



# When is a Techno-Fix Legitimate? The Case of Viticultural Climate Resilience

Rune Nydal<sup>1</sup> · Giovanni De Grandis<sup>1</sup> · Lars Ursin<sup>1</sup>

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## Abstract

Climate change is an existential risk reinforced by ordinary actions in affluent societies—often silently present in comfortable and enjoyable habits. This silence is sometimes broken, presenting itself as a nagging reminder of how our habits fuel a catastrophe. As a case in point, global warming has created a state of urgency among wine makers in Spain, as the alcohol level has risen to a point where it jeopardises wine quality and thereby Spanish viticulture. Efforts are currently being made to solve this problem technologically by developing (non-GMO) strains of yeast that produce less alcohol. If successful, this could help save Spanish viticulture. This kind of technological solution is routinely criticised for offering simplistic “techno-fix” solutions to solve complex societal problems. However, it is not clear what features are criticised by the notion of techno-fix and hence how to avoid this criticism. In our interpretation, the techno-fix notion is not exclusively used as a dismissive term. The notion points to a general *virtue* of engineering: to create technological solutions that work silently in the background. This asset of technological solutions might sometimes be problematic and sometimes not. Hence, it needs to be analysed case-by-case by paying attention to the moral relevance of the hidden implications of the technology and of the unreflective actions and habits that they facilitate. Such moral analysis will in turn inform strategies for foregrounding this technology to counteract silencing. We discuss what this means in the case of modifying yeast as a viticultural climate resilience strategy.

**Keywords** Virtues of engineering · Stories of legitimation · Sociotechnical opacity · Agricultural resilience · Climate change mitigation

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✉ Rune Nydal  
Rune.nydal@ntnu.no

<sup>1</sup> Department of Philosophy and Religious Studies, Norwegian University of Science and Technology, Trondheim, Norway

## Introduction

Climate change poses a threat to agriculture for several reasons, including food security, biological diversity, cultural preservation, and political stability. Technological strategies offer potentially powerful tools to support agricultural climate resilience. However, there is a worry that these strategies, while addressing some climate change impacts, might counteract climate change mitigation and ameliorate symptoms rather than address causes.

In this paper, we address one aspect of this worry, which is often referred to as the “techno-fix objection”. Our concern is not the technological strategies for upholding agricultural practices (such as cattle farming) and traditions that *contribute* to climate change. This paper does not focus on the agricultural carbon footprint as such. Rather, our concern is the technological strategies for upholding agricultural practices and traditions that are *threatened by* climate change. These technologies may all face the following dilemma: The more efficient they are as tools for agricultural climate resilience, the less sensitive we might become to the need for climate mitigation.

This may occur, we argue, due to a general feature of technology. Successful technological strategies are characterised by their ability to background the socio-technical context that conditions their success, including the stories of legitimisation of those strategies. When this occurs, technological success may entail moral desensitisation. Whether such desensitisation occurs for those who use those technologies or benefit from them should be investigated case by case. Hence, to counteract cases of desensitisation, we propose that technology developers and societies should find ways to foreground sociotechnical contexts by putting the technology and the problem it addresses in plain view.

Technologists’ ability to background the conditions of their success calls attention to a key aspect of the techno-fix objection. The common techno-fix objection expresses an important concern of something being forgotten or not receiving appropriate attention. The *real* moral issues, one could say, are prevented from presenting themselves and are silenced in disturbing ways. In this paper, we aim to clarify the moral significance of the techno-fix notion and the techno-fix objection by discussing why and when it is morally questionable to elide technologies’ techno-social conditions. We then use our interpretation of the techno-fix notion to discuss an attempt to preserve Spanish viticulture by means of a technological solution. Our case study thus illustrates the usefulness of our conception of the techno-fix objection.

The techno-fix objection, in our interpretation, involves the concern that climate resilience strategies may conceal the urgency of climate change issues and of the need for climate change mitigation. This is illustrated by our case study: an effort to save Spanish viticulture. This case is compared to the effort to save European ski cultures. We will argue that while it is hard to imagine how the technological strategies to save ski cultures may silence the threats of climate change, this is not the case with the technological strategies harnessed to save Spanish

viticulture. This illustrates why our conception of the techno-fix objection call for analysis of whether such silencing takes place and how to counteract it.<sup>1</sup>

### Technological Preservation of Spanish Viticulture

Climate changes have mostly benefitted wine production for some decades, but today they are beginning to pose serious challenges to winemakers (Fraga, 2019; Hannah et al., 2013). Winemakers are currently searching for ways to expand their tool case for climate adaptation, as the limitations of currently available tools have created a sense of urgency (Mozell & Tach, 2014). Indeed, the uncertain future of wine has alarmed producers (Familia Torres, 2019) energised stakeholder conferences (The Porto Protocol, 2019) and scientific conferences (Science and Wine, 2019) and captured the attention of the media (Daniels, 2020; Fichtner, 2014; Ledson, 2020).

The steady growth of alcohol percentage in wine is an indicator of how climate change is affecting the wine production process. Since the eighties, the alcohol level in commercial wines has increased by almost one percentage point each decade, leading to a total increase of 2–3 percentage points in the last thirty years (Mercer, 2021). Climate change is considered an important factor for the rise in alcohol levels in wine due to the increased sugar level in grapes it engenders (Goode and Harrop, 2011). There are, however, other causes, most notably the decision to pick grapes later to achieve higher phenolic maturity, which reflects a shift in preferences from light and fresh wines to ripe and full-bodied wines (Alston et al., 2015, Smith 2013).

