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YOUNG ACADEMY SCIENCE DAY: SUSTAINABILITY

DIVERSE PERSPECTIVES ON THE ROLE(S) OF RESEARCH IN MASTERING SOCIO-ECOLOGICAL CHALLENGES

SCIENCE DAY: SUSTAINABILITY

DIVERSE PERSPECTIVES ON THE ROLE(S) OF RESEARCH IN MASTERING SOCIO-ECOLOGICAL CHALLENGES

LECTURES AND PANEL DISCUSSION ON THE 23RD OF SEPTEMBER 2022, ORGANISED BY THE YOUNG ACADEMY

ÖAW

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INTRODUCTION

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This publication presents the proceedings of the OeAW Young Academy's Science Day on sustainability. The event took place on 23 September 2022, on the day of the global climate strike. The background to the Young Academy's commitment to this subject is its determination to explore potential for more firmly embedding sustainability issues in its agenda.

Humanity faces a multiple sustainability crisis: global resource consumption has reached a level transgressing several planetary boundaries (including, e.g., climate change and biodiversity loss), while at the same time major societal challenges prevail, including ending hunger, reducing poverty, ensuring equal rights and sustaining world peace. Across disciplines, research addresses diverse and interconnected sustainability challenges, departing from diverging starting points and developing a plethora of theoretical and methodological approaches, problem diagnoses, and potential solutions. Despite having become a topic of public interest in recent years (e.g., in the context of the Sustainable Development Goals, the Paris agreement, and the climate movement), crucial evidence from sustainability research still does not feed sufficiently into political and economic decision-making to achieve ecological and societal sustainability goals.

In view of these considerations, and as groundwork for advancing its sustainability agenda, the Young Academy solicited positions from its members and selected guests in order to determine the bandwidth of approaches. Three questions were asked:

1) What characterizes the current sustainability crisis?
2) How would societies need to change to attain a transformation toward sustainability?
3) How can research contribute to mastering this challenge?

The responses and associations were diverse. The philosopher **Anne Sophie Meincke** sought solutions not only in political decision-making but in our very structures of thought. She proposes that the branch of philosophy known as metaphysics might contribute to overcoming unsustainable living practices. Meincke argued that today's ecological crisis has been facilitated by a 'metaphysics of things' that has long dominated Western thinking. The systemic change necessary to battle the ecological crises (also) requires thinking along the lines of a 'metaphysics of processes', however. Such an approach is currently gaining popularity among philosophers of biology.

The social ecologist **Simone Gingrich** presented insights from ongoing research on the long-term climate impact of land use. She introduced empirical quantifications of ecosystem carbon stock dynamics and agricultural greenhouse gas emissions

in several national case studies and at the global level, covering one to two centuries of data based on historical land-use statistics. Based on these data, she discussed trade-offs between forest recovery and agricultural intensification, aiming to draw general lessons for land-based climate-change mitigation.

Maximilian Hartmuth and **Tadej Brezina** inquired from their different backgrounds in the humanities and mobility research about structural and systematic obstacles to increasing sustainability in the mobility sector and its broader spatial planning contexts. Through a case study of a historic transalpine connection compromised by modern international borders (and resulting infrastructural divergences), they explore problem-solving scenarios for the short, medium, and long term. In so doing, they expose both potentials and limits to making European mobility more sustainable.

The Indologist **Nina Mirnig** and the archaeologist **Katharina Rebay-Salisbury** discussed how our dealings with the material remains of the past in humanities research might become more sustainable. They point to the fact that knowledge production cannot be easily sustained if the context of objects is disregarded. Through removal of artefacts from sites and the discarding of other layers, which often (but not always) occurs in the case of development-led excavations, they are being de-contextualized. In the authors' own projects in Central Europe and Nepal, alternative practices are being considered.

The energy economist **Johannes Schmidt** addressed the ambitious goal set by Austria to achieve climate neutrality by 2040, analysing historical emissions, current trends, and the necessary changes in emission rates to meet this target. He delved in detail into the heating sector, presenting three distinct and contrasting scenarios to highlight the challenges involved. Ultimately, he identified the existing barriers and enablers that must be navigated for the transition to be successful.

The experimental physicist **Birgitta Schultze-Bernhardt** introduced a novel technique for atmospheric sensing that utilizes dual comb spectroscopy. This cutting-edge approach offers an unparalleled combination of high temporal and spectral resolution, enabling the precise determination of atmospheric component concentrations. By shedding light on the mechanisms of photochemical reactions and their impact on atmospheric composition, this method has the potential to enhance our understanding of weather and climate patterns.

In the afternoon, a round-table discussion with the environmental scientist **Aleh Cherp** and **Simone Gingrich** followed, moderated by the journalist **Verena Mischitz**, who focuses on broaching environmentally relevant news, especially targeting younger audiences, in the Austrian daily *Der Standard*.

A concluding discussion among the Young Academy members assessed how these positions and the ensuing discussions might be used to influence the body's agenda-setting. In light of the diversity of approaches and perspectives, it was agreed that documentation of the event's contributions in the series *Akademie im Dialog – Forschung und Gesellschaft* may be a logical stepping stone in that process. Thus, what you are holding in your hands is a preliminary output of this exchange, a collection of inputs, and by no means a treatise on sustainability. If anything, it demonstrates that sustainability can, and must, be conceived as a multidimensional challenge affecting ecological, socio-economic and cultural processes.

WHY WE NEED A PROCESS METAPHYSICS OF SUSTAINABILITY

ANNE SOPHIE MEINCKE

Anne Sophie Meincke is an Elise Richter Senior Research Fellow at the Philosophy Department of the University of Vienna.

Metaphysics as an academic discipline investigates the basic structures of reality: What exists most fundamentally and what does it mean for something to exist? In a looser but related sense, the term 'metaphysics' may refer to the supposed answers to these questions: to the set of most fundamental beliefs about reality that tacitly or explicitly inform a given community's intellectual and practical engagements with reality at a given time.

In the Western world, man's relationship with reality has been dominated over the last two millennia by a particular type of metaphysical beliefs, namely by what I call a *metaphysics of things*, or *thing ontology*. *A metaphysics of things* is a metaphysics according to which reality most fundamentally is made up of things. A *thing*, metaphysically speaking, is an entity for whose identity change is not essential. It does not need to change in order to exist. Those things – known among philosophers as 'substances' – are supposed to be ontologically independent and clearly demarcated from one another.

My thesis is that this type of metaphysics has facilitated the practices which led to today's ecological crisis. It has done so, most importantly, by fostering dualism and a particular type of rationality. So far the bad

news. The good news is that we can change our most fundamental beliefs about reality. We can adopt an alternative metaphysics: a *metaphysics of processes*, or *process ontology*, according to which reality is fundamentally processual. My – second and positive – thesis is that a metaphysics of processes can support the systemic change needed to overcome the ecological crisis.

METAPHYSICS OF THINGS: SUBSTANCE DUALISM

Historically, there have been different versions of a metaphysics of things. One of these is Descartes' substance dualism. According to Descartes, there are exactly two kinds of substance: *res extensa* (the extended substance or thing) and *res cogitans* (the thinking substance or thing). Nature is *res extensa*, i.e. mere matter subject to the physical laws of Newtonian mechanics. This implies that animals are mindless automata. By contrast, humans are considered to be *res cogitantes* (minds) contingently attached to a *res extensa* (body).
Descartes argued that the *res cogitans* can recognize itself as being ontologically independent of the *res extensa*, as expressed by the slogan "Cogito ergo sum": we can doubt the existence of material things, including our own bodies, but we cannot doubt our existence as immaterial things while we doubt. The cogito argument was defining for the subsequent development of Western philosophy. Supposedly providing a firm foundation for knowledge, it helped initiate what is now known as Enlightenment: an intellectual movement of the 17th and 18th centuries that sought to promote human progress through reason and science.

SAPERE AUDE! ENLIGHTENED ABSOLUTE AUTONOMY

Enlightenment, as Immanuel Kant, its probably best-known advocate, puts it, "is man's emergence from his self-incurred immaturity [*Unmündigkeit*])" (1991 [1784], p. 54). To become mature, man must think for himself instead of blindly accepting the dogmas taught by institutions such as the church and the monarchy. *Sapere aude!* – dare to know! – is the motto of Enlightenment.
More specifically, the Enlightenment movement is characterized by three core tenets: (i) *rationalism*, i.e. the idea that knowledge is primarily gained through reason; (ii) *individualism*, i.e. the idea that man (i.e. the class of all male humans; women were not usually included here) has dignity and individual rights, e.g. to life and liberty; (iii) *autonomy*, i.e. the idea that we (men) ought to have full authority over our actions, being unaffected by feelings, inclinations and any other aspects of our personal lives (women, Kant believed, could in principle achieve this kind of autonomy but usually lack the courage to do so).
According to Kant, the most perfect expression of autonomy is man's free self-subjection to the moral law. The Kantian transcendental subject exercises absolute self-legislation in a noumenal world of freedom – detached from the empirical realm of nature, which is governed by deterministic laws.

THE DARK SIDE OF AUTONOMY OR: THE DIALECTIC OF ENLIGHTENMENT

Most people in the Western sphere think that, overall, the Enlightenment was and is a good thing. Without it, we would still live under medieval conditions. There would be no liber-

al society and no science in a proper sense. The flourishing of the sciences that we see today is a direct result of the endeavour of Enlightenment.

Yet, the Enlightenment has been subjected to criticism. Investigating, in their influential 1944 book *Dialectic of Enlightenment*, the conditions under which fascism could arise, German thinkers Max Horkheimer and Theodor Adorno diagnose a failure of the project of Enlightenment due to its identification of reason with instrumental reason, i.e. a type of rationality that aims at the "subjugation of everything natural to the sovereign subject" (p. xviii). Instrumental reason engages in a threefold domination: over the external nature, over our internal nature and over other people. As a result, "humanity, instead of entering a truly human state, is sinking into a new kind of barbarism" (p. xiv).

Horkheimer and Adorno were mainly concerned with the state of society (fascism and capitalism), but their analysis applies to the current ecological crisis too: the metaphysics of mastery that underlies Enlightenment thinking facilitates the grand scale exploitation of (external) nature that we have been seeing since the industrial revolution. In the light of this, calls for a New Enlightenment have been raised. The key claims, some of which are laid out by French philosopher Corine Pelluchon in her 2021 book *Les Lumières à l'Âge du Vivant (Enlightenment in the Age of the Living)*, are that reason needs to distance itself from instrumental reason, and that the subject must be reconceived as relational and dependent instead of absolute and atomistic, and, likewise, as carnal and finite, not abstract and noumenal.

A METAPHYSICS OF PROCESSES: RETHINKING OUR RELATIONSHIP WITH NATURE

Currently, a metaphysics of processes is becoming increasingly popular among philosophers of biology. This is in recognition of the fact that life is dynamic at all levels of organization and on all time scales. Clearly, evolution is a process; one that continues to create ever new species. Just as dynamic is development, the process that creates individual members of species. And none of this happens in a vacuum – how evolutionary and developmental processes proceed depends on the environments in which they take place. Whatever lives manages to do so only through continuous interactions with surrounding beings, whether these be conspecifics, organisms of other species or elements of the abiotic environment (Meincke 2019a, 2019b, 2021).

By conceptualizing reality in terms of dynamic networks rather than static assemblages of things, process metaphysics enables us to reconceive our relationship with nature and with one another. There is no doubt that humans are part of nature and depend on it, just as on other humans. A process ontological perspective can make perfect sense of the relational constitution of human selfhood, as stressed by proponents of the New Enlightenment. It replaces the divisions and dichotomies characteristic of traditional thing ontological thinking with an emphasis on interconnectedness.

A PROCESS METAPHYSICS OF SUSTAINABILITY: TOWARDS A NEW ENLIGHTENMENT

Process metaphysics provides us with a framework for reconsidering and revising the key concepts of Enlightenment. Here are my suggestions.

