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EXECUTIVE SUMMARY

This document constitutes Deliverable 4.1: 'A conceptual analysis of standards,' of the H2020 project *Fostering Synthetic Biology Standardisation Through International Collaboration* (acronym BioRoboost).

'A conceptual analysis of standards' has been generated in the context of Work Package 4: The social infrastructures of standardisation.

The document presents a conceptualisation of standards and standardisation based on social scientific scholarship and empirical case studies. The conceptualisation makes use of the concept of 'social infrastructures,' which is central to Work Package 4.

The document presents an overview of social studies of standardisation. It explains basic social scientific concepts and then uses a case study concerning BioBricks to demonstrate their relevance to standards in synthetic biology.

The main body of the text introduces and details a social conceptualisation of standards and standardisation. The document first presents an overview of what constitutes an infrastructure. It begins by explaining its character as an enabler and a complex assembly. It then discusses its ubiquity, importance and inconspicuousness. Next, the document explains how standards can be understood using the concept of infrastructures, and demonstrates it by using the case study of the Synthetic Biology Open Language (SBOL).

Having introduced infrastructures, the document then explains *social* infrastructures. It discusses the manner in which group coordination and ordering make standardisation possible and give it its final character. It uses the case study of synthetic biology metrology to demonstrate how social infrastructures operate and how they support standards in synthetic biology. Specifically, by creating the support necessary for people to establish and sustain those standards, must as electrical networks enable people's use of electrical devices.

The document then explains how a social understanding of standardisation reveals important political issues. These include the manner in which those building standards build politics 'into' those standards.

Finally, 'A conceptual analysis of standards' presents suggestions for how other BioRoboost work packages can make use of the conceptualisation in their work.

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1. INTRODUCTION

BioRoboost is a project about synthetic biology standards and standardisation. This document presents a social scientific understanding of both. Those who are responsible for fulfilling standardisation rely on scientific and technological understandings of standards and carry out their work accordingly. BioRoboost's Work Package 1 (WP1) explores gaps in the standardisation process and proposes solutions to challenges such as metrology and modelling. Work Package 2 (WP2) examines standard chasses and their role in standardised synthetic biology constructs. Work Package 3 (WP3) investigates technical challenges associated with yeast and mammalian systems and identifies unaddressed standardisation needs. Their work is meant to contributes to what has been a defining element of synthetic biology.[1]

Each of those teams employs and introduces scientific and technological perspectives. This document's social scientific conceptualisation is not meant to substitute those viewpoints. Instead, it complements and contributes to them. Most importantly, it encourages synthetic biologists to reflect on aspects of standardisation that they take for granted. This includes fundamental questions about what it means to standardise, what standardisation involves and what it produces.

The text also contributes to those work packages concerned with ownership and 'shareability' (WP5), biosafety and risk assessment (WP6) and dissemination and policy (WP7). It offers conceptual and analytic tools shared by social scientists and which those work packages may find useful.

This document proposes and explores one overarching idea: standardisation is a social practice. It depends upon social communities: groups of people who exist together, and interact and influence each other. Only by coordinating what people think, say and do can standardisation work. It is a process whereby the community coordinates itself and establishes a certain order. What choices the group makes—scientific-technological *and social*—define that order and so shape the standards established. A social scientific perspective makes social choices conspicuous. That makes it easier to understand the workings of standardisation. Without such an understanding, many important decisions will be nothing more than the results of chance.

This text also introduces tools for understanding standardisation as social practice. It presents a perspective based on the idea of 'infrastructures.' Standardisation depends on many kinds of infrastructures. Some are easy to identify, such as laboratory spaces and communication networks. Others are harder to see, such as *social infrastructures*. These support the coordination and

[1] Synthetic biologists have written extensively about standardisation. Prominent texts include: Anderson et al. (2010), Andrianantoandro, et al. (2006), Arkin (2008), Canton et al. (2008), Endy (2008), Endy and Arkin (1999), Hartwell et al. (1999), Heinemann and Panke (2006) and Sauro (2008).

ordering needed to establish standards. Though they are less visible, social infrastructures are no less important. They enable standards just as electrical infrastructures support electrical devices, and robotic systems enable automation in synthetic biology. The perspective presented here makes it easier to identify those infrastructures and the choices made in building and using them.

The text first introduces the basics of understanding standardisation as a social practice. Second, it presents a conceptualisation of standards based on ideas about infrastructures. Finally, it considers what such a conceptualisation reveals about the politics of synthetic biology standardisation. Ultimately, it contributes a different understanding of what projects like BioRoboost seek to accomplish. It offers synthetic biologists a way to reflect on how they are arranging themselves as a group of people. It encourages social scientists, philosophers, policy experts and other partners in the enterprise to think about their involvement in social ordering.