Because there are multiple causes of this increase in alcohol level, its link with climate change is not straightforward. Nevertheless, this increased alcohol level, if accompanied by wine narratives on its places of origin, climate and vintage characteristics, can effectively remind us of the impact of climate change. Therefore, we argue that wine narratives are crucial for realising the potential of wine to sensitise consumers to climate change. Narratives have thus far given wine a special cultural status; now, they are also needed to make the techno-fixing of wine morally acceptable by making it clear that it is a response to climate change. Viticulture and winemaking are particularly powerful reminders of ecological vulnerability, as wine production exhibits an intimate relationship between humans and nature in cultures involving the fine-tuned interplay of climate, soil, plants, microbes, and human practices.

The ecological vulnerability of wine is exemplified by the impact of global warming on alcohol level in wine. Wine's alcohol content has recently risen to a critical point where it seriously threatens the quality of wine in several historical wine-producing regions, most notably in Spain, which is particularly vulnerable to climate change (Santos et al., 2020). Consequently, the geographic distribution of

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<sup>1</sup> This paper is part of a conversation of how technology affects our identities and moral judgements. There is always a danger of being misled by language in such discussions. Our use of the term silencing should not be understood as an attribution of agency to technology. By contrasting efforts to save viticulture and ski-cultures by means of technology, we aim to show, from the start, what we mean by silencing.

wine production might eventually shift towards cooler locations, possibly moving away from long-established wine regions.

A novel technological strategy to preserve the traditional viticultural locations threatened by global warming is to modify wine yeast (through a non-GMO technique) to yield less ethanol without compromising wine's characteristic colour, flavour, or aroma (Gonzalez et al., 2013). Thus, contemporary biotech laboratories may help preserve threatened viticultural regions by offering powerful tools for adapting to climate change.

The current prospect of losing highly valued viticultures conveys a strong message of what may be lost if we do not take radical actions to mitigate climate change. If successful, however, the efforts to modify yeast will be a strategy of technological resilience that consumers will not notice. In this way, it would disconnect the experience of wine consumers from the effects of climate change. That is, consumers would be less prone to be reminded of the climate crisis when enjoying a glass of wine.

Hence, the yeast-based technological strategy to save Spanish viticulture may enforce the silencing or forgetting of the climate drama, whose effects on wine quality could otherwise have been noticed by wine lovers and could have partly spoiled their enjoyment of wine. The technology that has saved wine quality, along with any stories of why Spanish viticulture needed saving, would not be visible. A truly successful technological intervention will thus mask the root cause of the climate drama played out in Spanish viticultures. Hence, an opportunity for raising social awareness about climate change in the societies most responsible for it would be lost.

### Technological Preservation of Ski Cultures

In regard to the efforts to use technology to help save ski cultures, the situation is similar but at the same time quite different. On the one hand, there is a similarity in how skiing cultures experience the effect of climate change every winter. In Norway, for instance, the skiing season has been reduced by one month or more in most regions in the last thirty years, and experts suggest that the climatic snow line will be pushed towards higher altitudes in the coming decades (Saloranta and Andersen, 2018).

The value of preserving ski culture is explicitly stated on the webpage of a research project in Norway that aims to develop energy efficient ways to produce artificial snow, even at temperatures above the freezing point: "Skiing is part of the Norwegian identity and innately defines Norway culturally in a global context. With the future challenges of climate change and lack of snow in people's communities, the foundation of skiing and other traditional winter activities is being threatened" (Snow for the future, 2020).

Climate changes have been accompanied by similar research projects along with other climate adaptation strategies. In the Norwegian city of Trondheim, large amounts of snow are stored outdoors under chopped wood during the summer to make it possible to start the skiing season in November—one or two months earlier



**Fig. 1** Parsenn ski slopes with artificial snow

than would otherwise be possible. Outdoor ski resorts are also regularly maintained by the production of artificial snow in the attempt to preserve the traditional skiing season.. In January 2020, one of the largest indoor ski resorts in the world opened—in Norway, of all places in the world! These efforts all help preserve Norwegian ski culture. The effects of climate change are thus removed as the skiing season is extended by one or two months by various technological means, returning to how it used to be three decades ago.

In the case of skiing, in contrast to the case of wine making, it is hard to imagine that these climate adaptation strategies could silence the tragedy of global warming. Such strategies cannot be backgrounded enough to silence this drama. Snow production and preservation in a snowless landscape remind skiers of climate change. It is difficult to enjoy skiing in a snowless landscape without simultaneously being reminded of climate issues. The techno-fix is not hidden but operates in the open, for everybody to see. This presents a striking difference from the unnoticeable resilience technology of wine yeast modification. The machineries of snow preservation and production operate in plain view. We are, then, graphically reminded of what may be lost, which in this case comprises highly appreciated Norwegian ski cultures.

This is perhaps even more evident in the Alps, where the systems for producing artificial snow are very widespread. It has become common to see snow-covered ski slopes against a background of snowless woods and pastures (Figure 1).