First, rationalism must deploy a humble notion of rationality. Reason is indeed what saves us; however, this is true only for the right kind of reason: a reason that is aware of both its inner limitations – its being prone to error – and its outer limitations – its being embedded in multiple systems that facilitate it, with society being one, and the ecosystem being another and even more fundamental one. The point, thus, is not to denounce reason and to advocate a new irrationalism; on the contrary, reason ought to be broadened to include non-instrumental forms of rationality.

In contrast to the classical conception of autonomy, reason can allow itself to be guided by sentiments and values. A process metaphysics of sustainability suggests that among these ought to be sentiments and values that reflect an appreciative and respectful attitude towards non-human living beings and inanimate nature, as opposed to the exploitative attitude facilitated by a metaphysics of mastery. Without compassion and moral compass, reason is liable to turning into an instrument of evil, as shown by Horkheimer and Adorno. This means, *second*, that acts of autonomy must display responsibility. Importantly, wo*man has a responsibility not only towards other people, but also towards nature, of which s*he is a part. So we may, *third*, want to consider discarding individualism in favour of a global communitarianism that includes non-human species.

I believe these intellectual moves are crucial to complement and support ongoing and future efforts in science, technology, economics and politics towards a more sustainable way of human life on this planet. To make these moves, we need a process metaphysics of sustainability: a metaphysics that, recognizing the dynamicity and interconnectedness of reality as a whole, reunites us with the process of nature instead of misconceiving of humans as spiritual things entitled to master supposedly mindless natural things.

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THE SUSTAINABILITY IMPLICATIONS OF LAND USE

A LONG-TERM SOCIO-ECOLOGICAL ASSESSMENT OF GREENHOUSE GAS IMPACTS

SIMONE GINGRICH

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In the project HEFT ("Hidden Emissions of Forest Transitions: GHG effects of socio-metabolic processes reducing pressures on forests"), funded by the European Research Council (ERC-StG 757995), I investigate with my colleagues[1] the sustainability challenges associated with land use in a long-term perspective.

The sector 'agriculture, forestry and other land use' currently causes about one quarter (22%) of annual anthropogenic greenhouse gas emissions (IPCC, 2022). Major processes include deforestation, causing CO_2 emissions, and livestock rearing and management (particularly ruminants like cattle), causing methane emissions. But terrestrial ecosystems not only act as sources of emissions due to land use, they also act as carbon sinks because they take up, or se-

[1] For a list of all project collaborators, see http://heft.boku.ac.at

quester, carbon in vegetation and soils. Overall, ecosystems still act as net carbon sinks today, despite ongoing emissions from land use.

In some countries, this sink function dominates, particularly in countries of the Global North where forests are recovering. This is where my research sets in. I am interested in how forest recovery emerges and how forest recovery is connected to other emissions and processes enabling it. This contribution focuses on the question of how ecosystem carbon dynamics and agricultural emissions evolved over time. We know that agricultural intensification increases emissions. On the other hand, intensification also reduces the demand for agricultural land through 'land sparing'.[2] There seems to be a double effect: forest recovery and ecosystem carbon sinks coincide with increased emissions from agricultural intensification.

So, is there a systematic trade-off between ecosystem carbon sinks and additional agricultural emissions? My contribution presents intermediate results on long-term trends in both agricultural emissions and ecosystem carbon dynamics, based on historical records. We work with historical agricultural and forestry statistics and a bit of modelling on national as well as global scales.

First, let us look at forest dynamics: what did forest recovery look like in different countries? Some examples of countries we have been studying: Austria, Spain, and France (Gingrich *et al*., 2022; Infante-Amate *et al*., 2022). All of these countries have experienced forest expansion since at least the 19th century: France and Austria sometime in the early or mid-19th century, Spain only in the mid-20th century. Not only forest area, but also forest biomass density, i.e. the amount of biomass per unit of forest area, increased in all countries. This means there are more trees or larger trees per unit of forest area. Spain saw the most radical shift towards tree plantations, for example plantations of eucalyptus, which are large trees that store a lot of carbon.

Now, how have agricultural emissions changed in these countries over time? Based on ongoing work, and comparing only partly consistent data, we can identify some general trends. For Austria, work in progress, led by Christian Lauk, investigates total agricultural emissions. In France and Spain, colleagues conducted similar studies with different methods and, in Spain, also different system boundaries (Aguilera *et al*., 2019; Garnier *et al*., 2019). Nevertheless, the general trends look rather similar. There are fairly stable but relatively high levels of emissions in the 19th century, then a steep increase in emissions due to technological change after 1950 or so (i.e. the 'Green Revolution'), and then stagnation or even decline of agricultural emissions since the 1980s. Livestock is one of the major factors here, consistent with the global trend. In addition, efficiency gains in agricultural production, i.e. the amount of emissions per unit of final product, play an important role in determining emissions trends.

When we compare these trends with the forest dynamics, we see that the rapid increase in agricultural emissions happens only after forest recovery started. So, the 1950s are a period in which in Austria, for example, forests had already grown for several decades. Similar processes happened in France and also in Spain, where the increase in agricultural emissions only started in the 1970s or so. Conse-

[2] 'Land sparing' describes the effect whereby agricultural intensification reduces land demand of agricultural production and thus results in agricultural abandonment.

quently, there appears to be a period before the Green Revolution when forests were already recovering. This means that agricultural intensification even before the large-scale introduction of mechanization and mineral fertilizer may have been sufficient to reduce agricultural land demand and allow for forest recovery. This might be good news in terms of sustainable land use, indicating that ecosystem carbon sinks might be achieved without additional agricultural emissions. However, these analyses do not address the importance of agricultural trade, which might already have played a role in the early 20th century.

Beyond investigating national trends, we also started an investigation of land-use emissions on the global scale, looking at ecosystem carbon stocks and agricultural emissions. Let us first turn to global ecosystem carbon stocks. My PhD student, Manan Bhan, worked with historical statistics from the first global Forest Resource Assessment in 1950 and used these data to reconstruct how much carbon was stored in biomass globally in 1950 (Bhan *et al.*, 2022), including forest as well what is called other wooded land, but excluding soils. He came up with the following numbers: vegetation lost 8 to 29% of carbon through deforestation or degradation between 1950 and 2000, the high level of uncertainty being due to very uncertain values for both 1950 and 2000. Despite the uncertainties, these findings are consistent with the emissions estimates for the whole period, quantified through different approaches. We are currently continuing this work, looking at different Forest Resource Assessments in the 20th century and expanding the time series.

We are also currently quantifying agricultural emissions on the global scale. To that end, my colleague Michaela Theurl is investigating early statistics by the Food and Agriculture Organisation (FAO). The IPCC reports global agricultural emissions only from the 1960s onwards. So, we are producing data for a period which has never been studied globally in terms of agricultural emissions. We found that agricultural emissions globally roughly tripled between 1910 and 2015, but they have doubled since 1960. Again, emissions were already fairly high in 1910. Compared to trends in emissions from fossil energy use, agricultural emissions show a very different, less dynamic trend. On the global scale, emissions from deforestation persist, while agricultural emissions are still increasing. This implies that the ongoing processes of agricultural intensification are not sufficient to halt deforestation globally.

Now, are there some processes that we can identify based on national-level historical analyses where both agricultural emissions and agricultural land demand declined? Here are some thoughts on that. We found that increasing efficiency in agriculture is only one way to reduce emissions from land use. Another equally, or more effective, way is to reduce livestock production and consumption. Another process we identified in the three case studies is that non-industrialized intensification allowed forest recovery at relatively stable agricultural emissions. This could be good news for agroecological intensification, where improvements in livestock management and cultivation of leguminous crops are options which are currently being discussed. To conclude, I want to propose another option for land-based climate-change mitigation, that is, efficient agroforestry systems, which, in some less productive regions, can increase carbon stocks without significantly compromising agricultural (Bertsch-Hoermann *et al.*, 2021).

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DATED INFRASTRUCTURE FOR A MORE SUSTAINABLE FUTURE?

PROBLEMS OF TRANS-ALPINE MOBILITY USING THE EXAMPLE OF GORIZIA AND NOVA GORICA

MAXIMILIAN HARTMUTH AND TADEJ BREZINA

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Just as the Lithuanian city of Kaunas was inaugurated as a 'European Capital of Culture' (ECoC) in early 2022, complaints arose about its lack of accessibility using sustainable means of transport. An open letter,[1] instigated by passenger associations and addressed to the decision-makers in the European Union and the Lithuanian government, lamented that railway services into neighbouring countries had been discontinued by the national operators in 2020. Remarkably, in mid-2022, services to neighbouring Poland were actually reinstated.

This occurrence appears to indicate changed expectations in the age of climate crisis. More than before, deci-

[1] See https://kaunas.trainsforeurope.eu.

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sion-makers are expected to provide for a certain kind of accessibility, especially if the physical infrastructure is already in existence. A new touristic geography is emerging based on the question of which locales can be reached attractively using specific – public – modes of transport.

We take this as a point of departure for investigating the problems and potential of a 'capital of culture' in 2025: the twin cities of Gorizia (Italy) and Nova Gorica (Slovenia). The binational conurbation is traversed by a railway line that once provided frequent connections between Austria, over territory now in Slovenia, and the port of Trieste, now in Italy. As this transport corridor lost its significance following the dissolution of the Habsburg empire, so did the port's hinterland in the Isonzo/Soča Valley. The line became marginalized within the nations at whose fringes it is now located.

Our paper examines the technical, operational, infrastructural, and political obstacles to improving the rail-bound accessibility of a region on the frontier of different mobility systems and mobility cultures. We seek to disentangle a multilayered problem by engaging infrastructural, operational, historical, and cultural perspectives, identifying both 'quick fixes' and structural improvements in the medium term.

INTRODUCING 'THE GORIZIAS'

The appointment of a city as 'European Capital of Culture' is usually expected to be a catalyst for regional development (see e.g. Lähdesmäki, 2014; Meethan and Barrera Fernández, 2012; Richards, 1999). This moment of international visibility and attention results in both opportunities (notably for even more attention by visitors and investors) and risks (such as disillusionment).

In the twin cities of Gorizia and Nova Gorica, too, high hopes are invested in the year 2025. Together with the (Slovenian) municipality of Šempeter-Vrtojba they form a binational conurbation with a population of more than 70,000, split almost equally between two states. The western, Italian, half contains the historical centre with an old town below a castle. Its compact pre-modern settlement core was extended toward the town's first railway station in the southeast after its inauguration in 1860. The eastern, Slovenian, half consists of Gorizia's historical southern and eastern sub-

urbs as well as a new town called 'New Gorizia' (Slovenian: *Nova Gorica*). It was developed after 1947 to the northeast to fill the gap of an urban centre in the Yugoslav hinterland and is characterized by high-rise developments and tree-lined avenues. A second railway line traversing the conurbation from north to south separates the two cities. It had made Gorizia (and Trieste) accessible from Klagenfurt/Villach in the north and once delineated the city's eastern border.

Slovenia's independence (1991), accession to the European Union (2004), and inclusion into the Schengen Zone (2007) radically liberalized the trans-border movement of people and goods, with detrimental effects on the Italian side's border-focused local economy. Gorizia's central area saw a downfall of retail businesses focused on day-trippers. Meanwhile, on the Slovenian side, casinos became a main attraction for foreign visitors and the backbone of the town's post-industrial prosperity.

The development of public transport has been lagging behind in this recent dynamic of 'reconnecting' (Gabrovec, 2013). With the exception of a single (hourly) bus line crossing the border, transport services have remained restricted to their national halves.

In 2019 the two cities jointly applied to host the *European Capital of Culture* event in 2025. A 'bid-book' (Humar *et al*., 2019) contained substantial sections on 'soft' (i.e. culture-based) urban development. The success of the bid bolstered a common perspective.

INFRASTRUCTURE AND SERVICES

The conurbation is served by two railway lines with stations on both sides of the border. The Italian station (*Gorizia Centrale*) is a frequent halt on one of the two electrified lines connecting Trieste and Udine. The station on the Slovenian side is served by regional trains traversing Slovenia between its borders at Jesenice and Sežana on the line known as *Transalpina* (a.k.a. *Wocheinerbahn* or *Bohinjska proga*); it is not electrified and only single-tracked. Its marginalization resulted from the fact that the territories once connected by it became parts of other countries after the two world wars.