2. SCIENCE AND TECHNOLOGY STUDIES

The text draws most of its ideas and perspectives from science and technology studies (STS). STS uses social scientific theories and methods to challenges routine assumptions about science and technology. It replaces those presuppositions and ideals with observations and conclusions based on empirical research. It examines the processes by which bodies of knowledge or technological artefacts are designed and produced, and how decisions made shape the end-product. It begins with things that societies accept as finished—a physical law or a computer programme—and reveals how they came to be and what keeps them in place. Put differently, STS 'opens black boxes' to see what lies inside.

Black boxes are stable ideas or products. If successful, there is no need to 'look inside.' The group accepts and trusts them as objects that can be shared without difficulty. Engineers can trust an established physical law as applicable by different groups, for different projects and at different times and places. They can use that kind of black box to understand others' work and to collaborate more easily. Standards are archetypal black boxes. A person using a standard unit, such as a newton or a joule, does not reflect on the workings of the unit. She simply uses the unit. She can trust that the unit will work as a black box: portable across the group's work, understood by others and reliable in its operation. As a result, standardisation is a process of creating black boxes. If successful, standardisation produces things that can be shared, trusted and used with no need to examine why or how they work. Like all black boxes, how a standard came to exist is irrelevant; all that matters is its function. Emma Frow argues that synthetic biologists want to "manage (or 'black-box') the complexity of living organisms by decomposing their genomes into standardized genetic 'parts' that have predictable properties." (2013: 433) Those can then be combined to create functional constructs with their own predictable properties.

Opening black boxes can serve as a first step in self-reflection. Reflection makes possible asking why certain ideas or practices are now taken as given or accepted as correct. It allows questioning otherwise unquestioned things. Reflection when a black box is still being built—while a standard has yet to be established—encourages active decision-making. It becomes possible to examine what is being put inside. Evaluating technical choices is commonplace during standardisation. However, reflections about how those choices affect people and the community are rare. An STS perspective makes it possible to ask such questions. It also challenges researchers to question some of their most fundamental beliefs, such as: standardisation is a strictly technical problem in need of a technical solution.

3. SOCIAL STUDIES OF STANDARDISATION

A social understanding of standardisation begins with a basic understanding of the 'social.' Simply put, anything social depends upon the existence and the workings of a community of people. All languages are social. They serve to communicate meaning and share ideas with others. They depend on how the group operates. Only by putting different words and things into order can people establish a language, because only then can people agree about what words mean. Only by coordinating how people behave can the group share a way to use those words.

Something social reflects the qualities of its community. Different communities have produced different languages and those languages reflect the character of the group. For example, which words exist will depend on things such as where the community exists and what it needs to label. People won't need a word for a fruit that does not exist where they live and that they have never encountered. Languages will reflect the history of the group, just as the five Romance languages reflect the history of Rome's rise and collapse and the subsequent fragmentation of Latin.

Social communities are not concrete. They can and do change, and anything social changes with them. Languages have changed over time as communities and their settings transform. Spellings and pronunciations differ across periods and places. Meanings change as their objects change. New words are introduced when new objects are encountered, such as 'pulsars,' or produced, such as the 'telegraph.'

Finally, anything social is imperfect and it can always be undone. It makes no sense to label one language 'the best of all.' It's also wrong to suggest that a language is invulnerable. Languages have rules, but they are routinely ignored in everyday talk or intentionally broken in certain forms of writing. Finally, all social things have limits and imperfections. These place constraints on what something social can accomplish, and make it vulnerable to challenge and transformation. Many social things work only inside their own communities and cannot be transferred to others. Others can be rejected or deconstructed when they lose their worth.

3.1 STANDARDS ARE SOCIAL

Standardisation depends on the existence and the workings of a community of people, reflects the qualities of that community and changes as the community changes. It is a process of coordinating people, practices and objects. To say that a field has certain standards is to say that it has arranged itself in certain ways.