The techno-fix makes the reality of climate change very graphic: where snow was once a common and natural occurrence, it is now a technological product. This even

introduces the concept of “wild snow” to distinguish the dwindling naturally occurring snow from the snow increasingly produced by technological means.

This technological fix enables business as usual but not in a way that desensitises us to the effects of climate change. On the contrary, bringing hundreds of thousands of tourists to witness this technological strategy can possibly raise their awareness of climate change and lead them to ponder the sustainability of the practice. While it seems evident that the technological fix of ski cultures makes skiers *more* aware of the tangible impacts of climate change, the technological fix of Spanish viticulture may instead *fail* to remind us of the tragedies of climate change simply because this technological solution is more subtle and powerful and thereby more hidden.

Our comparison shows that the acceptability of techno-fixes depends on whether they conceal issues of moral importance. When that is the case, the techno-fix objection is pertinent and creative solutions are needed to prevent moral desensitisation to happen.

Before we continue the discussion of our case, we need to take a step back and explore the history and interpretations of the techno-fix notion to expand on how the techno-fix objection calls attention to the matters of concern being silenced.

## Techno-Fix Interpretations

Nuclear physicist Alvin Weinberg introduced and promoted the notion of the technological fix in the 1960s by calling attention to the potential of technological solutions to address societal problems. Sean Johnston describes how Weinberg played a key historic role in raising the awareness of, and confidence in, *technologists* as social and political actors. Technologists should not only be part of conversations on political, social, or cultural problems but also take a leading role in solving them. Technologists have powerful problem-solving capacities and should be recognised as key builders of modern societies. Modern societies and policy-makers should take political lessons from engineers, and they should learn how to think like an engineer (Johnston, 2018).

Weinberg’s notion of the technological fix has become a negative rather than positive concept in contemporary discourses. As Dane Scott (2011) explains, the techno-fix notion tends to refer to a technocratic mindset favouring technological solutions even if the problem primarily calls for social solutions. Weinberg’s call to think like an engineer has, arguably, been viewed as a call to translate any social problem into a technical problem: social problems should primarily be approached with the mind frame and tool case of engineers.

Applying this critical understanding of techno-fix to our case, the challenges that climate change creates for winemakers are understood, translated or reduced into a problem formulation with a specific technical solution. The techno-fix objection is thus as follows: Given that climate change calls for radical political, economic, and cultural changes, thinking like an engineer rather than a social scientist, politician, or activist may lead us to target the wrong problems or create more problems than those we solve. In thinking like an engineer, we may become fixed in a reactive loop where we keep applying patches and procrastinate tackling causes, potentially until

it is too late to address them. This is, then, a mindset where the root problem never moves into the front seat or informs the technological work.

This techno-fix notion is widespread, we suggest, because it expresses an important moral intuition, i.e., the most important issues are efficiently hidden from sight without us even noticing what is going on. Today—and this is key to our interpretation—the widespread notion of techno-fix serves the theoretical purpose of explaining how issues are silenced. In our interpretation, the prevailing negative understanding of techno-fix formulates a version of a reductionist critique where complex societal problems are reduced to simple technical problems—a *quick fix*. In other words, a techno-fix is *an illusory or symptomatic fix of a social problem*. A techno-fix will need another technical fix as soon as the problem manifests itself again in a new form.

This critical techno-fix notion plays an important role, in the context of dealing with environmental challenges. In this context, it is imperative to emphasise that one *should* be sceptical of simple technological solutions to climate change, as they may undermine social action. The fact that it is often emphasised that technology *cannot* solve all environmental problems and that technology *will not* save us is arguably a reaction to a misguided techno-optimist mindset at work in our societies (Hueseemann and Hueseemann, 2011; Ruser and Machin, 2016).

The techno-fix notion has limited analytical value, however, if it simply refers to a reductive ‘mindset’ representing a naïve and dangerous techno-optimism. In contrast, important insights into how moral issues are silenced will be lost if we adopt this interpretation. As Scott observes, “[t]he fact that ‘technological fix’ has become a dismissive term in public rhetoric hides its significance as an important concept for understanding the roles technologies play in contemporary life” (Scott, 2011: 208). The moral concerns that the notion of techno-fix expresses, Scott suggests, are important sources for understanding the *ambiguous* nature of the complex relationships among contemporary societies and technology. We are at risk of missing this ambivalence if we unreflectively dismiss any attempt to solve social problems by means of technology as a form of category mistake. The critical techno-fix notion, Scott suggests, reveals a taken-for-granted assumption that it is possible to make a clear distinction between technical and social problems.

One way to address the moral ambiguity we often experience in adopting new technologies to fix social problems is to pay close attention to the interconnected nature of technological and social orders. As Morton Winston (1999) observed two decades ago, understanding the dynamics of this interconnection is a key challenge of the ethics of technology. This mirrors what Sheila Jasanoff (2004), in general terms, referred to as the dynamic of coproduction: the ways in which science and technology acquire knowledge of the world are inseparable from the ways in which we choose to live in it. It is no longer particularly controversial to state that new technology restructures technological orders and thereby, simultaneously, the associated social orders. From this perspective, however, the techno-fix notion cannot be understood as a purely dismissive term. A recovered techno-fix notion can become an important resource for discussing the proper role of technology in a particular case. Because the notion of techno-fix calls attention to the possible moral objections to a given technological strategy, it simultaneously calls attention to the

possibly problematic interconnections of technical and social orders that need to be adjusted.