The *Transalpina* is a mountain railway with maximum gradients of 26 ‰ (Schweers + Wall, 2010, p. 11, 27), a general speed limit of 70 km/h and short stretches with only 40 km/h. It links the Klagenfurt Basin, the Sava Valley, and the Bohinj Basin through the protracted Karawanks (7,976 m) and Kobla (6,327 m) tunnels, before continuing along the curvy alignments of the Bača and Soča (Isonzo) rivers to Gorizia, reaching its traditional final destination (Trieste) after crossing the Karst Plateau (see Figure 1). In recognition of its advantages over other transport infrastructure, shuttle services have been offered through both tunnels.[2]

PATHS TO RECONNECTING 'THE GORIZIAS'

The fact that neither of the agglomeration's two railway stations is currently served by cross-border services is a key shortfall in the international accessibility of Gorizia and Nova Gorica (hereafter: 'the Gorizias').

In a first step, we have sought to identify the most potent hub from which significant passenger flows may be sourced. A spatial visualization (Figure 2) of regional rail services also exposed as a root of the Gorizias' current marginalization that it is being

[2] A long-lasting car shuttle through the Kobla Tunnel and a short-lived bicycle shuttle through the Karawanks Tunnel.

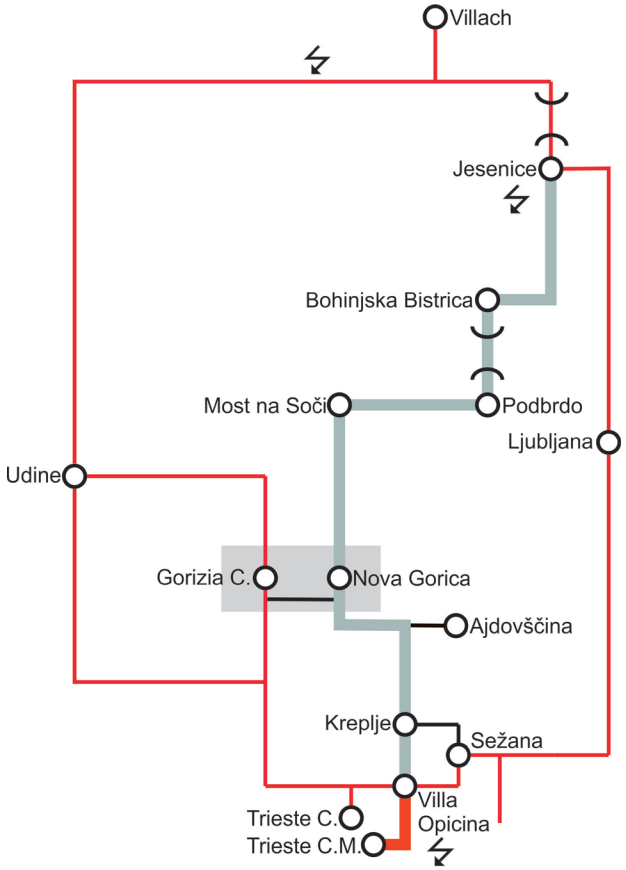

Figure 1: Scheme of the international regional railway network. Electrified lines are highlighted in red, with a flash indicating a change in electric current, while non-electrified lines are in grey (Transalpina) and black. Illustr. by T. Brezina

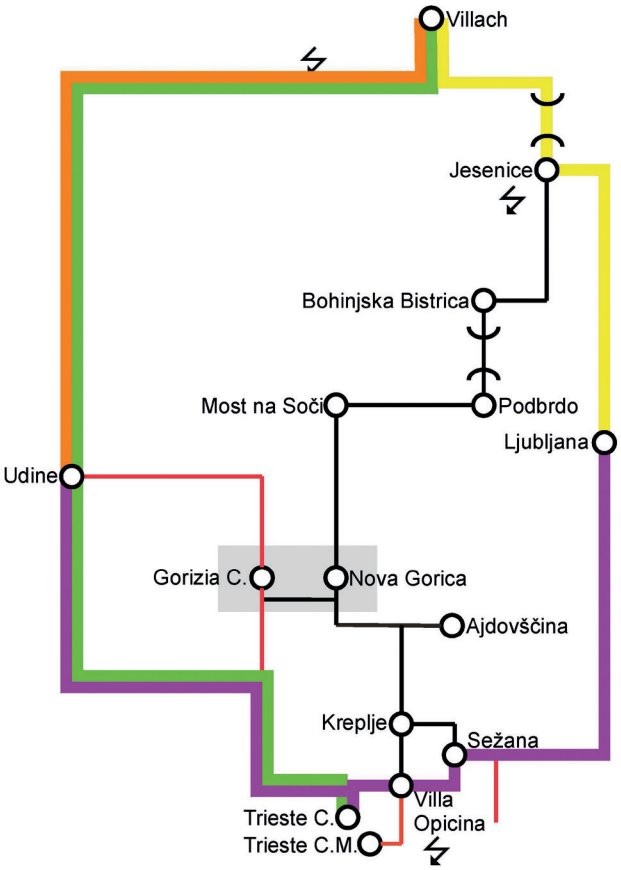

Figure 2: Quadrilateral of international services bypassing the Gorizias. Illustr. by T. Brezina

bypassed by the regular trans-border connections between the region's most important transportation hubs – Udine, Villach, Ljubljana, and Trieste.[3] A new or adapted service to link the Gorizias is likely to be oriented on one of these places.

Trieste is an unlikely candidate in light of its *cul-de-sac* position and limited connectivity. Ljubljana's location on the 'wrong' side of the Julian Alps, too, makes it an improbable hub for efficient railway linkages. An attractive connection between Nova Gorica and Ljubljana is already provided along the highways, which better correspond to the modern nation state's spatial organization. Udine, on the other hand, is already an excellent hub for the whole of northeast Italy, with frequent services in all directions. Even so, Udine does not actually constitute the point at which services from the greatest variety of places of origin converge.

This is the competitive advantage of Villach, where trains from Germany, Austria, and Switzerland meet before they continue into Slovenia, Croatia, and Italy. Thus, a new kind of service designed to efficiently connect the Gorizias is likely to intersect with other services at Villach.

Since *Gorizia Centrale* is already well-served via the interchange at nearby Udine (where a reversal would also be necessitated if trains were to continue eastward), we will focus on improving the agglomeration's international connectivity through Nova Gorica. Its station is conveniently situated at the interface of both municipalities' urban areas, with the respective downtowns accessible in less than 20 minutes on foot. This increases the potential to take on the role of the agglomeration's 'international' station.

Next, the kind of train service to be realistically targeted must be discussed. The two options are a direct line, connecting unswervingly the relevant sources of passenger potential abroad (via Villach, as proposed above), or a branch line, connecting with such flows (again, at Villach).

This decision is likely to be made in favour of the latter on account of very disparate infrastructural frameworks. The single-tracked and non-electrified *Transalpina* is not ideally suited for continuous operations from the corridors converging on the quadrilateral of Villach, Ljubljana, Trieste, and Udine (Figure 2). All these cities are served by frequent trains operating at reasonably high velocities on a double-track electrified infrastructure. Hence, a new service that branches off from these established railway axes and continues to operate – for lack of immediate alternative – on diesel traction, appears to be the most realistic option for a swift improvement of the Gorizias' railbound accessibility.

Next, we have investigated to what extent such a service may be integrated in current timetables, thus increasing the likelihood of swift implementation. Specifically, we have investigated at which time of day services extended from the *Transalpina* to Villach would encounter the largest passenger potentials from the greatest variety of places there. In the 2022 timetables, trains from two Central European metropolises, Vienna and Munich, regularly arrived at Villach within a few minutes of each other. This would allow a feeder service from Nova Gorica to connect at Villach with services to Vienna/Munich. Thereafter, it would wait to collect passengers arriving from Vienna/Munich, as we have illustrated in figure 3.

[3] Current cross-border services between Ljubljana and Udine as well as between Villach and Trieste bypass Gorizia and take the route via Trieste Airport instead.

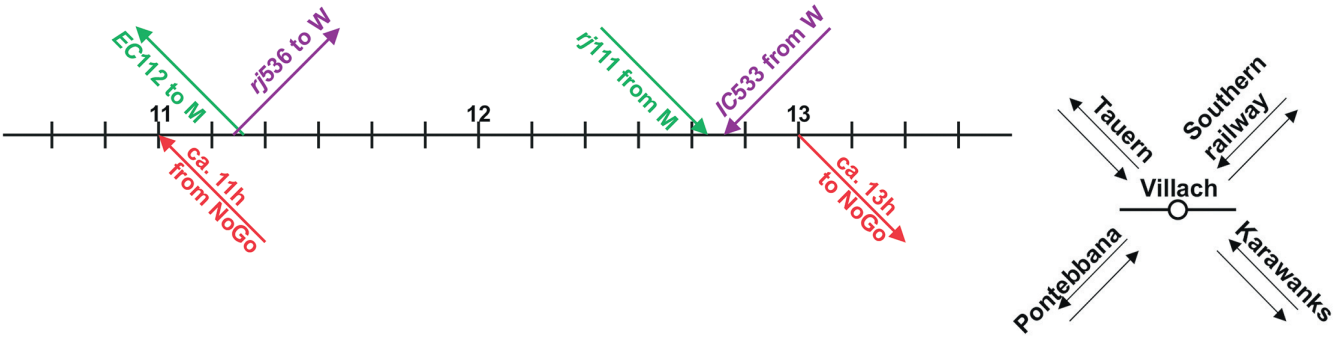

Figure 3: Geographically differentiated arrival and departure timeline at Villach for services to/from Munich (M), Vienna (W) and Klagenfurt (K). Feeder services to/from Nova Gorica (NoGo) are shown in red with approximate running times. Illustr. by T. Brezina

While this appears an easy fix at first sight, two major challenges must be considered: 1.) large stretches of single-track infrastructure (notably the Karawanks Tunnel), with double tracks for passing only in selected stations (Clar-Novak, 2022); 2.) two different electrification systems meeting a non-electrified line at Jesenice. We have identified three possible scenarios to overcome these obstacles:

Scenario 1 ('Sustainable Piggyback'): In this scenario, the existing regional service operating between Nova Gorica on a single or multiple-unit diesel railcar is attached to intercity services waiting at Jesenice to continue to Villach. The diesel railcar is then hauled through the tunnel across the border, unloads its passengers at Villach and is later reattached to intercity services departing from Villach towards Jesenice. There, it is detached and continues operating on the line to Nova Gorica. For this, the schedule of the regional service would need to be moderately adapted and operational resources would have to be devoted to marshalling.

This scenario's principal gains would be the establishment of a non-stop service and the exploitation of synergies between already existing operations. From an ecological perspective, the propelling of the diesel railcar would be limited to a section (Jesenice to Nova Gorica) on which it is currently without alternatives. While passengers will likely favour this scenario as it allows them to avoid interchanges, transport operators are likely to disapprove of the increased marshalling effort.

Scenario 2 ('Karawanks Shuttle'): In this scenario, the regional service currently operating between Nova Gorica and Jesenice on a diesel railcar is rescheduled (by ca. 20 minutes) to connect with the intercity services terminating or originating in Villach in such a way that they can be used as cross-border shuttles. This has the advantage of quasi cost-neutrality for the operator, who would merely have to adapt schedules on a line of

secondary (i.e. to intercity services) importance.
With one additional interchange (compared to scenarios 1 and 3), this scenario would be less attractive to passengers. The risk of missing connecting services could be minimized significantly if arriving and departing services were to utilize the same platform. Landing the three relevant services on the same platform and continuing in their respective directions without additional delays would be possible with improved cross-border coordination.

Scenario 3 ('Diesel Sprinter'): This scenario introduces an entirely new service between Villach and Nova Gorica. It would likely run as a regional express train, only halting at selected stops, qualified by their passenger potentials,[4] and, at least initially, operate on diesel traction. This is certainly the most beneficial scenario from a passenger perspective, but also the most incisive change to current operations. Running fuel-driven rolling stock on electrified infrastructure would need to be tolerated, making this only a provisionally practicable solution.

