THE DREAM OF A UNIVERSAL SKI WAX: SCIENTIFICATION AND INDUSTRIALIZATION OF SKI TECHNOLOGY IN THE MID-20TH CENTURY

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Introduction

If you are a cross-country skier, you probably do not think much about the innovations you use to get across the snow efficiently. Indeed, the few centimetres separating the snowpack from the human foot contain layers of knowledge and tradition (shoes, boots, bindings, wax) that have been rationalised, lightened, and commercialised over the ages. If we were to crosscut these layers at the end of the 19th century, we would see how efficiently the resources of the surrounding landscape were used in the pre-industrial age of skiing.[2]

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2 Lidström & Svanberg & Ståhlberg 2022, 11.

Instead of socks, skiers wore shoe hay around their feet.[3] Shoe hay is a semi-grass of the sedge family that has a remarkable ability to absorb moisture and keep feet dry. Skis were made by hand from birch or other wood. Tar pits turned pine stumps into tar, which was spread on the underside of the ski. Skis made from compressed wood (in Sweden usually called *tjur* or *tiör*), i.e. coniferous wood with a natural curvature, contained so much resin and turpentine that waxing was unnecessary.[4] The waxes once extracted from the plant kingdom bear little resemblance to the chemical material used under skis today. In this way, the change and refinement of wax seems to reflect the development of society at large; sport, ski waxing, and modern society are united by a passion for technological progress.

This chapter focuses on a landmark change in ski wax production that took place in the 1940s. The production of synthetic waxes, developed as a result of scientific testing and engineering, replaced the previously small-scale and experience-based ski wax production. The chapter explores the historical circumstances and processes – such as industrialization and scientification – that affected the technological development of skiing and paved the way for this change.

The study of ski waxing is first and foremost a field of scientific research, the aim of which is to understand what happens when the ski meets the snow and the tribological nature of this encounter.[5] The purpose of a glide wax is to reduce friction and obtain an optimal sliding speed. This is attained when the surface of the ski is hydrophobic, thereby repelling

3 Collinder 1888, 24–25.
4 Lidström & Svanberg & Ståhlberg 2022, 11.
5 See for example Almquist et al. 2022.

the water as opposed to adhering to it and has a surface structure of a configuration which is beneficial to the temperature, humidity, and constituency of the snow at the time of skiing.[6]

At the same time, the art of waxing is a practical skill with a professionalism based on testing for the best possible glide and grip, as shown by ethnologists' studies of ski waxing as a cultural phenomenon.[7] The friction between scientific theories and empirical experimentation has long characterised the knowledge of how wax is made and how it is applied to the underside of skis. We have seen similar tensions between experiential and scientific knowledge in many other sports, including specific technologies or more overarching issues such as tactics and coaching.[8] In this article we aim to place the theory and practice of waxing in a historical context. As far as cross-country skiing is concerned, earlier research has identified a change in the early 1950s, when the training of elite athletes became rationalised and based on the scientific knowledge of physiologists, rather than the experience-based 'natural' training that had previously prevailed. This scientific turn in cross-country skiing was not limited to the design of training methods and the evaluation of performance but had implications also for which equipment that was used, how the landscapes of ski competitions were adapted and how the style of skiing developed. While science was an important factor here, so was technology. It was the technological developments which allowed for machine-made tracks, plastic skis, field-based endurance tests, and so on.[9] The increasing role of technology in elite sport has continued to develop and even accelerate.[10]

6 The finer details of these requirements have been described by Leonid Kuzmin (2010), and others.

7 Planke 2003.

8 See for example: Hjelseth & Telseth 2023, Fouché 2017.

9 Svensson 2016.

10 Fouché 2017; Toner 2023.

In this chapter, we aim to add to our knowledge of the scientification and technologization of cross-country skiing by showing how it had an impact on the material dimension of the sport already in the years before the Second World War.