As a starting point, consider a less familiar definition of 'standard': "A flag, sculptured figure, or other conspicuous object, raised on a pole to indicate the rallying-point of an army." (OED) Military commanders use standards to bring their troops into order and to guide their movement on the battlefield. This type of standard is a tool for group coordination. Standards like those in synthetic biology share this basic quality. (Thévenot 2009)

Groups produce and employ standards to create coordination. They want to ensure that different people act in similar ways. For example, a standard protocol establishes "criteria on whether, when and how next steps are to be taken." (Timmermans and Berg 1997: 296) In theory, an experimenter in one laboratory can understand work done in a very different lab if the other researchers have followed a standard protocol. If she has followed the same protocol, the first experimenter can compare her work to the others'. This kind of coordination make actions and products "comparable over time and space." (ibid.: 273) It is also a way of disciplining people into order. Ultimately, standardisation is relevant only if one wants to create coordination and order. (Mallard 1998: 582) If individuals had no interest in engaging with others' work and results, standards would not be needed. They might even be a hindrance, since they place limits on what can be done.

Frow's discussion of BioBricks offers evidence of standards and group coordination in synthetic biology. She explains that repositories of standard parts, such as the Registry of Stanford Biological Parts used by iGEM participants, can establish a technological platform for the field's work. People can carry out their work in a shared space, defined by standard materials and practices. Frow also points out that such repositories support "the development of a community of practitioners with common professional identities revolving around collectively owned concepts and materials." (2013: 437-438) Synthetic biologists have made similar arguments, claiming that "scientific, technical, operational and semantic standards" are needed for the field to come together as a coordinated, "full-fledged engineering discipline." (Beal et al. 2020: 1)

Standardisation brings into order the many different things that make up a community. A social community include more than people, what they do and what they make. For example, a scientific community includes things such as institutions, regulations, writings, traditions, pedagogy, supplies and finances. Such a collection of different components has to be kept from falling apart; shared standards are one way of doing so. (Bruyninckx 2017) Standard units ensure that people rely on the same types of instruments, the same ways of quantifying, the same ways of reporting results, the same forms of training new researchers, the same guidelines for securing supplies and the same methods for calculating material expenses.

Synthetic biologists like Drew Endy proposed standardisation as one of multiple principles that could bring the many parts of the field together into a novel type of work. (2005) In her social scientific research, Frow examines how standardisation has contributed to arranging communities according to such principles. She demonstrates that synthetic biologists have cast standard parts as tools for “reorganizing the biotechnology landscape, so as to overcome current limits to biocapital and generate new and diverse sources of wealth.” (2013: 437) Other social scientists have argued that standardisation plays a role in how the biological parts of a community are presented as functional components, thus putting them into that community’s order. (Mackenzie et al. 2013)

Like all social things, standards reflect the makeup of their social community. Its needs, resources, aims, norms and interests will shape what standards exist and what they look like. And like all social things, standards change as their communities change. New experiments may require new kinds of measurements, and those may require new kinds of standards. Schools of thought may be replaced by others. Those may rely on different ways of organising the community and may use different standards. Inevitably, a field will run into difficulties and suffer disruptions to its work. Fixing those problems may require abandoning certain standards.

Standard parts in synthetic biology will be designed and built to satisfy technical specifications. However, those criteria will reflect the community’s goals, priorities and values. Specifications like “modularity, easy assembly, predictable function, [and] reusability” reflect a community that wants to “facilitate innovation by an ever-growing number of practitioners.” (Frow 2013: 437) Such an ambition is a quality of the social group.

At the same time, standards can reflect a community’s lack of unity. During her research, Frow observed that despite its widespread appeal, standardisation in synthetic biology faced a lack of agreement regarding “what constitutes a valuable design.” (2013: 439) Such disagreements can characterise a social community no less than consensuses, and the result can be that different people develop “their own collections of biological parts—in formats often incompatible with others’ collections.” (ibid.)

Standards also shape their communities. Most clearly, standards organise communities into certain orders. They also change what they standardise. A community’s objects are not standardised “until scientists or their technicians take the trouble to make them so.” (O’Connell 1993: 166) People also employ standards to cement certain community orders; that is, standards help keep communities more uniform than they might otherwise be. That shapes directions taken by the group and possible outcomes. (Hanseth et al. 1996)

Once standards are developed, they many increase the weight of some priorities while undermining the importance of others. In synthetic biology, standards that can be employed by a diverse population of users may strengthen the case for accessible, democratic practice. Standards created with “aspirations about the utility, scaling up and industrialization of bioengineering” may elevate the importance of the community’s partnerships with commercial actors. (Frow 2013: 435) In both cases, the shape of standards influences the shape of the group responsible for building them.