Scenario 3+ ('Hybrid Sprinter'): In this additional mid-term scenario, the diesel railcar is replaced by a catenary and battery-driven hybrid railcar of the kind recently successfully pilot-run in Austria, in similar terrain, as the 'ÖBB Cityjet eco'. It would be powered by catenary lines between Villach and Jesenice and run on a battery between Jesenice and Nova Gorica, where it would recharge for the return journey.[5]

Scenario	1	2	3	3+
Ideals				
No operation of diesel railcar on electrified infrastructure	✓	✓		✓
No interchanges between Villach and Nova Gorica	✓		✓	✓
Express service with limited halts			✓	✓
No marshalling		✓	✓	✓

Table 1: Schematic representation of different scenarios' advantages and disadvantages.

In Table 1 we propound the different scenarios' benefits and deficits in light of four different ideals: fewer interchanges (and hence reduced stress), fewer stops (and hence shorter travelling time), fewer emissions, and lower staffing requirements.
Looking at the short-term scenarios (1-3), we find that the scenario most attractive to the consumer (3) is not necessarily the most ecologically sustainable. The most ecologically sustainable scenario (1), on the other hand, requires additional effort by the operator. Only Scenario 3+, as a hypothetical solution still requiring technological consolidation, meets all expectations.

[4] Notably Vintgar, Bled, Bohinjska Bistrica, Podbrdo (end of the Kobla Tunnel), Most na Soči, Kanal, and Solkan. Travelling time may thus be reduced from 110 (or more) to 90 (or less) minutes, if a time gain of 2 minutes per station not served is computed.

[5] The feasibility with regard to energy requirements and current technological possibilities would need to be assessed in detail.

PRELIMINARY CONCLUSIONS

In the course of our study, three different interests have surfaced:

- From the *passenger* viewpoint, the number of stop-overs should be minimized, while the number of halts should be reduced to those likely to be of use to most passengers.
- From the viewpoint of an *ecologically sustainable transportation culture*, services on diesel traction should be limited to non-electrified railway infrastructural areas.
- From the *service operator's* viewpoint, logistic handling (marshalling, change of rolling stock) should be kept to a minimum, as it increases operational costs.

These interests are not easily reconcilable within the existing operational and infrastructural framework. The question of which concrete actions need to be taken by whom cannot be answered as straightforwardly as it appears in public discourse on the *Transalpina's* potential.

In this discourse, the electrification and double-tracking of the line are typically assumed as the logical next steps on the line. Yet, such a physical upgrading would require enormous investments over an extended period of time.

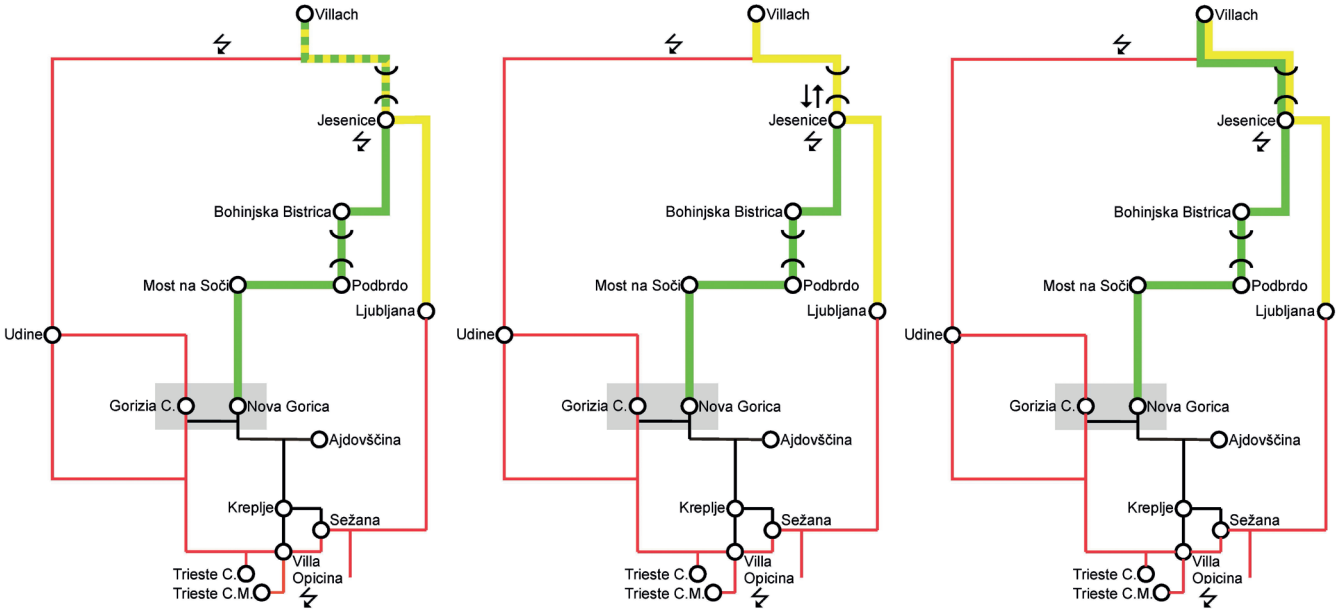

Figure 4: Schematic comparison of scenarios 1, 2, and 3/3+ (left to right). Illustr. by T. Brezina

Instead, we have suggested focusing on the question of which kind of trips could be realistically substituted with novel railbound services. The more recent highway infrastructure has become an insuperable competitor for railway services within Slovenia – especially to/from Ljubljana. This concerns not only private cars but also public bus services between many of the country's urban centres. They are, and will remain in the foreseeable future, considerably faster than corresponding rail connections. The potential for improved services is most substantial on routes lacking top-level automobile infrastructure that are currently not exploited to the best advantage, such as the *Transalpina*.

As rail services operate on inflexible infrastructure, their realistic potential is prefigured straightforwardly. Vienna and Munich are the largest concentrations of people (outside Italy) that could be connected to Nova Gorica by rail with only one stop-over (at Villach). Put differently, travellers intent on travelling to the Gorizias specifically by train are most likely to come from these countries, improved services provided, while most travellers from other countries are more likely to use other transport modes. While visitors from Italy will find existing railbound services to Gorizia Centrale sufficient, visitors from Slovenia and Croatia are more likely to reach the Gorizias by bus or private vehicle.

PERSPECTIVES

Our case study has highlighted a number of obstacles to improved cross-border rail operations. Political borders as transitions between different administrative and operational regimes constitute merely one of these limitations. In our case study both the many single-tracked sections and the intersection of two differently electrified lines with one non-electrified one pose a challenge.

In this special situation we have suggested that fuel-powered railcars under catenaries might help to bridge this gap. Yet, this is only a provisional solution in order to generally repopularize ecologically sustainable mobility. We have also discussed instances in which diesel-powered multiple units could be attached to electrically-powered ones to reduce that compulsion.

In the short term, compromises need to be sought between three stakeholders: the operator, the customer, and the environment. As the appraisal of our scenarios has shown, their interests are not easily reconciled.

In the medium term, a variety of measures may be taken. They include the use of alternatively-powered railcars (as discussed in scenario 3+) and a better cross-border integration of timetables. Infrastructural improvements may be made to smooth the operations on a single-tracked line. This includes a partial electrification to enable mid-service charging of battery-driven vehicles and a partial upgrading to double tracks to facilitate passing and overtaking. Yet, if the aim is to bring about betterment in the short term, infrastructural improvements will be of only secondary importance.

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SUSTAINABILITY IN ARCHAEOLOGY AND HERITAGE PRESERVATION – THE IMPORTANCE OF CONTEXT

NINA MIRNIG AND KATHARINA REBAY-SALISBURY

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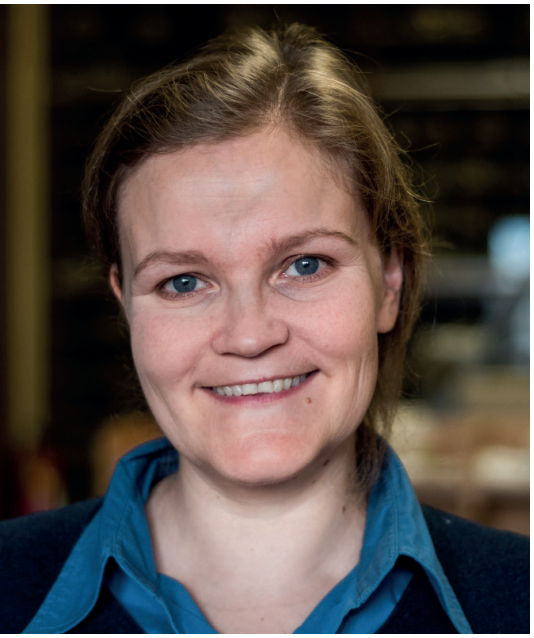
The preservation of cultural heritage has not been identified as a separate Sustainable Development Goal in the 2030 Agenda for Sustainable Development, adopted by the United Nations in 2015 (https://sdgs.un.org/2030agenda), despite UNESCO's call for doing so in light of the imminent threat to cultural heritage due to globalization, urbanization, and climate change, amongst many other factors (UNESCO 2015). At the same time, policy debates over the past years have increasingly recognized the significance of cultural heritage for developing sustainable societies and safeguarding cultural diversity.

To this effect, ICOMOS has published a policy guidance document for Heritage and the Sustainable Development Goals in 2021. In the report, the authors highlight that heritage is an "evolving resource that supports



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identity, memory, and 'sense of place', and has a crucial role in achieving sustainable development". At the same time, the authors also point out that despite this recognition, which is reflected in some of the SDGs, "the 2030 agenda fails to acknowledge fully and affirm the importance of heritage as an essential driver and enabler of sustainable development" (Labadi *et al.*, 2021, p. 12).

It is in the context of these debates that we would like to address some of the challenges and prospects relating to tangible heritage from the perspective of our own research contexts and disciplines, namely archaeology in the case of Katharina Rebay-Salisbury, and epigraphy and the cultural history of South Asia in the Himalayan region in the case of Nina Mirnig. We would like to do so by focusing both on sustainability in heritage practice and sustainability in academic practice.

Archaeology and sustainability are quite difficult to reconcile. By definition, archaeology is the study of the human past through material remains. These material remains are often the product of excavations, which are a constitutive element of the archaeologist's identity and generate data about the human past. However, excavations are also destructive. By default, they destroy the unique prehistoric and historical context, a practice that is only mitigated by documentation, sampling, conservation, and storage of finds. In a way, we can think of archaeological sites as the resources archaeologists draw from. On the one hand, they are not renewable as each of them carries a very unique set of information about the human past. On the other hand, meaningful sites keep being discovered and they are constantly being made.

A few years ago, nobody would have thought that Denisova Cave in Siberia would be a very important source of information about our genetic ancestry (Higham, 2022). Some of these sites retreated deep into prehistory and some sites are from the very recent past, memorable places, sites of commemoration that are constantly being made, for better or for worse. In archaeology, the context is key to interpretation. An archaeological context is defined as the surroundings and environment in which an artefact is found and which may provide clues about an artefact's function and/or cultural meaning.

What we as archaeologists do is to observe this context. The observa-

tion of stratigraphy – the sequences in which archaeological deposits have been made – is of the utmost importance. Layers are added and removed, and generally speaking, older layers are at the bottom and younger ones are on the top. The sequence of events, with pits and cuts, erosion and removal, and many other processes, plays a role in forming the stratigraphic record, all of which carries meaning. We generally try and remove layers in the reverse order of deposition, but that is easier said than done, and once a context has been excavated, it is destroyed.

If the contextualization is questionable, the scientific value radically decreases. The Nebra sky disc, a bronze and gold astronomical object found by metal detectorists on the Mittelberg hill near Nebra in Germany in 1999, may serve as an example. Those who found it claimed that this unique, unparalleled metal item was taken out of the ground with two daggers, some tools and ornaments, which would date the complex to the early Bronze Age around 1800-1600 BC. Apart from their word, however, there was no proof – as a stand-alone object, the Sky disc could also be of much later, perhaps Iron Age date. Perhaps it is not even from Germany, but from Western Asia; without context documentation, we do not really know. Scientific studies then focused on the production context of the metals and on investigating the soil in which the disc was found to prove its authenticity (Pernicka *et al.*, 2020). In archaeology, interpretations rely very much on the find context. This is what we are trying to preserve, but we have to think about preserving much more.