This is why the basic moral intuition expressed by the techno-fix objection matters. The objection calls attention to the key matters of concern being silenced, backgrounded, and forgotten and thereby not receiving proper attention in the moral assessment of a technology. This silencing, however, needs to be understood as a basic feature of technology in our interpretation of techno-fix. Such silencing is of general concern and matters more than ever, as technologies have come to permeate modern societies, causing what Shannon Vallor describes as a “growing techno-social blindness, a condition that I will call *acute techno-social opacity*” (Vallor, 2016: 6).

### Techno-Social Opacity

The reduction of social complexity to technical simplicity lies at the heart of the negative version of the techno-fix notion. This reduction, as it assumes a decoupling of technical and social problems, makes it difficult to formulate the positive version expressed in Weinberg’s original vision of techno-fixes. Techno-fix, we suggest, should not be used as a dismissive term. Technological fixes may be both a blessing and a curse because technology has both the potential for solving problems and for creating techno-social opacity. Defining techno-fix as a simplification of complex social problems into simple technical problems does not need to assume a sharp division between social and technical problems. Techno-fix is not morally problematic in itself. It can provide effectiveness without any consequences of moral significance.

To illustrate, we can use Latour’s (1992) standard example of comparing seat-belt alarms in cars with legal measures or moral campaigns. This technical solution provides a simple and reliable alternative to unreliable and complex social solutions. In this way, technological solutions may offer powerful alternatives to social solutions, as technology restricts the available range of individual and social action. This ability to solve complex social problems with simple technological solutions makes technologists powerful social actors. Even if it is a matter of techno-fixing, the techno-fix objection does not seem to apply when we investigate the implications of examples like this. The options removed by the techno-fix are not worth mourning. In this case, the solution does not appear to silence issues that we truly should pay attention to, given the goal of car safety.

Hence, the question of the legitimacy of a techno-fix in our interpretation is not whether it simplifies a societal problem into a technological problem but whether this technological simplification silences issues of key importance. The capacity to solve problems through technology simultaneously makes us morally vulnerable. This vulnerability follows from the ways in which a technology tends to hide its sociotechnical conditions simply because that is how it functions at its best. It is this work of hiding that engineers are systematically trained to do.

Technologies function efficiently when experienced as a tool, as a technical artefact, allowing users to not pay attention to them. It is an integral part of the



professional training of engineers to find ways to background—or black box—their technologies by seamlessly integrating them into our daily habits and practices. Engineers thus succeed when their products are no longer noticed, i.e., when the technology they produce becomes so user friendly, domesticated, and backgrounded that they are deemed a natural part of a practice. Arguably, the less the works of engineers are visible, the better engineers fulfil their tasks. The work of silencing the conditions of their own success is a key *virtue* of engineering practice. Engineers are trained to find ways to hide technological solutions by integrating them into users' daily habits and practices. Hence, the more engineers make themselves and their products invisible, the greater their success.

Moral vulnerability follows the backgrounding of the complex sociotechnical conditions of technology. As we domesticate a given technology, this background becomes so smooth and mundane that we are no longer aware of the conditions that make the technology possible, the problems that it may imply, or the alternative possibilities.

Techno-social opacity, in Vallor's sense, thus becomes morally problematic when it alienates us from our role as the makers of the world we live in, rendering us incapable of being aware of what is implicated by our actions (Vallor, 2016). The opacity of technological systems therefore ultimately produces and sustains moral self-deception: we become comfortably blind to the preconditions and consequences of our daily actions and habits.

## Putting Technology in Plain View

Our interpretation of techno-fix indicates that what design conceals may need moral attention. The work of Ross Harding (2019) illustrates this point. Harding advocates a need for “a new normal”, directing our attention to the ways in which we normally organise our cities. The problem of sustainability is not restricted to issues such as a circular economy or zero emission systems. Part of the problem is that our daily habits and mindsets are disentangled by design from the technological systems that condition our comfortable lives. For instance, our energy, water, and waste management systems are efficiently kept out of sight. This might be ethically and politically unproblematic. It is, however, problematic if the opacity of these technological systems desensitises us in ways that counteract our awareness that the existential threat of climate change is driven by actions we take in our daily comfortable lives. In other words, the normal design principles of technology help sustain moral self-deception.

In this situation, Harding suggests a new normal, where we make our technologically mediated life conditions visible by building vital infrastructures in plain sight in the middle of town. That this might be uncomfortable, depressing or too risky illustrates an important point; we should be able to acknowledge the technologies that enables our comfortable lives. Deliberate design efforts to put such technologies in plain view provides the means to “connect culture with technology”.

In line with Harding's suggestion, our point of departure is formulated quite simply: we propose finding ways to put any technology in plain sight if it threatens

to desensitise us, as is the case with the consequences of our habits and lifestyles concerning climate change. Transparency alone, however, is not the answer to large problems, but it at least contributes to preventing the negative effects of technological concealment and facilitating climate alertness.

When should we take active steps to place a technology in plain view? The difference between the strategies to preserve ski cultures and viticultures illustrates our approach. We do not need to take action to call attention to how and why a given technological strategy is mobilised to help save ski cultures. The drama of global warming is evident on the ski slopes covered with artificial snow amidst snowless hills or mountains. In the case of technological efforts to save viticultures, however, the urgency of climate crises and what needs to be done to prevent them may be hidden by using modified yeast.