Nonetheless, the social nature of standardisation is hard to see. Standards are form of community coordination and ordering. Once established, they become regular practice. Because they constitute normal behaviour, they go unquestioned. (Thévenot 2009) Because they support communal unity and enable fruitful interactions between people, there is little cause to ask why they exist as they do. In fact, the usefulness of standardisation depends on a form of “blind confidence that favours coordination.” (ibid.: 795) Standards gain and keep their value because the community trusts them and uses them like ‘black boxes’: without paying attention to their inner workings. The result is a lack of reflection on important consequences of the standards that they use.

4. A CONCEPTUALISATION OF STANDARDS

O’Connell argues that establishing a new standard involves “the creation of a new society.” (1999: 137) That is, creating a standard involves creating a group of people coordinated in specific ways. Without the group, the standard cannot exist. That, along with the other qualities discussed above, demonstrates the social nature of standards. However, that social nature is not easy to see, especially when one makes routine use of standards as part of a larger body of work. A social scientific perspective offers a way of understanding standards that might help make that social nature more conspicuous.

So far, this text has emphasised that standardisation is a kind of collective behaviour. As a result, to make sense of a standard is to make sense of how people act as a joint bunch. One way to do so is to think about collective behaviour as a form of infrastructure. In summary, collective behaviour is a type of enabler, everywhere-present, necessary and valuable. Most often, it is inconspicuous and so hard to see. Finally, like all infrastructures, collective behaviour requires maintenance and can break.

A conceptualisation based on the notion of infrastructures is useful. It is an accessible concept. Infrastructures are parts of everyday life and most people have a basic sense of what the word means. It is easy to think of examples. Scientists and technologists also engage with, rely on and participate in specialised technical infrastructures. The concept offers a chance to demonstrate how they engage with, rely on and participate in specific kinds of collective behaviour.

4.1 INFRASTRUCTURES

Infrastructures surround us and play important roles in our everyday lives. For instance, systems that generate and distribute electrical power can be found in most nation states. Many commonplace activities rely on electricity, so the infrastructure is embedded deeply in our lives. Roads systems support transportation and are taken for granted by those with routine access to them. A person who drives to work every morning and back home every evening depends on such infrastructure. They form a necessary and regular part of her life.

Moreover, specialised infrastructures exist for certain kinds of work. For instance, the National Aeronautics and Space Administration's Deep Space Network (DSN) is a communications infrastructure that supports interplanetary probes like *Voyager 2* and *New Horizons*. Unlike electrical networks and roads, DSN is not used by large populations, has little impact on most routine life and has less flexibility of use. Nonetheless, it displays many of the same qualities as commonplace infrastructures.

Synthetic biology makes use of many different infrastructures, some commonplace and others specialised. Everyday infrastructures such as electrical grids and telecommunication networks support what synthetic biologists do. Longstanding specialised infrastructures such as systems for distributing chemical and biological resources are also vital. Discipline-specific infrastructures such as parts assembly facilities and computational systems are important elements of the field's expansion and development. So too are its standards.

Infrastructures are enablers. Infrastructures are peculiar insofar as their purpose is to make other purposes possible. (Sims 2007) All technologies have functions of some kind, but unlike most technologies, infrastructures' sole function is to support other functions. An electrical grid makes possible the use of electrical devices; the DSN allows probes to send their data back to Earth. Star (1999) describes such infrastructures as "ready-to-hand," because their existence makes sense only as long as they create potential that is available for use.

Put differently, infrastructures exist because of what they enable. If electrical devices did not exist, there would be no need for electrical infrastructures. Moreover, infrastructures exist in their full sense only as long as what they support is present and in use. Electrical towers and cables wouldn't vanish if electrical devices were abandoned, but they would no longer be something with full existence, since what they are depends on what uses them.

As a result, infrastructures are never self-standing. To exist in their full sense, infrastructure have to be "sunk into and inside other structures, social arrangements, and technologies." (Star 1999: 381) A system of roads needs drivers and automobiles. To understand infrastructures, one must understand them as parts of social communities, because they "become real infrastructure in relation to organized practices.” (ibid.: 381) Roads need travel.

Infrastructures are complex assemblies. Infrastructures are best understood not as single things, but as assemblies of “related parts, nodes, or components that are structured or connected.” (Sovacool et al. 2018: 1069). A term like ‘electrical infrastructure’ is shorthand for something that is “large, coordinated, and varied.” (ibid.: 1069) Its parts work in coordinated ways to accomplish a specific task, such as creating and distributing electrical power.

Components differ greatly and can be “bundled together in different arrangements.” (Meckin 2019: 6) An infrastructure’s parts have different functions, different ways of operating, different physical makeups and different requirements. They depend on different types of practices and experts. Their parts are located in different places (physically and operationally) and are active at different times. They require repair in different ways and at different times, and their lifetimes differ.