The removal of objects from the context raises questions: what should we leave behind, what should we keep? Originally, the focus of archaeology was on collecting pretty objects for museums. Excavations at the cemetery of Statzendorf, for example, which were carried out between 1912 and 1922, focused on collecting only the pottery – the cremated human remains were removed from the urns and simply left in the trenches (Rebay, 2006). Today, we consider human remains the most valuable finds. In the current FWF-funded project "Unlocking the secrets of cremated human remains", for example, we aim to extract the maximum information value from Bronze Age urns. The recently recovered Bronze Age urns from St. Pölten, for example, were put through a CT, micro-excavated, and then fully analysed (Waltenberger *et al.*, in prep). We carried out an age and sex assessment of the cremated human remains, histological thin sections and isotopic analysis of the remains, which can give us people's exact age at death and mobility history.

What we usually clean away carries an incredible amount of information – chemical signatures of the surrounding soil: the faunal remains in the soil inform us about farming practices; botanical micro-remains, including a lentil, inform us about people's diets. To be honest, the urn, the ceramic vessel, is the least interesting of all the multiple components that constitute this single grave context. From this, we learn about the people, their environments and their cultural history.

And yet, we have a large number of collections of de-contextualized artefacts, for which not even the site is known, or how they came to be in the museum. Such collections are curated, but they are not sustainable – it is no longer clear why they are maintained, but there is no strategy for dissolving existing collections of artefacts.

Development-led excavations – which today constitute the vast majority –

are excavations that try and rescue as much material as possible before archaeological sites get destroyed by building roads or houses. They generate an unsustainable amount of archival material that researchers have no resources to deal with properly. This is an ongoing problem, not only in Austria but worldwide. Most digging companies do their best, and there are minimum standards for documentation, but there is often too little time, and the standards are not sufficient for specific research questions. Scientific advances can only be achieved by applying multiple, cutting-edge technologies to projects in which clear research questions and goals have been defined.

What are the alternatives that make research field projects sustainable? Remote sensing provides opportunities to investigate built structures; artefacts are sometimes best left in place; and minimally invasive coring might help to recover datable material, ancient DNA and proteins, chemical signatures and more – without destroying the irretrievable contexts. Minimally-destructive interventions, comparable to key-hole surgery, for intact archaeological sites might replace large open-plan excavations in the near future as a much more sustainable way to engage in archaeology. This also implies, however, that we need to rethink the job description and the identity-formation of archaeologists.

Bio-archaeology – a subdiscipline of archaeology that primarily deals with human remains – is also going through a phase of rethinking how to work towards sustainability. Here, too, the context of the findings is important. Today, nobody would unwrap a mummy, as happened to King Tutankhamun, removing the wrapping, the amulets, and all the associated information, to leave him somewhat bereft in his burial chamber.

Today, the hunt is on for ancient DNA (Alpaslan-Roodenberg *et al.*, 2021). Papers on ancient genomics have exponentially multiplied over the last decades, moving from the 10,000s to 100,000s of ancient genomes recovered each year. Human bodies are likewise a finite resource, in particular because ancient DNA does not usually preserve that well in our bone tissues. We know that high yields of DNA come from the petrous part of the inner ear that can be retrieved by drilling into the skull. If we are lucky, we have two petrous parts, but we certainly do not have more per person. Ancient genomics has made incredible technical advances in the last years, so we can take smaller and smaller samples to get higher and higher amounts of endogenous DNA. However, the context of where the DNA comes from is still frequently neglected.

Ancient DNA research has lately centralized in very few large laboratories that also share the DNA libraries they get from ancient skeletons. This is an important step towards sustainability and hopefully helps to preserve the resource of ancient bonds, at least from further destruction.

Interestingly, tracing migrations and admixture events between populations has been the primary concern of scientists using ancient DNA – questions that archaeologists had actually largely abandoned in the aftermath of the Second World War came back with force, and with them, questions about if and how clusters of genes define ethnic groups. Here, we need to ask if the questions we ask in ancient genomics are sustainable, and if there are not more interesting research avenues on the table.

Sustainable archaeogenetics needs to use all available data and interpretation from the context of the grave. The way bodies are placed in relation

to each other, for example, embodies social connections, and with the additional genetic information, we can move forward to understanding to what extent kinship was based on biological relatedness. Investigating the interplay between the social and genetics is, in my opinion, much more interesting than returning to outdated questions of ethnicity. The process, practices and research goals of archaeology all need to be reconsidered in the light of sustainability.

Issues of sustainability and the problem of de-contextualized artefacts are also a pressing concern in the area of South Asian cultural history. Just as in the case of archaeology, the disciplines of philology and epigraphy are confronted with important questions of sustainability in academic practice which call for a rethinking of our conduct and horizon of our interpretation.

For this paper, I would like to discuss these issues in the context of my current research in Nepal. Kathmandu Valley is a World Heritage property with seven inscribed Monument Zones. In the UNESCO World Heritage List it is recognized that these Monument Zones are an exceptional testimony to the "cultural traditions of the multi ethnic people who settled in this remote Himalayan valley over the past two millennia, referred to as the Newars", and "manifested in the unique urban society which boasts of one of the most highly developed craftsmanship of brick, stone, timber and bronze in the world." It further outlines that "the property is tangibly associated with the unique coexistence and amalgamation of Hinduism and Buddhism with animist rituals and Tantrism" in its design, symbolism and environment, which is "closely associated with legends, rituals and festivals" (World Heritage List, Kathmandu Valley, Dossier 121bis – https://whc.unesco.org/en/list/121/).

In its characterization, UNESCO focuses particularly on the historic period of 1500-1800 CE, an assessment which focuses on the extant built structures, the majority of which date from the 16th century onwards. However, there is much earlier evidence from subsurface archaeology, as well as fragments and inscriptions that bear testimony to a highly developed culture as early as the third century CE (see, e.g. Slusser, 1982; Verardi, 1992; Coningham *et al.*, 2016; Mirnig, 2016). Yet, these are not mapped as part of the ancient landscape, precisely due to the issues addressed above, namely the challenge of de-contextualized artefacts, which are frequently moved and viewed with little understanding of associated or earlier subsurface remains, many of which have not yet been scientifically analysed.

At the same time, these artefacts have been recognized for their national significance in each of these Monument Zones. Preserved textual data on inscribed objects lend these cultural spaces a historical dimension, one which in some cases becomes central to the construction of local identities and is also of interest for public representation, education and tourism, the last of which is one of the main sources of income in Nepal. However, due to the fact that they are moveable objects, issues of academic interpretation and historical reconstruction, but also preservation and sustainability are problematic.

As part of the FWF-funded project "Mapping piety, politics and power in early medieval Nepal" (FWF V755-G) conducted at the Austrian Academy of Sciences – in collaboration with partners from the UNESCO Chair at Durham University, the University of Oxford, and the Department of Archaeology in Nepal –, we systematically document this

early layer of Sanskrit inscriptions throughout Kathmandu Valley with the aim of producing new digital editions and multilingual translations and developing multi-disciplinary approaches for linking these decontextualized artefacts and inscriptions to the existing archaeology and material culture. Here, we face similar challenges to those outlined by Rebay-Salisbury earlier.

But going beyond these methodological challenges, it is not this particular research context which I will address on this occasion, but rather the way we are collaboratively advancing our methodology for documenting these inscriptions, an ongoing process which aims to respond to important questions of sustainability and of how the collection, organization and presentation of data needs to be designed in order to align with sustainable heritage practices. This is a rather innovative endeavour in the field of South Asian epigraphy and inspired by initiatives for sustainable heritage practices in archaeology and the documentation of intangible heritage (e.g. Coningham and Lewer, 2019). Thus, beyond recording the textual and material data of the inscribed objects, we expand our documentation activities to include the state of preservation and threat levels and data from interviews with stakeholders about significance and usage. We are not anthropologists or sociologists, but these interviews enable us to collect important data that helps us to understand the modern usages of these inscriptions – which frequently differ very much from their original context –, and also to see to what extent they are significant for maintaining the social cohesion of local communities or determining the usage of the space. Furthermore, in some cases these processes help us to recover information about the earlier context of inscriptions, data which, in turn, is relevant to historical reconstructions.

Through this method, we have already gained interesting insights. For instance, we were able to document how a large number of royal administrative stone charters inscribed on free-standing stone steles became integrated into temple sites and transformed from records of purely documentary value into divine cult objects. In rural areas, such artefacts frequently came to be regarded as protector deities, either as divine guards for local deities or as protectors against snake bites. Through such transformations, these royal

Figure 1: Sanskrit stone stele inscription, 7th century CE, Changu Narayan Temple, Nepal 2021. Photo: Nina Mirnig

charters become loci of worship and are often smeared with worshipping substances such as oil, vermillion, or even blood – worshipping practices that also significantly damage the inscribed surfaces and at the same time force us to rethink the rationales underlying preservation strategies (see fig. 1). Should the aim be to preserve the historic value and clean, repair

Figures 2 & 3: Villagers cleaning the inscriptions fixed to the walls of the water tank, Sankhu, Nepal 2017. Photos: Nina Mirnig

and conserve these objects, divorced from these current practices? Or should these changes of perception and modern worshipping practices overrule such notions of preservation? To what extent do the views of responsible authorities and various communities align?

Other inscribed fragments mark sites of water distribution, a system in place since the beginning of the first millennium. Kathmandu Valley has an extensive ancient and complex water system of channels, through which ground and rain water is collected and directed towards fields and distributed as drinking water through the so-called hitis, the ancient traditional water source places of Nepal. Inscribed stone steles, as well as stone spouts and tanks still in use, highlight this ancient heritage. Sandhya Khanal from Tribhuvan University in Kathmandu, who is part of our field team, has been documenting rituals associated with these hitis. For instance, during a large festival dedicated to the Vaishnava deity Narasimha in Patan, a dancer impersonates the deity Narasiṃha and

eventually falls into a trance. Only water from the ancient tank Maga Hiti is believed to have the force to pull him out of this trance. This hiti thus constitutes a central element for the ritual community.

At the same time, these hitis are also important resources for everyday life and become focal points for village communities. Villagers come together regularly to maintain and clean the hiti, including old inscriptions that are fixed to the walls (see fig. 2). However, due to the rapid urbanization, increasing loss of understanding of the ancient landscape, and natural disasters, such sites and associated practices are under great threat. For instance, during rescue documentation activities in 2017 in response to the devastating 2015 Gorkha Earthquake, we came across a hiti in central Kathmandu (Yangal Hiti) which was badly damaged, flooded and overgrown, thereby putting at risk ancient inscriptions and sculptures dating back to the 7th century CE. A follow-up site inspection a few months later showed that the situation had worsened: due to the blocked drainage, water levels rose further and plant growth dramatically increased. However, during our investigations we saw that it was not only the damage from the earthquake that had caused this precarious situation but also modern building construction. Comparing the location with pictures from the 1970s, it became evident that the back side of the modern building has been built too close to the hiti, blocking the water system and thereby rendering the hiti unusable for local communities. The resulting discontinuation of community usage and water management most likely contributed to the lack of recovery work after the earthquake, leading to the deteriorating conditions, putting these invaluable objects at risk.

In response to such contexts, we are at a point within our academic discipline at which we also need to rethink our approaches to documentation, study and communication of research. In order to further sustainability of heritage, as well as identify and recognize the role of this heritage for building sustainable societies, we must develop and co-design documentation and research approaches that also take into account the threats to the inscriptions and the recognition of their role in contemporary societies. This requires close collaboration between academics, stakeholders, heritage practitioners and responsible authorities, however challenging this may be in the framework of research funding schemes.

After these reflections from the standpoint of our disciplines, we would like to summarize how archaeology and heritage artefacts may contribute towards achieving the UN's SDGs. As we have seen, the material remains frequently play key roles in contemporary perceptions of urban spaces, cultural landscapes, and identities of local communities. By co-designing, communicating, and sharing our research with authorities and stakeholders, preservation strategies can be developed that draw attention to archaeology and heritage in urban settings.