In relation to the commercialization of sports in general and cross-country skiing in particular, a process that accelerated in the 1950s, the emergence of new sport-related innovations started. Except from conventional technology development, innovation also denotes a form of economic interest which also follows the commercialization trajectory. The agency of innovation practices turned from an individual small-scale practice to a systematic firm-driven from the 1950s and after. In order to understand the shift, we draw on studies in innovation theory. Contrasting early innovation theorist like Schumpeter[11] who often emphasised the role of the individual entrepreneur who challenged an existing paradigm – willful inventors with the capability to break completely from one technological paradigm to another – contemporary innovation theory put more emphasis on understanding system, institutions, and system change.[12]

The groundbreaking research by Thomas Kuhn show a new picture of the progress of science which clearly differ from earlier, inductivist approach to science as something accumulated over time. Instead, Kuhn saw how science progressed like revolutions. Gradually, the boundaries of the prevailing view of knowledge are stretched to challenge and eventually replace it, resulting in a paradigm shift.[13] The progress stages can be

11 Schumpeter 1934/1992.
12 Baldwin et al. 2024.
13 Kuhn 1962.

viewed through *pre-science, normal science, crisis, revolution, new normal science, new crisis*, and so it continues. The provoking with Kuhn is that this way of interpreting scientific progress makes old knowledge partly obsolete when old paradigm is abandoned (this also resonates with Schumpeter's idea of *creative destruction*).[14]

In a Kuhnian tradition, Ron Johnston defined technological paradigms as 'a set of guiding principles generally accepted by practitioners in a particular field of technology.'[15] In other words, technological paradigms 'describe the punctuated nature of technological change and the path dependency of innovation processes in times of incremental progress'.[16] While scientific research's highest ambition typically is The Truth, technological research goal is often practical usability.

Having said this, for the development of ski wax it is therefore crucial to identify the actors who influenced the technological change in ski wax production, and also understand where in the technological evolution a certain technology is. As the first synthetic wax was produced in Sweden, this chapter is based on Swedish source material. In particular, the Swedish Ski Association's (*Svenska Skidförbundet*) jubilee books, annual reports and board minutes have been studied. It is also based on articles in the Swedish Outdoor Association's (*Föreningen för skidlöpningens främjande*, later on *Friluftsfrämjandet*) yearbook, *På skidor*, and articles in the Swedish daily press.

14 Kuhn 1962/2012.
15 Johnston 1972, 122.
16 Peine 2008, 508.

Traditional Ski Waxing

Ski waxing is an overlooked culture, historically characterised by the lively experimentation of dedicated enthusiasts. The search for the best glide and the best grip is older than the sport of skiing itself. In pre-modern Nordic society, skiing took place mainly in the northern parts of Sweden, Norway, and Finland. A distinctive feature of this period was that both skis and wax were made from resources found in the surrounding landscape. The Sámi, the indigenous people who live in an area commonly referred to as Sápmi, which covers the northern parts of Norway, Sweden, and Finland, as well as northwestern Russia, have left a great deal of written material about how skis were treated with wax. In his book *The History of Lapland* (1674), John Scheffer mentions the Sámi practice of treating skis with pitch and resin.[17] From the 18th century there are several records of tar being burned into the undersides of skis. Fat from fish and other animals was also used. Tallow and lard were used to make skis glide better. Instead of wax, skins from fur-bearing animals such as elk or reindeer could be placed under the skis, performing the same function as today's synthetic ski skins.[18]

The following note, taken from an essay written by Erik Collinder in 1888, testifies to the major problems caused by ski waxing in thawing weather when cross-country skiing became popular:

> The biggest obstacle to skiing is thaw and wet snow. Many remedies have been tried, but with little success. In addition to lard, tallow, cod liver oil, seal blubber, fish oil and kerosene, the skis have been coated in various places with herring milt, a pinch of herring, herring brine raw linseed oil, tar, wax, German soap and American pork, but the effect was always poor and the coating had to be reapplied.[19]

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17 Scheffer 1674, 99.

18 Åström & Norberg 1984, 114–116; Manker 1938, 88.

19 Collinder 1888, 24.

For many centuries, the skier's quest for glide and grip has been characterised by creativity, ingenuity and a deep knowledge of the flora and fauna resources that can be used for such purposes. When cross-country skiing became a modern sport in the late 19th century, the production of ski waxes followed suit. Tar-based products formed the backbone of ski waxing. While the manufacture of skis underwent rapid industrialization around the turn of the century, wax production remained a small-scale activity, largely carried out by the skiers themselves.