Moreover, infrastructures are *heterogeneous* assemblies. Their parts include social components. For instance, different groups of people are involved in designing, building, running and using infrastructures. Each community comes with its own ways, and the infrastructure they help constitute shapes and is shaped by those particularities.

People who design and build infrastructures work on technologies in doing so, but they also work on “people, texts, regulations, markets, and so on.” (Geels 2007: 123) Those building an electrical infrastructure must take into account social components like power companies, government regulations, economic competition and prices, user expectations and behaviours, community crises and political movements. These are just as important as physical elements like generators and wall sockets.

And yet, despite their complexity and heterogeneity, infrastructures are relatively coherent and stable. One reason is the need for consistent, reliable enabling. A population that depends on electrical devices will not be served well by an electrical infrastructure that does not provide power consistently. As a result, infrastructures are designed, built and maintained to be stable. Certain difficulties accompany that goal. Stability can make infrastructures obdurate and so resistant to transformation. (Sovacool et al. 2018) Changes, even though they may improve the infrastructure, are not easily made.

Infrastructures are ubiquitous. Infrastructures’ stability is one aspect of their ubiquity. Infrastructures are ever-present and embedded into our existence in many ways. Which infrastructures exist and how widespread and present they are reflect how a social community arranges itself. Choices about activities, spaces, governance, economies, alongside many others, create particular needs for specific infrastructures. For instance, many societies now depend on electronic technologies for everyday communication. As a result, electrical and telecommunication infrastructures are built to be as expansive, encompassing and consistent as possible.

Ubiquity takes many forms. Infrastructures are often physically ubiquitous. Cities and their surroundings are saturated with streets, roads and motorways. They are fundamental to the physical layout of many cities, affect the physical behaviour of the population and are easily visible. Infrastructures are also functionally ubiquitous. What they enable is regularly pervasive. Telecommunication networks enable people to send and receive messages with their mobile phones at different times and places. Most of the time, the potential they produce is ready-to-hand.

Finally, infrastructure have ubiquitous influence. Infrastructures are created by people, but once they are installed and activated, they "bend human routines and material practices" in many ways. (Howe et al. 2015: 551) Just as they make new things possible, infrastructures constrain behaviour. For example, as groups come to depend on electricity, "our practices and language change, we are 'plugged in' and our daily rhythms shift." (Star and Ruhleder 1996: 113) Meckin argues that new robotic infrastructures in synthetic biology will require "new modes of knowledge, technical detail, and accuracy that were not needed for the parallel manual practice." (2009: 11) New infrastructure will influence and replace existing practices.

Infrastructures are important and valuable. Infrastructures enable things that we come to depend on, such as roads for travel or electrical power for many devices. What they enable often becomes embedded in everyday lives, such as continuous interactions with others through mobile communication systems. As a result, even the most basic and routine of activities comes to depend on some form of infrastructure, such as drinking a glass of water. That dependence makes them important.

Infrastructures' importance, particularly if it results from necessity, contributes to their value. Infrastructures possess functional value. Because groups value what they enable, they value infrastructures' ability to enable it. Infrastructures also have economic value. Most simply, they have economic value because it costs to build them. One can also charge for access to their potential, as do electricity, gas and telecommunications providers. Infrastructures can themselves be products to market and sell. They have social value because they can enable valued forms of social interaction and order. Road networks bring order to the movement of automobiles, which might otherwise be chaotic. Finally, infrastructures have symbolic value as icons of development, signs of achievement and emblems of unity. At its start, internet connectivity was heralded as an impressive technological feat and as something that could draw together communities across the world.

Infrastructures are difficult to see. Despite their ubiquity and importance, infrastructures are relatively invisible. Even those that are easily 'seeable' routinely go unseen.

Some infrastructures are difficult to see because they do not exist physically. A person cannot take hold of knowledge or of information infrastructures such as databases or virtual private networks. Physical infrastructures may be difficult to see because it is difficult to reach them, such as underground piping and orbital positioning satellites. Others are difficult to see because of social regulations. Power stations are not open to any curious person. That part of an electrical infrastructure is hidden as a result of how people organise themselves, rather than a station's physical layout. However, even those infrastructures that are physically accessible and easy to look upon, such as motorways, can go unseen.

One reason is their role as enablers. Things enabled depend on infrastructures, but they are also more present in people's experiences. When typing an e-mail, a person's immediate concern is for the computer, rather than the system that feeds it electrical power. She observes the screen, taps the keys and hears their tapping, but pays no attention to what makes screen and keys operate.