## Technological Preservation of Viticultures

The authors of this paper are part of a European research project coordinated from Spain. The end goal of the project is to help preserve the Spanish wine sector, whose future viability is threatened by global warming. The project proposes a (non-GMO) bioengineering of new yeast strains that can moderate the alcohol level in the wine without compromising its characteristic colour, flavour, or aroma (see Casado-Marin & Anzil 2022 and Gonzalez et al., 2013 for a fuller description).

The project addresses a key challenge for Spanish wine makers and, as such, can be seen as an effort seeking legitimacy as a climate resilience strategy. Researchers in the project have reached out to philosophers and anthropologists for assessing the ethical and societal legitimacy of the project. Our participation is part of the tradition of ELSA and RRI funding schemes integrating researchers from the social sciences and humanities in ongoing research projects. As our contribution to the project, we raise the question of whether the techno-fix objection applies in this case, whether it undermines the legitimacy of the project, and if so, what the consequences of this analysis should be.

Global warming affects the ripening process of wine grapes. This maturation process includes two separate processes that need to be balanced: sugar ripeness (or technological maturity) on the one hand, and physiological or phenolic ripeness (that affects colour, flavour, and aroma) on the other hand. Global warming and a higher concentration of CO<sub>2</sub> in the atmosphere accelerate sugar ripeness more than phenolic ripeness, making it more difficult to achieve the right balance and produce harmonious wines. Given these conditions, this project could be seen as a technological climate resilience project. It suggests a novel biotechnological solution (modified yeast) that would, if successful, help solve the complex technical, social and economic challenges that climate change poses to Spanish viticulture.

From a social and economic point of view, climate change's effects on viticulture threaten a commercially valuable and culturally important product of Spain, namely, wine, and hence the livelihood, lifestyle, and resilience of Spanish agricultural communities. Furthermore, wine, like food, has considerable value for the tourist sector, another important resource and source of livelihood in Spain. Moreover, viticulture,

wine production and consumption are important elements of regional and national identities and lifestyles. Finally, what is true in Spain is true in other southern European regions, such as Portugal, southern France, Italy and Greece. If this project succeeds, then, winemakers would have access to a powerful tool of particular importance in areas where viticulture is in jeopardy. This simple technological fix would prevent a social and economic crisis that these regions would otherwise have to face.

From a technical point of view, there are currently various options for adapting to climate variations to produce harmonious wine. Some are operated in vineyards, such as monitoring and controlling the growing conditions of vine plants (e.g., managing their temperature, sunlight exposure and water supply) or perturbing the ripening process more directly through chemical additives (Goode, 2019; Robinson, 2015). All these strategies are quite labour or resource intensive and do not guarantee the desired result. Other strategies are operated during the stage of wine making, such as reverse osmosis, an invasive and expensive process, or adding water to must, a practice that is illegal in Europe. Compared to those techniques, this effort to engineer yeast, if successful, would offer winemakers a powerful, affordable and relatively easy-to-use additional tool to confront the challenge of excessive sugar ripeness.

In our interpretation, the technological strategy of modifying yeast to help save Spanish viticulture constitutes a techno-fix strategy. The strategy expresses the hope of reducing a complex techno-social climate resilience problem to a manageable, simple technical problem. The technical challenge of yeast modification is not easy, so the problem is not simple in a technical sense. It is, rather, the expressed hope of reducing the complexity of the techno-social issues being problematized that evokes a possible techno-fix objection. The more powerful the technological strategy proves to be, the more the problem of saving Spanish viticulture can be reduced to the technical problem of yeast modification. We emphasise, however, that identifying yeast modification as a techno-fix does not automatically represent an ethical objection. Only if this solution silences key matters of concern, then there is an ethical problem that calls for action.

## Legitimising the Wine Yeast Techno-Fix

Global climate change calls for two responses: (1) climate change mitigation and (2) climate change resilience. Our concern is whether the yeast modification strategy is one of those technologies that would normalise our daily unsustainable habits and the economic and social structures that support it, in other words, if it could be a *climate resilience* action that undermines *climate change mitigation*. Given the existential risk of climate change, the mitigation of its causes rather than its consequences should arguably take priority. Climate change arguably calls for hard priorities. The fact that Spanish viticulture is at risk is less important in the grand scheme of things. It could entail a significant cultural loss for consumers and a very significant cultural and economic loss for producers and the Spanish economy. It would affect the livelihood of a significant number of wine growers and winemakers. However, given

what is at stake, even if all this is lost in Spain and in southern Europe, it may still be a necessary sacrifice to achieve more important goals, such as preventing famine, the flooding of vast areas, and disordered mass migration. Wine is, after all, a luxury product, and viticulture may be replaced by other forms of agricultural cultivation. Furthermore, wine production may survive and thrive elsewhere, at least over time, if viticulture migrates further north.

The drama of climate change should not be placed out of sight or silenced. A techno-fix objection to the legitimacy of the wine yeast project as a climate resilience strategy could be raised if the project desensitises wine producers and consumers to the larger issue of climate mitigation. The very qualities of this project, namely, its prospects for providing a powerful technical solution that can operate simply, effectively and discreetly during the winemaking process without being noticed by consumers, makes it vulnerable to the accusation of silently obscuring the impact of climate change on the quality and value of wine. The impact of global warming on viticulture would be mitigated, but at the price of making wine consumers oblivious to how climate change threatens this product that they enjoy. Viticultural climate resilience would then be achieved at the cost of lowering awareness of the seriousness of climate change, whereas we need to raise awareness.