Gustaf 'Husum' Jonsson (1903–1990) was typical of his time, both as a skier and as a ski wax producer. He had a modest upbringing and as a child did animal husbandry work in the forest. At the age of 16, he began to work as a forestry worker in the woods. His work with the axe, bark shovel and lifting hook was the basis for the fitness that made him an internationally renowned skier. After winning the Swedish championship in 1925, he changed his profession and started to work in a factory, where he did not like the monotony and the fixed working hours. As a factory worker and a top athlete in the national ski team, Gustaf Jonsson began to remember how he had worked in the tar pits in the forest as a child and how well the tar burned in the pits worked as base wax for skis. If the tar was boiled long enough without turning into pitch, the turpentines and resins came into their own. The combined experience of making wax from tar and working in a factory led Jonsson to set up his own small factory to make wax and sell his products.[20] However, he was not alone in this market: the supply of ski wax in the inter-war period was unmanageable. There were hundreds of varieties. Although tar was still the mainstay of ski wax, it was gradually being mixed with by-products from obsolete modern vehicles. Car tyres and bicycle inner tubes were melted down. Even gramophone discs were used

20 Sima & Eriksson 1988.

in ski wax. The scent of the old and the smell of the new rose from the increasingly well-prepared tracks where the elite athletes competed.[21]

Scientific Ski Wax

A characteristic feature of modern sport is the ideal of 'fair play'. In order for a competition to be meaningful, competitors need to have a level playing field. The great importance that ski waxing has historically played and continues to play in ski competitions means that more than just the technique, strength and fitness of the athletes determine the outcome of ski competitions. It has sometimes been a delicate task to decide whether victories should be credited to the wax or to the competitors. The capricious influence of the waxing on the results of the competition has therefore appeared as something of a disturbing element. For this reason, the Swedish Ski Association set up a special committee in 1918 to solve the so-called 'waxing problem'. After several years of work, the committee announced that it had failed to solve the problem.[22] It would be more than two decades before another attempt was made.

In 1939 a new investigation was set up, funded by a grant from the Swedish lottery profits. The fact that the study was called 'scientific' signalled that standards were now higher than before.[23] By looking to science for a solution to such a problem, the Swedish Ski Association was associated with the technological optimism that prevailed in the late 19th and early 20th centuries, a period marked by the progress of industrialization in Sweden. The peri-

21 Lidström 2017, 23–24; Bjerke 2023, 3.
22 Bergman 1943, 29; 'Protokoll, hållet vid sammanträde med Svenska Skidförbundets styrelse den 19 januari 1920'. Svenska Skidförbundet. A1a:1, Arninge.
23 Bergman 1943, 29; Kar 1939, 17.

od was characterised by a belief in development and technological optimism, supported by industrial owners, entrepreneurs, engineers, and inventors. The First World War, however, put an end to this wave of optimism. The early 20th century, on the other hand, was marked by a significant advance in the natural sciences, which was reflected in the ambitions of the Swedish Ski Association.[24]

The initiative of the association was to be the starting point for an intensive search for knowledge about waxing and skiing, involving both science and large-scale industry. With the Norwegian Ski Association making a similar effort at the same time, a national arms race in ski technology developed. Sixtus Jansson, the president of the Swedish Ski Association, spoke to the Swedish newspaper *Aftonbladet* about his hopes and the challenges ahead:

> We are by no means behind Norway when it comes to waxing. On the contrary, we have been working for more than a year now, using purely scientific means, to produce a universal wax with the highest efficiency in all weather conditions and on all types of snow [...][25]

Hugo Nikolaus Pallin approached the subject from a scientific point of view. He was a professor of road construction and communication technology at what is now KTH, the Royal Institute of Technology in Stockholm. His interest in skiing stemmed from the fact that, alongside his profession, he was a mountaineer who was used to skiing long distances in rough terrain. Several travelogues in the form of articles and books and a long-term commitment to the Lapland Mountaineering Club were the result of this leisure activity. The combination of professional and recreational interests led Pallin to publish a short article in 1920 entitled 'Några ord om beteckning av skidföre' (A few words on the description of ski friction), the

24 Cf Frängsmyr 2000, 101–115, 212.
25 'Vetenskapliga vallningsprov' 1939, 18.

aim of which was to achieve precise measurements of ski friction on a scale between 'glop' (*klabb*) and 'sumptuous' (*överdådigt*).[26]