Sites provide focal points of identity creation and thereby foster social cohesion and community resilience. Concrete examples such as the water systems of Kathmandu Valley can demonstrate that the preservation of the tangible and intangible heritage related to these sites is not only crucial to the cultural integrity of communities, but also determines resource management. We firmly believe that sustainable heritage should become a focus in the next conceptualization of the UN's Sustainable Development Goals.

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KATHARINA REBAY-SALISBURY *is Professor of Prehistory of Humanity at the University of Vienna and directs the research group 'Prehistoric Identities' at the Austrian Academy of Sciences. Enthusiastic about the European Bronze and Iron Ages, her research focuses on combining interdisciplinary approaches for insights into people's lives, identities and social relations in prehistory. Her current research explores themes such as sex and gender, motherhood, kinship, mobility and migration through ERC and FWF-funded projects analysing burial contexts and human remains from Central Europe.*

ELIMINATING ALL CO_2 EMISSIONS IN AUSTRIA BY 2040? A SKETCH OF THE CHALLENGE AHEAD

JOHANNES SCHMIDT

Johannes Schmidt is an associate professor in energy and resource economics at the Institute of Sustainable Economic Development at the University of Natural Resources and Life Sciences, Vienna.

Austria aims to become climate neutral by 2040. In the project "NetZero 2040" that we are conducting in cooperation with the International Institute for Applied Systems Analysis and with the Austrian Energy Agency, we develop scenarios of how the Austrian energy system can be transformed to support that goal. These are preliminary results – my aim today is to give an overview of the challenge ahead.

Why do we need to achieve zero emissions? The reason is simple: if we globally stop emitting CO_2, the temperature will stabilize and even start falling slightly over time. Eliminating all greenhouse gases (including e.g. CH_4) will lead to a more pronounced fall in temperature over time.

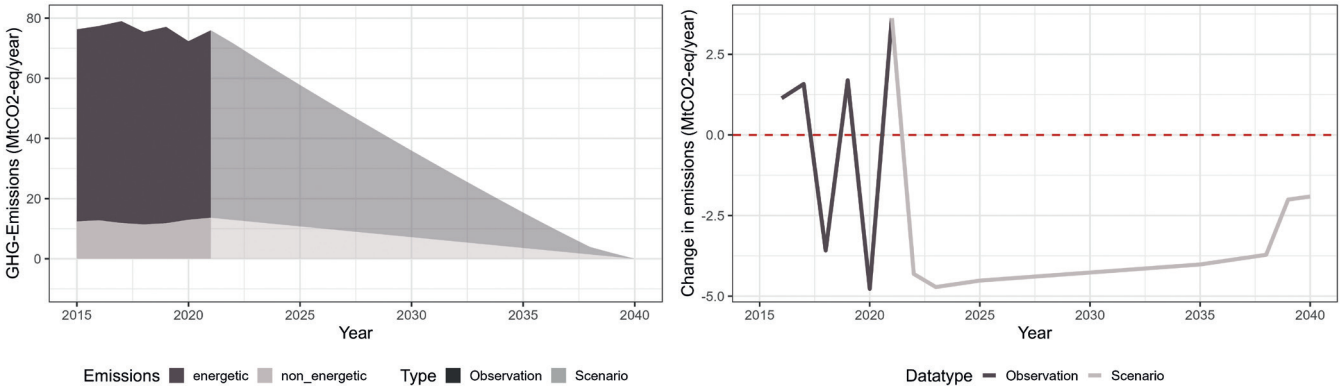

Figure 1: Pathway to climate neutrality in 2040, in line with Paris goals (right). Annual emission changes to reach the pathway (left). Source: Based on Steininger and Kirchengast (2021). Treibhausgasbudget für Österreich auf dem Weg zur Klimaneutralität 2040. https://wegccloud.uni-graz.at/s/ezopLM6ycRk8Txo

This is why net zero emission goals[1] are important. Of course, Austria alone reaching climate neutrality is not sufficient to limit warming in a meaningful way as climate change is an inherently global challenge. However, Austria is in the best position to start the transition: it is a wealthy country and hosts significant amounts of renewable energy resources.

What is the challenge ahead? Figure 1 shows historical emissions from 2015 to 2021 and one of the possible pathways down to net zero emissions in 2040. The pathway shown here is in line with the Paris goals of limiting global warming to well below 2°C.[2] On the right side of the figure, the required decrease in absolute greenhouse gas emissions in each year is shown, compared to past changes. The change in emissions in the year 2020 was at about the required level. In 2021, however, emissions rebounded. The challenge is therefore to maintain emission reductions at the level of 2020 every year until 2040, bearing in mind that 2020 was an extraordinary year due to the COVID-related lockdowns.

In a long-term perspective, total emissions in 2019 in Austria were higher than in 1990, as shown in Figure 2. Austria did not even come close to reaching the EU goal of re-

[1] Net zero emissions are achieved if any residual CO_2 emissions to the atmosphere are balanced by removal of CO_2 from the atmosphere elsewhere in the system.

[2] Of course, this will depend on emission reductions in other world regions. Here, we assume that Austria can use a fair share of the remaining carbon budget.

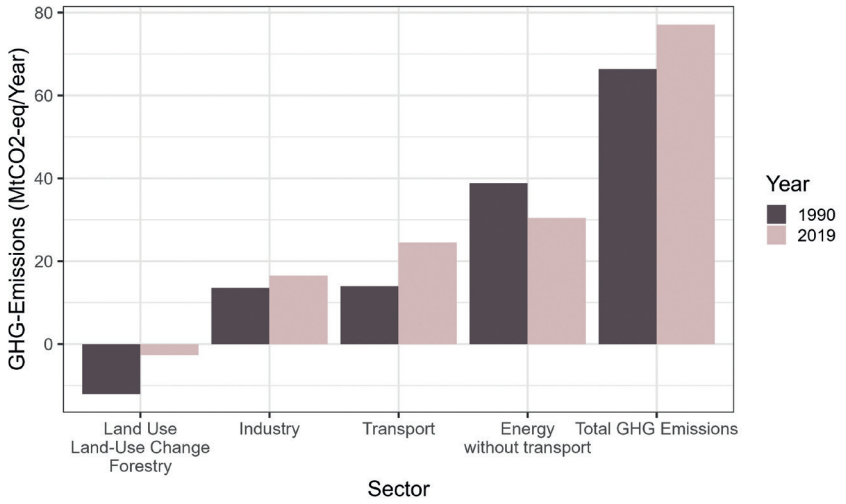

Figure 2: Greenhouse gas emissions in Austria. Source: UNFCCC Greenhouse Gas Inventory. https://di.unfccc.int/flex_annex1

ducing emissions by 20% in the period 1990–2020, which was achieved by most other EU countries. In Austria, industry, transport, and energy are the main emitting sectors. While the energy sector has decreased emissions in the past 20 years, industry and in particular the transport sector have significantly increased emissions. Furthermore, emissions from land use and land-use change are also increasing. Austrian forests and land-use activities are sequestering less airborne CO_2 than 30 years ago and the recent revision of the national greenhouse gas inventory has shown that the sector even became, in individual years, a net emitter of CO_2. The long-term forest carbon sink that Simone Gingrich discusses in her contribution appears to be levelling off or even reversing.

In the following, the challenges ahead are illustrated more concretely by scenarios for completely decarbonizing the heating sector. Since 2004, the total inhabited area in buildings has increased by about 20%, implying that a 20% larger area potentially has to be heated. The area increased because the Austrian population has grown, but also because the area per person has increased. At the same time, Austria is heating more efficiently. Less energy is used to heat the same area – or the area is heated less.[3] Furthermore, Austrian households emit less CO_2 emissions per unit of heating energy. In total, emissions in the heating sector have decreased by around 15%.[4]

Figure 3 shows three scenarios for how to fully decarbonize heating in Austria. Of course, none of those scenarios alone is realistic, most likely a mix of all three approaches is going to be required. The figure on the left

[3] Part of the increase in inhabited area per person is caused by an aging population: if people continue to live in their family houses even after their children have left, the area per capita of course increases. At the same time, parts of the building may not be heated under such circumstances. The available data does not allow us to differentiate between an increase in technical efficiency (e.g. due to better building insulation) and in behaviour (e.g. due to less area being heated).

[4] This is a coarse estimate and assumes that biomass emissions are balanced by plant growth.

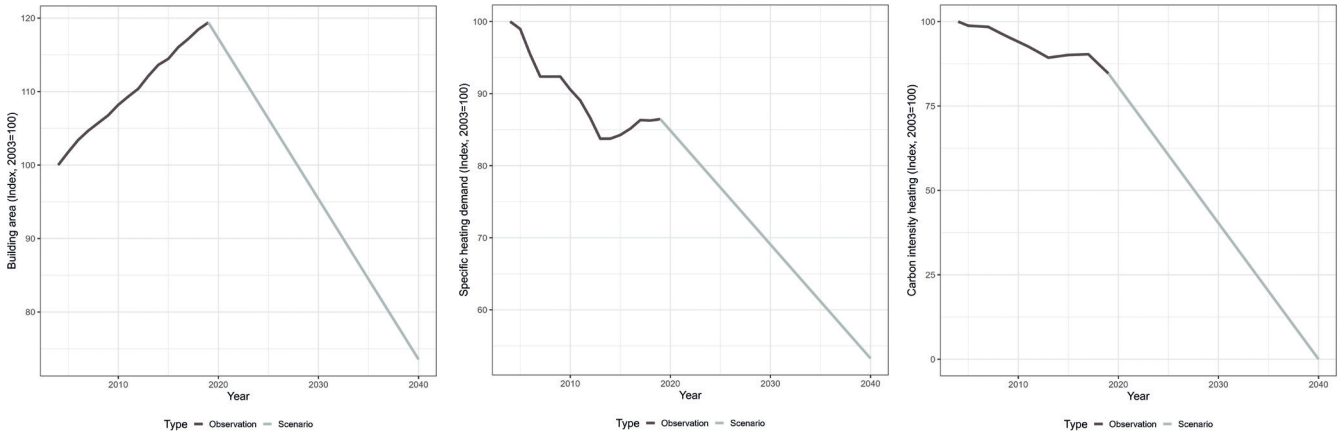

Figure 3: Three scenarios for reaching climate neutrality in the heating sector in Austria. Sufficiency (left), efficiency (middle), decarbonization (right). Source: Statistik Austria (2021). Austrian Energy Balance. Own Analysis.

side is the sufficiency scenario: here, the total inhabited area in buildings has decreased, but households heat with the same efficiency as in the last year in the observations. Under these assumptions, a building area which is 45% lower than today could be fully supplied by the amount of renewables currently used in heating. However, this also implies that, at constant population, per capita area has to decrease from 45 m^2 per capita to 27 m^2 per capita. Please note that this is in contrast to the trend in recent years, which showed a significant increase in inhabited area per capita.

In the second scenario, the efficiency of providing heat increases. This can be achieved by better insulating buildings, by reducing the indoor temperature or by partly stopping heating parts of buildings. Austria was on a good track towards achieving climate neutrality in the long term from 2004-2013, but the trend was discontinued. If building area had been kept constant, net zero emissions in the heating sector would have been reached by 2040. This is, of course, a theoretical assessment, but shows how efficiency increases can support reaching climate neutrality goals.

In the third scenario, demand for heating is kept at current levels, but heating systems are decarbonized, e.g. by installing heat pumps in combination with renewable electricity generation instead of gas boilers. The figure shows that current trends are moving in the right direction, but the rate of change has to be drastically increased to reach climate neutrality by 2040.