To explain our concern for the possible moral desensitisation in this context, below, we draw attention to some very interesting and unique properties of wine, which can make it an especially well-situated product for promoting climate change awareness.

### **Wine and Climate Awareness**

Wine production and consumption constitute traditions and cultural practices that are valuable because they reveal the interdependence of humans and nature. Wine as a cultural product, as opposed to wine as a mere commodity, always comes with a story: it conveys something about a place, its nature and climate, and its culture and traditions.

The story of a wine also includes the temporal dimension of a vintage and its unique climatic features, as well as the individuality of a producer, and reflects her work, dedication, vision, and taste. These stories are an integral part of wine identity: they inform how a wine is perceived and valued. Wine lovers even visit the most renowned wine-producing regions and their various estates because they are interested in the stories of these places and the people who produce wine whose character is reflected in the wine. The wine-producing sector has a deep connection with locality and is intimately sensitive to climate variations. Wine tells a story of the interactions among nature, cultural traditions and individual efforts and visions. The language in which such a story is written is the aesthetic of wine, bringing together multiple sensory qualities in a harmonic way. What a wine is supposed to express is a multidimensional matrix. Specifically, a wine may be expected to express any (or most) of the following qualities: the grape variety (for single varietals) or a certain style (for the most traditional blends); the soil and microclimate of a region or of a subregion or even of a single vineyard (a *cru*); the unique character of each vintage;

the winemaking tradition of a nation, region or even single estate; and the vision of the single *vigneron* and/or winemaker.

This exceptional position that wine holds is epitomised by the notion of “*terroir*”. In the world of wine, *terroir* is a matter of origin, taste, and authenticity. *Terroir* is a matter of uniqueness, and the art of winemaking is the ability to preserve and cultivate this uniqueness into a characteristic and tasteful wine. Technological standardisation is thus in many ways the antithesis of the *terroir* ambition of the makers of premium wines. The choice of an authentic and unique wine further promises establishing a connection between its consumer and local natural and cultural conditions. Even though it is scientifically controversial (see, for instance, Matthews, 2016 for a critique of it and Goode, 2014 for a defence), it carries with it an aspiration—a compelling story of humans coexisting with natural conditions, expressed in a story that emphasises the fragile nature of this coexistence.

Since wine is not simply a commercial commodity but a cultural product that tells a story about people, places, and climate, it is in a special position to communicate the drama of climate change and to raise awareness of what can be lost. Amidst climate change and the dramatic story that it can bring about for humanity and nature alike, telling the story of the struggle that winemakers face to continue producing the wines consumers enjoy could help people to reckon with the challenge we are facing.

This powerful technological strategy to mitigate the effects of climate change therefore threatens to weaken the unique potential of wine in promoting climate awareness. The effort to techno-fix Spanish viticulture comes at a risk of moral desensitisation simply because, unlike the case of skiing cultures, it makes the drama of climate change less visible as an immediate threat. In this situation, efforts could be made to counteract this silencing of the drama by making visible the relevant technological solutions and the problems that they address. If this can be successfully achieved, the efforts to save Spanish viticulture could even strengthen the potential of wine to raise awareness of the seriousness of climate change, as we have argued is the case with the technologies being used to save ski cultures.

### Putting the Modified Yeast in Plain View

A story that brings together the *terroir* narrative and the climate change narrative could put this new yeast technology in plain view and legitimise it.

This story could support consumers’ full experience of enjoying a *terroir* wine while at the same time making them aware that climate change is undermining the production of these wines through traditional and natural processes, whereby only technological interventions that marginally lessen *terroir* character make their survival possible. In short, the yeast techno-fix needs to be made apparent to consumers to foreground the impact of climate change on their cherished products and must balance the act of providing an enjoyable experience with sharpening the perception of the losses that climate change will bring.

It is as if a wine should tell its consumer, “Hey, I am still here to please you, but I am a little different. I had to be helped by biotechnology to preserve my balance.

I am truly an endangered species, like many other traditional agricultural products. If you want me to survive, show care for the fragile planet that makes my existence possible.” If this story can become an unmissable part of the identity of techno-fixed wine, reminding everyone of the losses that climate change can bring about and of the need to take action to mitigate it, the technological strategy of viticultural climate resilience through yeast modification might be deemed legitimate. As in the case of skiing culture, once accompanied by this story, the yeast techno-fix would not bypass or silence the drama of climate change. If climate change did not have anthropogenic causes and was just part of a natural cycle of variations, the techno-fix objection would not apply simply because the techno-fix would not obscure matters for which we have important responsibilities and that call for collective action.

Accordingly, we conclude that if it is possible to find effective ways to foreground this technological intervention and make it part of the story that wine conveys to consumers, then the morally problematic opacity of the technical intervention can be overcome. We do not know whether the marketing or regulatory strategies that could make this possible will be discovered or successful. However, we believe that the unique symbolic and cultural features of wine make it an especially promising case for exploring new ways of combining technological solutions and communication strategies to sensitise consumers to climate change.

