, 3:170. [10.12688/openreseurope.16194.3](https://doi.org/10.12688/openreseurope.16194.3)

UNESCO Ethical Impact Assessment Tool of the Recommendation on Ethics of Artificial Intelligence (<https://www.unesco.org/en/articles/ethical-impact-assessment-tool-recommendation-ethics-artificial-intelligence>)

Falk, A.; Pogany, A.; Aungkavattana, P.; Bañares, M. A.; Beitollahi, A.; Bim, V.; Briffa, S.; Bochon, A.; Cassee, F.; Doridot, F.; Exner, T.; Farias, P. M.A.; Favre, G.; Franzese, G.; Friedrichs, S.; Hristozov, D.; Hunt, N.; Indaraprasirt, R.; Karim, Md. E.; Khandelwal, N.; Malsch, I.; Marcoulaki, E.; Marjovi, A.; Rasmussen, K.; Rocca, C.; Singh, P. P.; Thongkam, W.; Tsuruoka, S.; Wilkens, T. A. (2022). **INISS-Nano: revised concept and action plan (International Network Initiative on Safe and Sustainable Nanotechnologies) (Version 03)**. Zenodo. DOI: [10.5281/zenodo.7877359](https://doi.org/10.5281/zenodo.7877359)

Valsami-Jones, E., Cassee, F. R., Falk, A. (2022). **From small to clever: What does the future hold for the safety and sustainability of advanced materials?** *Nano Today*, 42, 101364. DOI: [10.1016/j.nantod.2021.101364](https://doi.org/10.1016/j.nantod.2021.101364)

Groenewold M., Bleeker E., Noorlander C., Sips A., van der Zee M., Aitken R., Baker J., Bakker M., Bouman E., Doak S., Drobne D., Dumit V., Florin M., Fransman W., Gonzalez M., Heunisch E., Isigonis P., Jeliakova N., Alstrup Jensen K., Kuhlbusch T., Lynch I., Morrison M., Porcari A., Rodríguez-Llopis I., Pozuelo B., Resch S., Säämänen A., Serchi T., Soeteman-Hernandez L., Willighagen E., Dusinska M., Scott-Fordsmand J., (2024). **Governance of advanced materials:**

Shaping a safe and sustainable future. *NanoImpact*, Volume 35, 2024, 100513, ISSN 2452-0748. DOI: [10.1016/j.impact.2024.100513](https://doi.org/10.1016/j.impact.2024.100513).

Soeteman–Hernández, L.G., Apel, C., Nowack, B., Sudheshwar, A., Som, C., Huttunen-Saarivirta, E., Tenhunen-Lunkka, A., Scheper, J., Falk, A., Valsami-Jones, E., Rocca, C., Brennan, M., Igartua, A., Mendoza, G., Midander, K., Strömberg, E., Kümmerer, K. (2024). **The safe-and-sustainable-by-design concept: innovating towards a more sustainable future.** *Environmental Sustainability*. DOI: [10.1007/s42398-024-00324-w](https://doi.org/10.1007/s42398-024-00324-w)

Wolf, C., Rudelstorfer, G., Leybold, C., Voglhuber-Höllner, J., Reinfelds, M., Weiner, A., Muriana, A., Lux, A., Mair-Bauernfeind, C., Falk, A. & Spirk, S. (2025). **Safe-and-sustainable-by-design redox active molecules for energy storage applications.** *Energy, Sustainability and Society*, 15, 10. DOI: [10.1186/s13705-024-00503-x](https://doi.org/10.1186/s13705-024-00503-x)

Sudheshwar, A., Apel, C., Kümmerer, K., Soeteman-Hernández, L.G., Scheper, J.K., Falk, A., Batel, A., Markard, J., Som, C., Wang, Z., & Nowack, B. (2025). **Safe and Sustainable-by-Design under The European Green Deal — Regulatory Readiness or Pressure for Companies?.** *Integrated Environmental Assessment and Management*, *vjaf188*. DOI: [10.1093/inteam/vjaf188](https://doi.org/10.1093/inteam/vjaf188)