Most importantly, infrastructures are designed to be inconspicuous. Their success consists of uninterrupted operation. That form of reliability leads to overlooking. A driver has no need to reflect on the makeup of the motorway if she can drive her car as intended. Concern is focused on making use of potential, rather than attending to the source of that potential. Star argues an infrastructure is designed to be 'transparent,' so that it "does not have to be reinvented each time or assembled for each task, but invisibly supports those tasks." (1999: 381)

As a result, infrastructures become conspicuous upon their failure. There is no need to be aware of a home's wiring until its wall sockets no longer offer power. Only then is attention required to address and repair the breakdown.

Infrastructures break. Their stability is often "more apparent than actual." (Howe et al. 2015: 553) They can and do stop working sometimes. More importantly, all infrastructures are subject to continuous changes which undermine and eventually overthrow them.

All infrastructures are characterised by an important paradox. They are "solid and durable," but at the same time are always "doomed to be outmoded, ruined, and exceeded." (Howe et al. 2015: 559) Despite their occasional troubles, most telecommunications networks offer consistent service. Broadly, people trust that their mobile can send and receive data. Infrastructure technologies can enjoy long lifetimes with ongoing maintenance. Nonetheless, telecommunications infrastructures have repeatedly given way to new systems once technological changes demand it. Designer and builders may supply their infrastructures with mechanisms for adapting to changes, but no such mechanism can prevent changes from occurring. (Sovacool et al. 2018)

People reconfigure their infrastructures as is needed. People may even adapt themselves and their artefacts to extend an infrastructure's life. However, infrastructures are doomed from the start. They are "continually changing and being redefined as new elements are included, redefined, and/or discarded." (Ureta 2014: 369) Eventually, their ability to adapt fails. Put simply, no infrastructure is invulnerable because what they must enable and how they must do so does not remain fixed.

Failure offers valuable insights. When things stop working, one enjoys a chance to explore their makeup. When they are restored, one can learn more about why they work when they do. Failure makes an infrastructure conspicuous. It must be made visible, studied and adjusted. Doing so reveals elements that are normally "left submerged, invisible, and assumed." (Howe et al. 2015: 548) That is, the black box is opened.

4.2 STANDARDS AND INFRASTRUCTURES

Understanding infrastructures serves understanding standards. All standards depend on multiple infrastructures. Infrastructures make their existence possible, and infrastructures shape what forms standards take. At the same time, standards are important in designing, building and operating infrastructures. Standards shape what infrastructures look like and what they do. Because infrastructures and standards are tied together so closely, insights into infrastructures contribute insights into why standards exist, how they exist and what impacts they have.

Standards depend on infrastructures. As enablers, infrastructures help make them possible and operative. For example, consider standard mechanical components, including basic parts like screws and hinges. Standardising such parts requires physical and practical infrastructures. Designing parts may involve using digital technologies, which depend on electronic systems. Fabricating parts requires facilities capable of transforming materials into artefacts (for instance, by melting ore and producing metal parts). Those facilities house their own infrastructures (for instance, those that produce the necessary heat and those that can hold molten ore). Once fabricated, parts must be evaluated with testing systems Finalised parts must distributed using storage and transportation infrastructures.

Standardising mechanical components also requires information and knowledge infrastructures. Communication systems allow designers to transmit specifications and instructions to those fabricating the parts. Databases allow producers to track supplies and their distribution. Systems for recording user experiences allow producers to identify anomalies and adjust design and production. Codification systems such as manuals, parameters and data sheets support making and using parts.

Consider the Synthetic Biology Open Language (SBOL), designed as an open standard for representing, codifying and communicating synthetic biology constructs. If successful, SBOL will provide a form of coordinating group behaviour and a shared way to order many elements of synthetic biology. (Galdzicki et al. 2014) Like all standards, SBOL is shaped by its community. Delgado refers to synthetic biology's tendency to borrow "software design's ways of representing and doing." (2016: 923) As a digital tool, SBOL puts this tendency to work. Such a standard also shapes community behaviour, as it institutes a type of practice defined by "selecting, clicking, dragging, cutting and pasting, uploading and downloading." (ibid.: 923) Rather than metaphors, these become lived experiences.