The previous example was to give an indication of the scale of the chal-

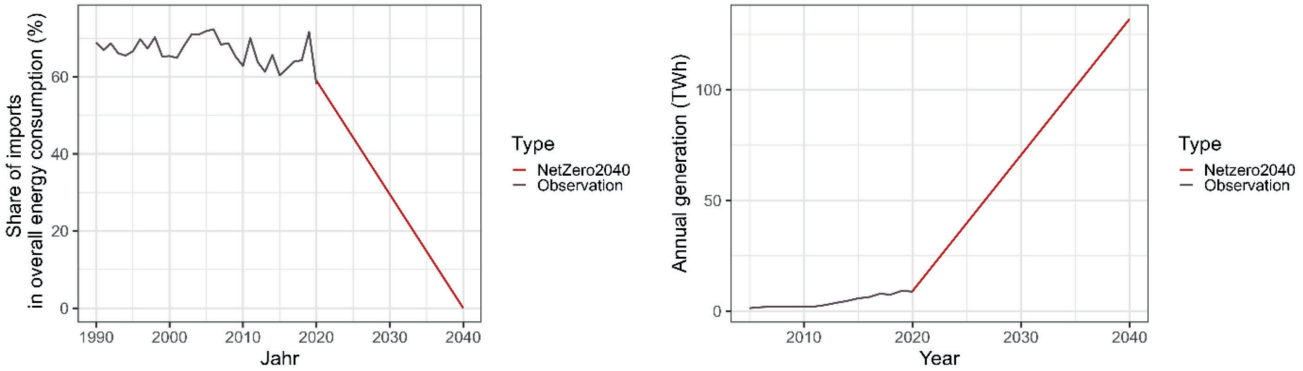

Figure 4: Share of imports in total primary energy use (left) and annual observed generation of wind power and solar photovoltaics in a scenario that allows climate neutrality to be achieved in a domestic production scenario (right). Source: Statistik Austria (2021). Austrian Energy Balance. Own Analysis.

lenge. On a more general level, Figure 4 shows the overall challenge in the Austrian energy system (left panel): more than 60% of primary energy consumed in Austria is not produced or extracted here but is imported from somewhere else. Almost all of these imports are fossil fuels. As these cannot simply be substituted with other carbon-free fuel imports due to limited availability, at least in the medium term, domestic production has to increase substantially.

The right panel of the figure shows how fast solar photovoltaic and wind power generation in Austria would have to be expanded if only domestic energy production was used for decarbonization. It is clear that a major change in the speed of renewable energy expansion would be required compared to past expansion under these assumptions, although, 2022 was a surprising year in terms of solar photovoltaics expansion. The year is not shown in the figure because final quality-controlled data is not available, but it seems that the expansion speed has doubled compared to 2021. However, the expansion rate would have to speed up even more to reach climate neutrality by 2040.

While in general, efforts to achieve rapid emission reductions are globally far from sufficient, there are some important drivers of decarbonization developing now. First, many long-term scenarios show that today a future without fossil fuels is economically more profitable than one with fossil fuels in many world regions, even when neglecting the cost of climate change impacts from continued combustion of fossil fuels. This may therefore spur decarbonization even in regions without strong climate policies.

The political agenda in some regions, e.g. in the EU and in the US,

also shows a strong commitment to decarbonization goals, and accompanying policies are put into place. Furthermore, huge emitters like China are committing to net zero emissions. The current geopolitical situation also drives decarbonization, at least in Europe, because decarbonization is also a way of increasing security of energy supply.

However, there are bottlenecks in how fast technologies are developed, how quickly public infrastructure can be expanded, and how efficiently accompanying policies necessary to reach climate neutrality can be implemented. Energy projects and infrastructure in general move slowly as it takes a lot of coordination between different state institutions, stakeholders and citizens to realize projects, and as there are very long temporal lock-in effects due to longevity of infrastructure. So besides stepping up labour qualification and establishing supply chains for new technologies, resources in the administration should also be increased to handle the complex processes accompanying infrastructure expansion.

Furthermore, distributional consequences of the transition are another important issue. The transition to climate neutrality is going to cause a shift in terms of jobs, income, and even in landscape quality due to the expansion of renewable energies. When the energy price crisis hit in early 2022, policymakers had to deal immediately with the distributional consequences of these impacts. This indicates that they will have to be at the core of all policy decisions.

On the policymaking side, while the EU commission is creating a framework which enforces climate change mitigation, policies at the national level are less stringent. The policies currently in place in Austria will not allow net zero to be reached by 2040. Most importantly, investment decisions taken today are already highly relevant in terms of reaching the climate neutrality goal: although in Austria no new fossil infrastructure with a lifetime longer than 20 years is meant to be put in place, this is still done, such as installing gas heating systems.

It is unquestionable that reaching a climate-neutral Austria is technically and economically feasible in principle. Although the currently high fossil fuel prices, the EU policy framework, and new technological developments are all pointing in the right direction in terms of decarbonization of the energy sector, I nevertheless have doubts about reaching climate neutrality by 2040. The speed of the required transition is unprecedented and just continuing past trends is nowhere near sufficient. Nevertheless, the ambitious nature of the climate neutrality goal in 2040 should not stop us from pursuing it: if Austria reaches climate neutrality in 2045 instead of 2040, this will also have been a major achievement.

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His main research interests are linked to the integrated modelling of carbon-neutral energy systems with high shares of renewables. In this context, he combines research on the assessment of optimal energy system configurations with the analysis of corresponding social, environmental, and land use implications of deploying renewable energies.

TRACE GAS DETECTION WITH LASERS

HOW A NOVEL SPECTROSCOPIC METHOD IDENTIFIES GAS SPECIES OF LOW CONCENTRATION IN OUR ATMOSPHERE

BIRGITTA SCHULTZE-BERNHARDT

Birgitta Schultze-Bernhardt is a university professor of experimental physics at Graz University of Technology.

It is my great pleasure to share with you our latest efforts towards developing a new absorption spectroscopy method for atmospheric sensing. In our project we are currently exploiting a technique called dual comb spectroscopy to determine the concentration of nitrous dioxide in the atmosphere of Graz. Our long-term objective is to develop a multidimensional and fast detection method for complex gas mixtures like the Earth's atmosphere.
I would like to start with a rather traditional example of absorption spectroscopy: the so-called Fraunhofer lines. Joseph von Fraunhofer was using a prism spectrograph shown in the right part of figure 1, more than 200 years ago. He examined the solar spectrum in unprecedented detail. He found that the rainbow one can produce from solar light has black lines that you can see in the left panel of figure 1. He could not explain the origin of those lines. It took more than 40 years until Kirchhoff and Bunsen were able to explain them. These absorption features are due to the solar

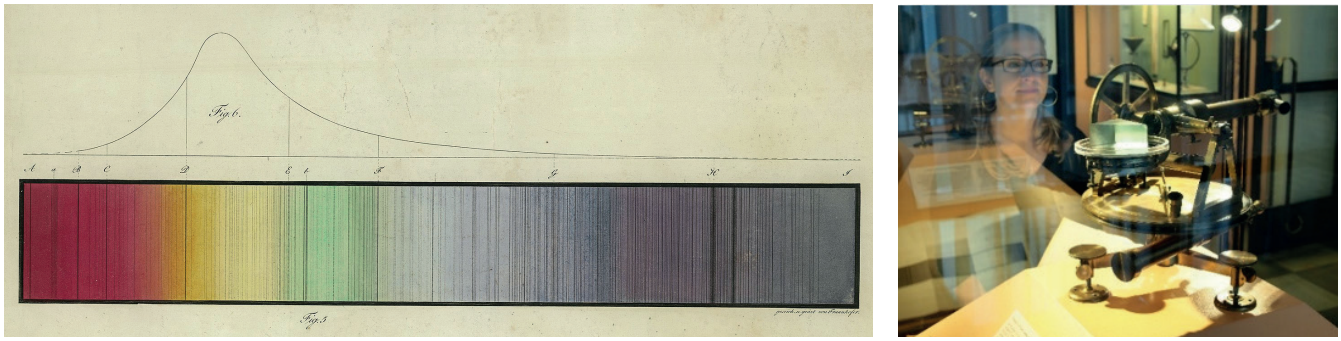

Figure 1: Sun spectrum with the Fraunhofer lines (left). Photo: Joseph Fraunhofer, 1814. Deutsches Museum, München, Archiv, BN43952, CC BY-SA4.0. Right: Photo of Fraunhofer`s prism spectrograph, located at the Deutsches Museum. Photo: Birgitta Schultze-Bernhardt

photosphere and the Earth's atmosphere, which consist of different types of gases that absorb different colours of sunlight individually.

I think it is a great example that shows how fundamental absorption spectroscopy can be utilized for different purposes. In principle, light matter interaction, and with that, absorption spectroscopy, can give you information about the consistency of gases, liquids or solids on a microscopic and macroscopic scale. Depending on the energy of the (laser) radiation used, you can acquire different information about the sample under scrutiny. Especially in gases, the molecules can vibrate and they can rotate. If using infrared light, for example, one can find out about those behaviours. If the higher energetic part of the electromagnetic spectrum is used, one can start to 'speak' to electrons. They can be very important for photo-induced chemical reactions. I discussed this introductory example of absorption spectroscopy. It consists of a very simple experimental setup, using a light source, a sample and a spectrometer. In the case that I mentioned in the introduction, Fraunhofer used the sun as light source. The sample was actually the atmosphere itself, although the experimentalist was not really aware of that.

Nowadays all of those black lines are fully understood. They originate partly from the sun's and partly from the Earth's atmosphere. Alternatively to the sun, other light sources are used in spectroscopy of course, both incoherent light sources and coherent ones – lasers. Finely tuneable lasers that can change their colour are very useful in order to attain a high spectral resolution. This is required to resolve very narrow absorption features, i.e. the narrow 'black lines' in our introductory example.

We use very special lasers in our laboratories. These are stabilized ultrashort-pulsed lasers, so-called optical frequency combs. Those frequency

combs emit hundreds of thousands of different colours at once: if one looks closely enough, one can see that it is not a continuum. The laser spectrum consists of equidistant modes. They are equally distributed, and as they look like a comb, it is called an optical frequency comb.

Theodor Hänsch and John Hall were awarded half of the Nobel Prize in Physics in 2005 for the invention of the laser frequency comb technique. It was actually developed for precision spectroscopy, but it turns out that it can also be very useful for different disciplines, including astronomy, for example, or in our case, also for environmental sciences. We are using two of those optical frequency combs in combination.

Figure 2 shows a typical spectrum that we can record with the device. It is a broad spectrum; in other words, many colours can be recorded at once, with just a single measurement. With this one-shot measurement we can cover all of those absorption features that you can see in figure 2. If we compare our technique with a traditional spectroscopic method that has been used for more than 40 years, the so-called Fourier Transform Spectroscopy, we can record one million times faster. At the same time, the

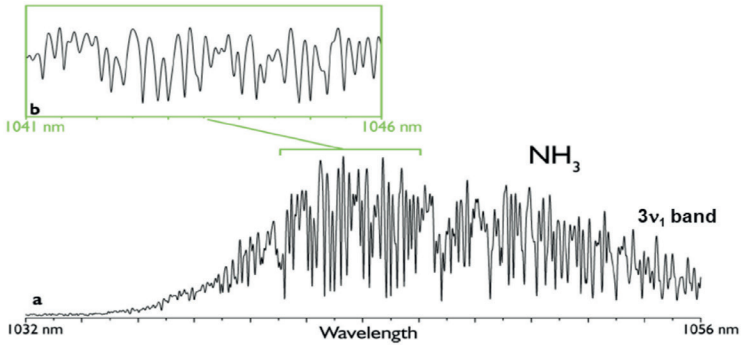

Figure 2: Dual comb transmission spectrum of ammonia.
Source: Birgitta Bernhardt, Dual comb spectroscopy, Dissertation LMU München, 2011.

measurement is very precise due to the frequency comb technique. We know the exact position of all those lines at a high level, and the spectral resolution can be very high, higher than 1 MHz.

It is common to compare a new development to established techniques. The traditional method that I mentioned can also have a high spectral resolution; this resolution basically depends on the size of the traditional spectrometer. The larger the instrument, the more advanced the spectral resolution can be because there is a moving mirror that has to be displaced a certain distance for the measurement. In order to build a traditional instrument with a resolution equal to our results, it would have to be the same size as the distance from Vienna to Bratislava.