However, placing skiing friction in a specific conceptual framework is a delicate task. This is evident in the book *Snö* (Snow), in which Yngve Ryd and Johan Rassa devote several chapters to describing the different characters and variants of ski friction and skiing conditions in Lule Sámi, one of the Sami languages.[27] The encounter between skiing and the snow is thus a complex and multifaceted phenomenon that cannot easily be captured in an objectively defined terminology. Almost two decades later, in an article published in 1939, Pallin returned to the problem of the terminology and measurability of skiing friction. His intention was to develop methods to 'express the nature of skiing friction in numerical terms'. For Pallin, it was 'quite remarkable how little skiing has been technically studied and rationalised'. And, of course, the 'diverse nature of ski wax' complicated matters.[28]

The scientific progress of the professor and the Swedish Ski Association coincided with an interest in skiing from large-scale industry. Börje Gabrielsson, CEO of the Swedish pharmaceutical company Astra, was a passionate cross-country skier and had been a keen observer of Swedish skier Martin Matsbo's success at Holmenkollen in Norway. With his background as a forestry worker and his desire to experiment, Matsbo was characteristic of the elite skiers of the day. He ran his own small ski wax factory and was the inventor of a ski pole made of rolled and glued veneer (the so called *Matsbostaven* [Matsbo pole]). After the factory burned down in 1942, Matsbo was approached by Gabrielsson, who by then had decided to create a competitive ski wax through his company.

26 Pallin 1920, 131.
27 Ryd & Rassa 2020.
28 Pallin 1939, 47.

Pallin assigned engineering student Rune Eriksson with kinetic resistance in skiing as the topic for his thesis. With the support of Matsbo, Eriksson carried out studies in Stockholm, Dalarna, Ångermanland and Lapland between 1942 and 1943 with the aim of deepening the knowledge of the 'geophysical' (weather conditions, temperature, type of snow) and 'sporting' (the skier's own actions while skiing) factors that affect skiing performance. The tests were funded by the Swedish Ski Association and Astra, among others. In an article published in 1945, Pallin presented some of the conclusions that he and Eriksson had reached. Among other things, he described how the sliding of the ski over a frozen surface relies on the lubricating effect of a thin layer of liquid water being generated by the pressure added by the skier. Although the tests appear to have been pioneering for the science that would eventually be called tribology, similar conclusions had been reached in some earlier studies.[29] The Norwegian scientist, polar explorer, and Norwegian national icon Fridtjof Nansen was among those who had conducted such discussions. The subject of Nansen's last public lecture was the gliding of skis on snow, an area of knowledge he had intended to develop further, but his death intervened. His lecture was published in 1930 in the yearbook of the Norwegian Association for the Promotion of Skiing.[30] Pallin's conclusions were also based on earlier tests of ski waxes that had been carried out by the chemists Ernst Føyn and Robert Smith-Johannsen.[31] The exact mechanism of skiing friction remains a subject of scientific discussion.[32]

29 Bowden & Hughes 1939.

30 Nansen 1930.

31 Pallin 1945, 90.

32 Persson 2015.

In parallel with the ski friction tests of the 1940s, Astra's engineers were busy experimenting with the artificial substances that would make up the wax of the future. Martin Matsbo was responsible for testing the waxes the engineers were experimenting with. The project was very expensive. Around SEK 200,000 (equivalent to USD 500,000 in value of 2024 money) is said to have been invested in the project, which was highly unconventional for a company that was otherwise involved in pharmaceuticals. Astra's board was sceptical at first, for obvious reasons, but Gabrielsson was able to convince them that the universal ski wax they envisioned would outperform all other products. It could therefore be exported abroad, to the Nordic countries and the rest of Europe.[33]

In the mid-1940s, cooperation between science (KTH) and industry (Astra) intensified. After Martin Matsbo and Astra's engineer Stig Hultberg had tested ski waxes outdoors in the winter, KTH provided cold rooms where the tests could be continued in the summer. During these tests, the traditional type of wax made from natural products such as tar and beeswax was finally rejected. Work on synthetic materials began on the seven-metre-long track in the -30-degree Celsius cold room.[34]

All the chemical and mechanical tests were completed in the autumn of 1946. Given the high expectations for a universal ski wax, the results of the project were initially disappointing. A universal ski wax for all types of skiing and weather conditions had not been achieved. 'Universal ski wax – wishful thinking', was the subtitle of a paper Matsbo wrote a few years later. Bertil Sjögren, head of Astra's laboratory, commented the outcome of the project in the newspaper *Aftonbladet*:

33 Bjerke 2023, 3–4.
34 Bjerke 2023, 5.

> Unfortunately, we cannot produce a universal wax that can be used in all conditions at the moment, but that does not mean that the problem has to be shelved forever. New substances with unexpected properties are discovered every day, and perhaps one day we will have the raw material we need to solve the problem.[35]

Despite the disappointing news, the project was to prove groundbreaking. Astra's newly formed subsidiary, Wallco AB, launched a series of ski waxes that were successful on the market. These were fully synthetic products, predominantly consisting of paraffin derived from refined petroleum, marketed under the name SWIX. These new waxes were successfully marketed with Martin Matsbo as the face of the business. He travelled the country demonstrating the new synthetic ski wax and a film, *Glid och fäste* (Glide and grip), which was shown in cinemas across the country.[36]

As a skier, entrepreneur and inventor in the public eye, Martin Matsbo came to embody the heroic ideal that was put on a pedestal in modernising Sweden. At the beginning of the century, the warrior kings of history were national role models for the masses. By the middle of the century, national heroes were instead sought among the masses, among those who had risen from the ranks of the foresters to become public figures through sporting achievements or other successful endeavours that made an impression on the public. Individuals like Matsbo represented a spirit of modernity in which success in life was in one's own hands, regardless of social background.[37]

Although there were sceptical voices about the new type of ski wax, the main critics were the elite wax manufacturers who, for protectionist reasons, cared about their own traditional and

35 Hkn 1946, 16.
36 See for example 'Martin Matsbo visar instruktiva skidfilmer' 1951, 14.
37 Cf Ehn, Frykman & Löfgren 1993, 55–56, 163.

home-made products.[38] SWIX was a product for both the elite and the general skiing public. The former was confirmed at the 1948 Winter Olympics when the Swedish men won gold medals in the 18km, 50km and relay races using SWIX wax. No one any longer doubted that chemistry prevailed over natural wax.

SWIX became a success story that originated in Sweden. But its history there was very short. The brand was sold to Norway at an early stage and is generally associated with a Norwegian success story, as described in a recently published book by Harald Bjerke.[39] Although hopes for a universal ski wax were not fulfilled, a clear paradigm shift had taken place with two distinct transitions. The first was the replacement of natural ski wax with a synthetic one. The second was the replacement of traditional, experience-based production with scientific, industrial production.

The Continued Capriciousness of Ski Wax

Although ski wax has been produced in new ways and from new materials, no solution has ever been found to its capricious effect on competitions. Cross-country skiing is still as much a competition of athletic skill as it is a competition of who has the best-prepared equipment. There are still many different brands of ski wax. Those who hoped for a reduction after the introduction of synthetic wax did not get their wish. ‘300 varieties – but choose the right one!’, was the cry of the Swedish newspaper *Expressen* after the 1952 Olympic 50 km race, when ski waxing failed.[40]

38 See for example ‘Förra skidstjärnan Elis Viklund …’ 1947, 15.
39 Bjerke 2023.
40 Andersson 1952, 16.

The history of ski wax has come to symbolise modern man's restless search for the simple solution to a complex problem. Thus, the rest of the 20th century saw further technological advances. This was particularly evident at the 1987 World Ski Championships in Oberstdorf. Italy had managed to conceal the use of a fluorocarbon powder that reduced friction under the skis and gave a noticeably better glide. The fluorocarbon compounds, originally developed by DuPont in 1938, are extremely hydrophobic while at the same time being oleophobic and thereby both repelling water and dirt present in the ski tracks. The Italian gold medals in the men's 15- and 50-kilometre races were attributed to the new wax. The next step in the artificialization of the art of wax was fluorocarbons and Teflon.