Creative and powerful marketing strategies could be developed to foreground rather than background techno-fixes for climate resilience. In Europe, the wine sector is about to undergo a radical transformation of its labelling to improve transparency. We cannot rule out the possibility, then, that more truthful stories about the role of technology in winemaking can help people think about the reasons for accepting or rejecting different technological interventions. Our RRI contribution to the yeast project is thus an invitation to explore a distinct, more transparent, and more socially and environmentally responsible way of communicating the rationale and mechanisms of this technological intervention in the wine-making process.

## Concluding remarks

The techno-fix notion and the techno-fix objection play an important role in discussions of technology-based climate change resilience and mitigation strategies. However, as Katerine Devolder notes in a paper published in this journal, “despite the fact that the objection has wide intuitive appeal, it is often not clear what exactly the moral problem is supposed to be” (Devolder, 2021: 1). The aim of this paper is to clarify how the moral problem arises and, consequently, what actions could be taken to address it. We find these questions to be urgent, as we need to determine a place for technological strategies of climate mitigation and climate resilience. Although some technological innovations are the main causes of climate change, we may still need more technology to help solve the problems caused by climate change. *Because* technology has the power to reduce complex matters to solvable matters, it offers actual options for powerful action.

In our interpretation, the morality of technological fixes needs to be investigated case by case. We should be careful when using techno-fix as a purely

dismissive term, as important insights might be lost. The moral problems expressed by the techno-fix objection, we suggest, arise as problems of socio-technical opacity followed by the ways in which technology is entrenched in daily mundane practices. Hence, analysing and solving moral problems involve finding imaginative and creative ways to counteract sociotechnical opacity as needed, i.e., discovering ways to put technology in plain view and its adoption open to question.

This paper has focused on technological climate resilience strategies, using technological viticulture resilience as our case in point. Climate change presents an existential risk that we cannot ignore; hence, the issue of climate mitigation looms over all questions of climate resilience. It is a problem if climate resilience strategies come at the expense of backgrounding the urgency of climate mitigation. This is particularly evident in our case, since viticulture is especially vulnerable to climate change. It is valued as an open-ended practice, in constant need of adjustment and finding sustainable ways to live with nature under shifting conditions. It may therefore be an exemplary practice worth preserving in traditional areas, such as Spain. The risk of losing cherished viticultural regions can potentially call attention to the existential risk of climate change.

Even if wine does not contribute to feeding the world, the preservation of wine as a culturally meaningful product can provide both extremely needed resources for agricultural communities and significant symbolic and exemplary value. If the remarkable storytelling capacity of wine includes an open and honest acknowledgement of the role of technology in wine making, then wine may have new potential for foregrounding technological solutions instead of hiding them.

The bioengineered yeasts that mitigate the alcohol content of wine may become another hidden techno-fix that operates behind the scenes and hides both the role of technology and the seriousness of the climate change problem, whose impact on viticulture it is supposed to fix. However, it may also become an example of a new, more transparent, more honest, more socially and environmentally responsible way of presenting technological innovations to consumers. Accordingly, it may be used as a test case for countering technological opacity in ways that draw attention to the drama of climate change.

Finally, the yeast project has prompted us to imagine a scenario in which a techno-fix can effectively but opaquely contribute to preserving the viability of the Spanish wine sector in the face of climate change challenges. Is it too visionary to imagine a scenario in which the same technology can contribute to saving wine production while at the same time making consumers more aware and engaged, rather than more desensitised and self-deluded, about the preconditions and implications of their habits and behaviours?