Our instrument is very compact; its footprint is smaller than one square metre. Most recently, we have made it even more compact and have put it on a portable cart in order to enable field measurements – not only in the lab but also outside – for atmospheric sensing. Figure 3 shows our portable spectrometer. The two boxes with the white lids are the two optical frequency combs. They emit in the near infrared region. We are shifting this colour, which is invisible to our eyes, into the green spectral region

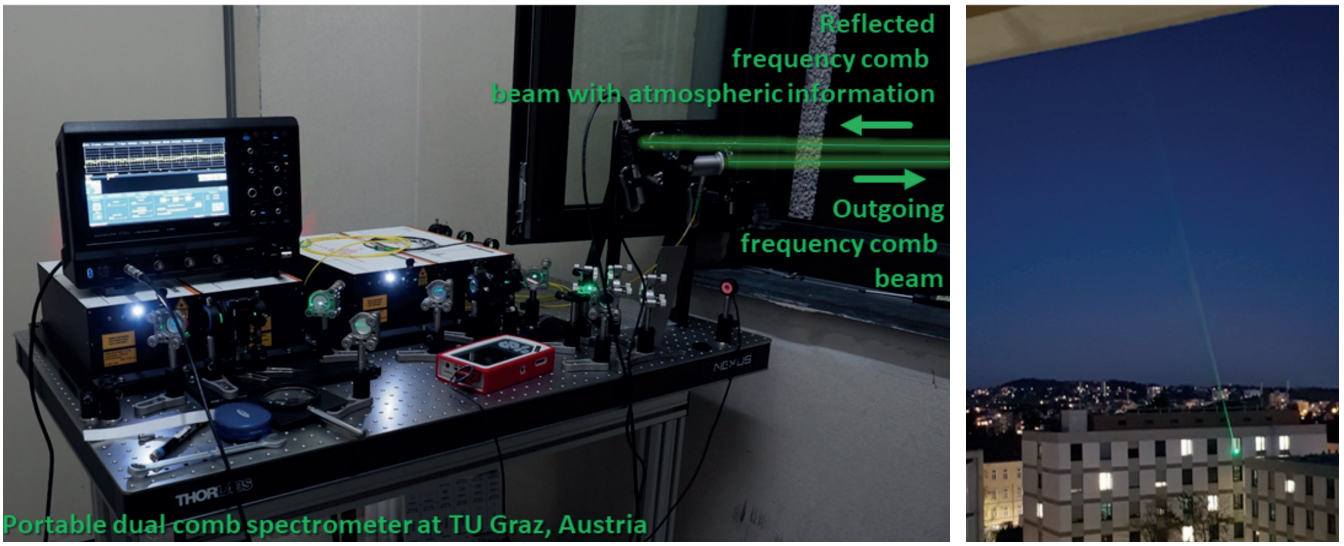

Figure 3: Portable dual comb spectrometer operating in the visible spectral region (left). Photo: Schultze-Bernhardt
Right: Photo of a field measurement: The laser beam is guided through the open window. Different retroreflectors attached to the neighbouring buildings reflect the beam to its origin where a photo diode detects the signal containing the absorption information depending on the path geometry and measurement time point. Due to the high coherence and efficiency of dual comb spectroscopy, low powers of less than 1 mW are sufficient. Photo: Alexander Eber

via a non-linear process. We do this in order to be able to detect the pollutant NO_2 in the atmosphere in the city of Graz. In this plot you can see the amount of NO_2 absorbed in the visible spectral region. We compare our results to NO_2 values published daily on the website of the Federal Environment Agency. During rush hour, the NO_2 amount stated there was about 95 micrograms per cubic metre.

In our case, we use the setup that you see in the photo. We moved our setup to different locations in our physics building at the university, sent our laser beam through an opened window and then used retroreflectors to send the laser beam back to its origin. When we detect this light that is transmitted through the atmosphere, it also carries information about the absorption of the atmospheric gas mixture, and with that, of NO_2. For

these first measurements we did not have to leave the building, so it is very useful for optimizing the operation of the spectrometer. One particular advantage is that the absorption is now rather high at the wavelength that we are using.

The right panel of figure 3 shows a photo of a field measurement by night. The laser beam is visible, although the power is rather weak, less than 1 mW is required. We do not even need eye protection for the measurements. Our measurements recorded a NO_2 concentration of about 60 micrograms per cubic metre. If we compare it to the previously stated values from the Federal Environment Agency, this value seems realistic because we have measured within a patio without traffic, while the agency's detector is located next to a street. We started at this certain wavelength of 515 nm for NO_2 detection but we plan to broaden our spectrum and to include more types of gasses because our atmosphere is rather complex. There will also be more laboratory investigations that target the electron dynamics in photochemical reactions.

With the field campaign example that I have presented here, I think it is a great opportunity to focus on the city itself because by changing the position of the retroreflector, one can actually make a map, for example, how the NO_2 concentration changes closer to the streets or away from the streets depending on the time of day. We can also measure by night because we are not dependent on the sun. We can monitor the NO_2 concentration by measuring every few minutes to determine how it is affected by traffic jams or special events involving a lot of visitors in the city, and also how it depends on weather conditions. Weather and climate are rather complex scenarios, and our investigations on smaller scales could contribute to an improved understanding of photochemical reactions' influences on our atmospheric composition, and with that, our weather and climate.

I would like to use the opportunity to also mention that I have accepted an offer from TU Graz for a full professorship that allows me to intensify exactly this kind of research direction that I have just presented. With my new working group "Coherent Sensing", we will develop the technique of dual comb spectroscopy further towards environmental trace gas sensing and other interdisciplinary applications in biophysics and photochemistry.

BIRGITTA SCHULTZE-BERNHARDT *has been a university professor of experimental physics at Graz University of Technology since October 2022 where she leads the 'Coherent Sensing' research group. After her PhD at the Institute of Quantum Optics, Germany, she was a post-doc at Lawrence Berkeley National Laboratory and UC Berkeley, USA, and at the Technical University of Munich, Germany, and a junior professor at Friedrich Schiller University Jena, Germany. Her research focuses on high-resolution laser spectroscopy in different spectral regions. She has contributed significantly to the development of dual comb spectroscopy, an innovative spectroscopic method that originates from precision spectroscopy and most recently expanded to incorporate interdisciplinary applications including environmental sciences, biophysics and photochemistry.*

PANEL DISCUSSION

WITH VERENA MISCHITZ (MODERATION), SIMONE GINGRICH AND ALEH CHERP

VERENA MISCHITZ

My name is Verena Mischitz and I am a journalist focusing on climate and the environment. Today, we will talk about the role of scientists in the climate crisis. Simone Gingrich is an assistant professor at the Institute of Social Ecology at the University of Natural Resources and Life Sciences, Vienna, and Aleh Cherp is a professor in the Department of Environmental Sciences and Policy at the Central European University and Lund University. Please introduce your work.

SIMONE GINGRICH

My work is on interdisciplinary sustainability sciences. I study environmental consequences of societal actions in a very long term, focusing on land use, resource use, and recently mostly also on climate impacts.

ALEH CHERP

I also focus on the long term, and the biggest question I work on is whether it is feasible to eliminate the causes of climate change – by reducing emissions or by other means. Realistically, what can be done?

VERENA MISCHITZ

Science is crucial in the ongoing crises. Science makes the problem visible and also offers solutions to tackle the crises. What do you think is the role of scientists in times of multiple crises?

SIMONE GINGRICH

There has been a shift in the role of sustainability sciences since I entered the field over 15 years ago. Since 2018/9 we are more visible thanks to the Fridays for Future movement. Also, within sustainability science there is increasing reflection about what effective contributions research can make. There are increasing numbers of researchers that say: let us not continue to write IPCC reports that will end up in a drawer but may not lead to action. Let us do other things. Let us demonstrate, or work with stakeholders to generate actionable, context-specific knowledge. For me personally, the major interactions I have with non-academic audiences are actually in teaching. We are also not only scientists, but we have different roles to play. We are also role models; we are people in families or relationships and social networks in which we can act and show what might be done against crises.

VERENA MISCHITZ

It is not enough anymore to generate the content?

ALEH CHERP

I do not think it ever was enough. I think the role of scientists is to facilitate democratic debate. A scientist should be a broker of various ideas which are offered to society. I also think that we should not only reflect on crises but also focus on more forward-thinking solutions. Science can participate in policy designs and a democratic dialogue with non-scientists.

VERENA MISCHITZ

Currently, tensions between science and society are noticeable. It happens repeatedly that science is saying one thing and politicians do something else. What are your experiences with that?

SIMONE GINGRICH

In my perception, the sustainability debate has become much more politicized than it was 15 years ago. At the same time, public awareness has increased a lot. In sustainability science in Austria there have already been a lot of funding schemes in which collaborations with non-academic stakeholders were promoted since the late 1990s. I myself have been working with schools or with NGOs.

VERENA MISCHITZ

Which institutional conditions are necessary for you to work successfully in the field between science and society?

SIMONE GINGRICH

I do not really work 'between' science and society; most of my work is basic research. There are interactions with practitioners, of course. For example, earlier this week I gave a talk at an event called Akademie in den Bundesländern ("the Academy [of Sciences] in the Provinces"), speaking to the local people of a mountain village about my research on sustainable forestry. I perceived quite a large gap between my research and the local context-specific realities. At the same time, the exchange was very productive, and I believe both parties – me and the local actors – learned a lot. The academic system, however, rewards basic research rather than more transdisciplinary outreach activities. So, whenever I do such things, I have less time to do the research that will be rewarded in terms of career advancement.

VERENA MISCHITZ

My next question is related to a recently published paper that talks about a new contract between science and society. Its authors call for a transformation of environmental research and propose a new science-society contract that recommends politics of environment and knowledge. Do we need such a contract or is there already such a contract between science and society?

ALEH CHERP

The president of the American Association for the Advancement of Science once talked not about a science-society contract but about a "social contract for science". She said: Just to do more science, that is not enough. We must take on ourselves three obligations. The first is to address what is most urgent to society. We must not just be driven by our curiosity, but also focus on what is important. The second is to communicate and disseminate knowledge widely in order for it to be able to inform decisions by individuals and institutions. So, thirdly, we should act with humility. Consequently, scientists cannot just say: Let us not do any more research because nobody listens to us.

SIMONE GINGRICH

To these three obligations of science may be added a fourth: monitor how the results are being used. For me, this paper represents a radical position by scientists. They say: "Let us stop doing research because the crisis is so vast that we cannot go on like before." I understand that they want to make a radical statement, but I think they are misjudging the potential of scientists to change the world by stopping research. Also, these are all tenured people who can afford to stop doing research. They speak from a position of privilege.

VERENA MISCHITZ

Would you describe yourself as an activist?

ALEH CHERP

I do not identify as an activist.

SIMONE GINGRICH

No, I am not an activist. I also do not think identities as a scientist or political person can be separated. To give you an example, a colleague who teaches sustainability topics to students and commutes by plane from Germany every week is unlikely to convince the students of the urgency of what they are being taught. I myself try to behave in a way that I can also justify when talking to students, or people more generally, about my environmental behaviour – not all of it, of course, but some.

VERENA MISCHITZ

Scientists are increasingly willing to take part in direct actions like civil disobedience. Could civil disobedience by scientists be a way to press for climate action?

SIMONE GINGRICH

I see the point of researchers who have been doing the same kind of scientific work for a long time and now, seeing that it did not lead to any noticeable change, consider different means. There was one interview a while ago with an extremely successful Swiss climate scientist who said: "If I had invested the thousands of hours of work that I put into the IPCC report in public engagement, I might have had a bigger impact" in terms of achieving political change. I can follow that reasoning, and I can understand why some researchers are turning to activism now. Of course, there is the risk of reinforcing

opposition when, really, new coalitions are required. So, there might be some drawbacks to that kind of activism, too.

VERENA MISCHITZ

What would be the most important thing for scientists in the coming years to combat the climate crisis?

SIMONE GINGRICH

What I am most interested in is to understand better the social conditions and possibilities for change. We understand the physical dynamics of climate change and also some of the ecological dynamics of the biodiversity crisis. What we understand too little about is how to improve the conditions for positive social change to happen – whatever that 'positive' may refer to: democratic, effective, or something else. For me, this is a highly relevant question and the logical next step.

IMPRESSUM

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