Madsen et al. argue that SBOL standardisation will depend on "the development of an infrastructure to store, retrieve, and exchange SBOL data." (2016: 487) The standard is meant to coordinate and order the community. Without a platform to sustain and share its extensive information, SBOL will not be able to coordinate such things as "the storage of genetic designs in repositories" or to bring order to representation of "genetic designs in publications." (ibid.: 487) The authors offer their SBOL Stack as a possible infrastructure for making SBOL standards viable. In a similar fashion, Myers et al. emphasise the importance of software infrastructure. Without it, it will not be possible to integrate SBOL into the instruments and practices of synthetic biologist laboratories. (2017)

Infrastructures depend on standardisation. The standardisation-infrastructure relationship is not uni-directional. Infrastructures rely on standardisation to operate successfully. A widespread electrical infrastructure, meant to service huge areas and millions of users, cannot be built using idiosyncratic components. Every tower cannot be designed differently. Every cable and wire installed cannot be unique. Each generator at a power station cannot have its own peculiar working. Infrastructures are complex assemblies of diverse elements. In order to operate successfully and consistently, those elements have to be linked and coordinated. Standardisation creates uniform materials that can be installed and operated in the same way across places and times. People and practices can be ordered in ways that prevent confusion and enable collective accomplishments. Extensions and maintenance can draw on parts ready to use and already understood.

Standardised understanding also enables and supports infrastructures. Building an electrical infrastructure depends on things like shared specifications, standard methods for drawing plans, standard practices for design and construction, and standard terminology for communicating ideas across the parties involved. Running an infrastructure relies on standard criteria and measurements for evaluating performance. And it needs standard guidelines to ensure that it satisfies demands placed on it by the encompassing social community. Making information and understanding uniform is no less vital than standardising material parts.

As established above, the Synthetic Biology Open Language relies on infrastructures to enable its standards. However, many advocates argue that SBOL standards can support novel forms of infrastructure. In turn, these can contribute to the development of the field. Galdzicki et al. contend that SBOL standards can support software infrastructures and establish shared workflows, a form of practical infrastructure. The authors argue that SBOL standardisation would "allow the growing number of software tools to more directly support an integrated design workflow." (2014: 545) As an example, they present a case in which SBOL allowed a team of institutions with "five different computational tools and four repositories to collaborate on the design of a genetic toggle switch." (548) Standards made the unifying infrastructure possible.

Myers et al. also emphasise the importance of standards for infrastructures. (2017) The authors discuss synthetic biology's myriad "computational tools that can be used in different stages of design, manufacturing, testing, and analysis." (ibid.: 794) Because of complex, diverse work, a system is necessary to "flexibly co-ordinate the operation of these tools." (ibid.: 794) SBOL information standards, they argue, can establish a platform of field-wide collaboration, a "complete standard-enabled workflow for synthetic biology." (ibid.: 800)

Finally, SBOL standards are meant to enable "the development of a wide variety of new capabilities, services, and business models in the industrial community." (ibid: 797) That is, standards affect both technical and *social* infrastructures.

4.3 SOCIAL INFRASTRUCTURES

In simplest terms, a social infrastructure is a type of coordination within social communities. It is an arrangement of people and things such as their practices, their objects, their ideas and their spaces. Such assemblies make other things possible: they enable. Members of the social community cannot circumvent its social infrastructures. Star writes that "being a member of a community means taking for granted arrangements, including infrastructures." (1999: 381) To belong to a community is to participate in, contribute to and be influenced by social infrastructures.

Standards require social coordination. Without specific ways of arranging people, their ideas, their practices, their objects and their places, there is no way to establish and sustain standards. Consider standard measurements. A 'centimetre' has no meaning outside of the community that understands the unit and puts it to use. Parts become standard because people agree to build and use them in certain ways. Standard screws satisfy requirements set by the group and are employed uniformly across many technologies. If told to follow a standard practice, people trained in it will act in the same way. If a group is told to carry out a standard practice, they will know how to arrange themselves and their behaviour. These examples reveal a fundamental lesson: anything standardised requires that that a group sponsor it, commit to it, follow it and maintain it.

A process of standardisation, like those pursued by synthetic biologists, is a process of creating social coordination. A term like 'standard measurements' is shorthand for the coordinated activities of a group of people, who use the same procedures to produce the same kind of data using the same units, and then codify that information according to the same parameters. Creating a standard is thus a process of creating shared activities and the resources that support them, such as instruments built and calibrated in uniform ways. One of the key aims of BioRoboost (and similar projects) has been to bring together diverse groups of people and to produce shared ways of thinking, designing, building and using: coordinating what groups of people do.