However, the situation has become more complicated. It is true that these new types of ski waxes have significantly improved glide. At the same time, the per- and polyfluoroalkyl substances (PFAS) contained in the fluorocarbon waxes have a detrimental effect on nature and human health. The rapid progress of elite skiers has been at the expense of their waxers, who occasionally suffer from fluoride-induced fever symptoms. Already in 2019, the FIS has decided to ban waxes containing highly fluorinated substances from international competitions. Due to the lack of sufficiently safe control methods, the ban did not come into force until the 2023/2024 season. The friction reduction provided by fluorocarbon waxes will thus be removed from the sport, and it has been proven that world-class skiers will now ski much slower.[41]

In the current debate, some people want to ban more than just fluorinated ski wax. In Sweden, sports commentator and former biathlon olympic champion Björn Ferry believes that na-

41 Westergård 2021.

tional teams should stop using wax altogether.[42] Although the proposal is unlikely to be implemented any time soon, the debate and the recent fluoride ban signal a possible turning point where the Olympic motto of *citius, altius, fortius* (faster, higher, stronger) no longer provides the obvious direction for sport.

Concluding Remarks

The change in the art of ski waxing over time has sometimes lagged behind, sometimes followed, and in some respects anticipated the development of modern industrial society. It did not directly follow the wave of industrialization that took place around the turn of the century 1900, when ski production changed from craftsmanship to industrial production. However, the fact that the wax so greatly influenced the result lists in skiing competitions prompted efforts that quickly challenged the traditional methods and materials that had previously provided skiers with glide and grip. The paradigm shift that took place can be attributed to the resource mobilization that took place in collaboration between the sports movement (Swedish Ski Association), industry (Astra) and science (KTH). While science was responsible for the mechanical problems associated with the ski's glide on the snow, industry was responsible for the chemical composition of the new type of wax to be experimented with.

A key factor in establishing this collaboration was that leading figures combined professional and lay interests that were of importance to technological development. That such a spectacular project as trying to develop a universal wax was carried out by chemical and scientific means at this time can also be explained by the great personal interest in skiing that both Pallin at KTH and Börje Gabrielsson at Astra had. Another contributing factor was that Sixtus

42 Andersson 2023.

Jansson, the chairman of the Swedish Ski Association, was particularly keen to drive the technical development of Swedish skiing, not only by improving the wax but also through specialised training and training camps for the elite.[43] Add to this Martin Matsbo's experience of cross-country skiing at the elite level, combined with his wilful experimentation with materials and equipment, and a picture emerges of a system of innovation and experimentation that together paved the way for the technological leap studied here.

With a Kuhnian terminology, the dominating paradigm became challenged by a radically new way to improve the existing practices of ski wax. Looking at the history of innovation, you can argue that this leap is a technology shift that paved the way for a new dominate design, simultaneously making the old technology obsolete. The trajectories of innovation for ski wax follows a historically interesting pattern, where a combination of enthusiastic entrepreneurs and a mobilised network with the right resources together reach a climax and push an existing technology over the brink of dominance under the process of creative destruction.[44]

The collaboration between high-tech industry, science and a self-taught inventor from a humble background seems, in the light of history, symptomatic for the boom years that followed the end of the Second World War. But as the future optimism has waned, the ski industry, like society at large, is now faced with the challenge of sacrificing growth and improved performance for the sake of environmental sustainability. Snow must be secured for the future, and the ecological footprint must be erased or at least diminished. After more than a century of sportification and continuous increase in performance levels, skiing may have ar-

43 Klercker 1933, 20.
44 Baldwin et al. 2024.

rived at a dead end of progressive thinking. The ban on fluorinated wax is the clearest example of this, but it is not the only one.

Making cross-country skiing more sustainable will involve a number of issues, including how the international competitions are scheduled and where they are located. The carbon footprint of elite skiers travelling to and from competitions and training camps is one challenge that is not going away. A study of 110 Norwegian elite winter sports athletes shows that their combined carbon dioxide emissions amount to 1 600 tonnes per year.[45] Another issue is the increasing level of adaptation of landscapes for cross-country skiing. Whereas the impact on the ground used to be limited, preparing a ski track for an international competition or a large-scale event like Vasaloppet involves advanced technology, consumes loads of energy and is increasingly done in weather conditions that are less favourable for snow sports. The expectations on the quality of a ski track suitable for competition has come a long way since the 1920s, and this improving quality has enabled more spectacular performance levels. This has, in turn, paved the way for the use of specific waxing to become a decisive factor. Sportification and the logic of performance is multifaceted, and to some extent self-reinforcing.[46] It remains to be seen whether ski waxing will be a historical parenthesis or if the answer to the sustainability challenge of cross-country skiing will be even more advanced technology.

45 Rognerud et al. 2023.
46 Svensson et al. 2023.

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