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## References

- Alston, J. M., Fuller, K. B., Lapsley, J. T., Soleas, G., & Tumbre, K. P. (2015). Splendide mendax: False label claims about high and rising alcohol content of wine. *Journal of Wine Economics*, 10(3), 275–313. <https://doi.org/10.1017/jwe.2015.33>
- Casadó-Marín, L., & Anzil, V. (2022). The semiotics of wine-related cultural consensus in two Spanish wine-producing regions. *International Journal of Gastronomy and Food Science*, 28, 100536. <https://doi.org/10.1016/j.ijgfs.2022.100536>
- Daniels, S. (2020). Climate change is rapidly altering wine as we know it. *Wine Enthusiast Magazine*. Retrieved October 28 from <https://www.winemag.com/2020/02/03/wine-climate-change/>
- Devolder, K. (2021). Genome editing in livestock, complicity, and the technological fix objection. *Journal of Agricultural and Environmental Ethics*, 34, 1–17. <https://doi.org/10.1007/s10806-021-09858-z>
- Familia Torres (2019). Familia Torres brings together international experts to present urgent actions to combat climate change. Retrieved October 28, from <https://www.torres.es/en/we-are/news-item/familia-torres-brings-together-international-experts-present-urgent-actions-combat>
- Fichtner, U. (2014). France’s great wines are feeling the heat. Spiegel international. Retrieved October 28, from <https://www.spiegel.de/international/zeitgeist/climate-change-threatens-french-viticulture-a-1000113.html>
- Fraga, H. (2019). Viticulture and winemaking under climate change. *Agronomy*, 9(12), 783. <https://doi.org/10.3390/agronomy9120783>
- Gonzalez, R., Quiros, M., & Morales, P. (2013). Yeast respiration of sugars by non-Saccharomyces yeast species: A promising and barely explored approach to lowering alcohol content of wines. *Trends in Food Science and Technology*, 29, 55–61. <https://doi.org/10.1016/j.tifs.2012.06.015>
- Goode, J. (2014). *The science of wine. Second edition*. University of California Press.
- Goode, J. (2019). Ripeness in wine. *Wineanorak. Global Wine Journal*. Retrieved October 28, from <https://wineanorak.com/2019/10/20/ripeness-in-wine-part-1/>
- Goode, J., & Harrop, S. (2011). *Authentic wine*. University of California Press.
- Hannah, L., Roehrdanz, P. R., Ikegami, M., Shepard, A. V., Shaw, R., Tabor, G., Zhi, L., Marquet, P. A., & Hijmans, R. J. (2013). Climate change, wine, and conservation. *Proceedings of the National Academy of Sciences*, 110(17), 6907–6912. <https://doi.org/10.1073/pnas.1210127110>
- Harding, R. (2019). A new normal. Retrieved October 28 from [https://www.youtube.com/watch?v=KA\\_9fWVvM1AE&fbclid=IwAR0eDfU7sKpxKf4FLh1q\\_7mIDqrk1cbP\\_2Unj1r7zcJlr5wurhkSJ5xNTcA](https://www.youtube.com/watch?v=KA_9fWVvM1AE&fbclid=IwAR0eDfU7sKpxKf4FLh1q_7mIDqrk1cbP_2Unj1r7zcJlr5wurhkSJ5xNTcA)
- Huesemann, M., & Huesemann, J. (2011). *Techno-Fix: Why technology won’t save us or the environment*. New Society Publishers.
- Jasanoff, S. (2004). The idiom of co-production. In S. Jasanoff (Ed.), *States of knowledge: The co-production of science and the social order* (pp. 1–12). Routledge.
- Johnston, S. (2018). Alvin Weinberg and the promotion of the technological fix. *Technological Cultures*, 59, 620–651. <https://doi.org/10.1353/tech.2018.0061>



- Latour, B. (1992). Where are the missing masses? The sociology of a few mundane artifacts. In W. E. Bijker & J. Law (Eds.), *Shaping technology/building society: Studies in sociotechnical change* (pp. 225–258). MIT Press.
- Ledsom, A. (2020). How climate change is altering your favorite glass of wine. *Forbes*. Retrieved October 28, from <https://www.forbes.com/sites/alexledsom/2020/09/12/how-climate-change-is-altering-your-favourite-glass-of-wine/?sh=7c28eb14491b>
- Matthews, M. A. (2016). *Terroir and other myths of winegrowing*. University of California Press.
- Mercer, C. (2021). Is alcohol in wine rising? New data released. *Decanter*. Retrieved October 28, from <https://www.decanter.com/learn/are-alcohol-levels-in-wine-rising-data-460879/>
- Mozell, R. M., & Tach, L. (2014). The impact of climate change on the global wine industry: Challenges and solutions. *Wine Economics and Policy*, 3, 81–89. <https://doi.org/10.1016/j.wep.2014.08.001>
- Robinson, J. (Ed.). (2015). *The oxford companion to wine*. Oxford University Press.
- Ruser, A., & Machin, A. (2016). Technology can save us, can't it? The emergence of the 'techno-fix' narrative in climate politics. Retrieved October 28, from <https://academia.edu>
- Saloranta, T., & Andersen, J. (2018). Simulations of snow depth in Norway in a projected future climate (2071–2100). Norges vassdrags- og energidirektorat Retrieved 28 October from [https://publikasjoner.nve.no/rapport/2018/rapport2018\\_12.pdf](https://publikasjoner.nve.no/rapport/2018/rapport2018_12.pdf)
- Santos, J., Fraga, H., Malheiro, A. C., Moutinho-Pereira, J., Dinis, L.-T., Correia, C., Moriondo, M., Leolini, L., Dibari, C., Costafreda-Aumedé, S., Kartschall, T., Menz, C., Molitor, D., Junk, J., Beyer, M., & Schultz, H. R. (2020). A review of the potential climate change impacts and adaptation options for European viticulture. *Applied Sciences*, 10, 3092. <https://doi.org/10.1016/j.wep.2014.08.001>
- Science and Wine. (2019). 1st Science and Wine world congress. The wine of the future. Retrieved October 28, from <https://www.ciencia-e-vinho.com/last-and-next-conferences/1st-science-wine-world-congress-the-wine-of-the-future/>
- Scott, D. (2011). The technological fix criticisms and the agricultural biotechnology debate. *Journal of Agricultural and Environmental Ethics*, 24, 207–226. <https://doi.org/10.1007/s10806-010-9253-7>
- Smith, C. (2014). *Postmodern winemaking*. University of California Press.
- Snow for the future (2020). Snow for the future. Efficient and climate-friendly snowmaking. Retrieved October 28, from <https://www.sintef.no/en/projects/2019/snow-for-the-future-will-produce-artificial-snow-s/>
- The Porto protocol (2019). Climate change leadership. Solutions for the wine industry. Retrieved October 28, from <https://climatechange-porto.com/>
- Vallor, S. (2016). *Technology and the virtues*. Oxford University Press.
- Winston, M. (1999). The scope of technology. In M. Winston & R. Edelbach (Eds.), *Society, ethics and technology*. Wadsworth Publishing.

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