As such, it is worth considering social coordination in more detail. Consider first an important distinction: action and practice. An action is something that a person does, such as raising a palm when facing another person and moving it hand from left to right and back again. By itself, that action is nothing more than a kind of physical event. It has no meaning. However, under certain circumstance raising a palm to another person and moving it from left to right and back again is ‘waving hello.’ It is a physical event with a specific meaning: a ‘practice.’ An action becomes a practice if it happens inside a social community, and if that community is coordinated appropriately. (Barnes 2001) People cannot wave hello to each other if nobody knows what it means to ‘wave hello’ or what movements it requires. Moreover, ‘waving hello’ depends on participation. Only because people keep the practice going does it exist.

Practices also make social communities possible. In some ways, a society is a ‘community of practice.’ (Wenger 1998) That is, societies are groups of people doing the same kinds of things together. A society is people ‘waving hello,’ ‘nodding yes,’ ‘playing football,’ ‘writing,’ ‘singing,’ ‘pipetting,’ ‘calibrating,’ *and ‘standardising.’* All of these coordinated behaviours, and countless others, are what make a certain group what it is.

Social communities also involve ordering people and their things. Just like particles are classified and arranged according to their characteristics and our physical theories, societies classify people according to shared ideas. Societies sort people out using categories such as sex, gender, race, ethnicity, age and ability. These shape people’s identities: who they are to others and to themselves. Communities create boundaries to define some people as members of the group and others as outsiders. Some as members of a professional academy; others are still applying for entry. Societies also order using qualifications, which give some permission to practice specific kinds of work.

Types of work are forms of ordering people and their activities. Without that kind of order, professions like medicine and engineering could not exist as they do, since not everyone can be allowed to practice surgery or design bridges. Sorting people according to work gives them specific permissions. A general practitioner can write medical prescriptions. Categories also come with responsibilities. Engineers are accountable for errors that lead to damage or disaster.

Finally, ordering includes norms: parameters that define acceptable and inappropriate behaviour. This type of ordering establishes how a social community *should* be. It also serves to keep the other orders and coordination operating as expected. A shared understanding of how people should exist within a community creates limits on deviation. Laws are an obvious example; routine rules in laboratories are another. Research disciplines have norms that define correct practice; most also have rules about ethical behaviour. These define what the collective ‘looks like,’ but they also keep its being in order.

4.4 SOCIAL INFRASTRUCTURES AND STANDARDS

The qualities that characterise infrastructures such as electrical power grids also characterise social infrastructures. They also demonstrate how collective behaviours and order make standardisation possible.

Social infrastructures are enablers. Standards depend on coordinated groups because they require people to behave in uniform ways. It makes no sense to describe a laboratory procedure as 'standardised' if every experimenter carries out the work in a completely idiosyncratic way. When a group coordinates its behaviour and organises people according to shared roles and responsibilities, it becomes possible to establish a standard procedure. If people do not create a certain part in the same way and put it to the same uses, then the part is not standardised. People must coordinate their behaviour to ensure that designs and fabrication produce the same results, and that those parts are ordered according to shared specifications and uses. Collective coordination enables these forms of agreement and so make standardisation possible.

Efforts by synthetic biologist to establish standardised metrologies demonstrate the role played by social infrastructure. Researchers have sought to develop standard materials, tools, practices, units and data formats for measuring in synthetic biology. For instance, Mutalik, et al. explored standard methods for measuring promoter strength. (2013a, 2013b) Standard metrology consists of a social community practicing in a uniform fashion. (Schyfter, 2015) That community must accept and give legitimacy to shared methods, instruments and concepts. Only because people act in concert can those exist as collective kinds of practice. More basically, standardised metrology requires a community committed to specific images of the field. In this case, the community sponsors a view of synthetic biology based on an engineering template and commits itself to quantitative data.

Social infrastructures are assemblies. Social communities are collections of people, their practice and their objects arranged in particular ways: heterogeneous assemblies that take distinct forms. Shared practices and orders define and maintain those forms, which include how people talk and think, what things they put to use together, the spaces that they create and the institutions that they establish. Only by keeping such things in stable arrangements can standards exist and operate. People must be situated in appropriate communities. Those communities must include specific types of objects, practices, knowledge and language. Those parts have to be sorted in ways that make standards possible.

The social infrastructures that underlie standardised metrology consist of many components operating together in a specific order. Multiple researchers with different responsibilities work together to design and carry out experiments, analyse data and present results. Their work must occur in physical spaces supported by institutions, such as the Biofab. (Baker et al. 2006) Promoters must be selected and introduced into chosen organisms. Instruments have to be chosen and prepared certain ways, such as a Varioskan and its settings for aeration and optical measurement. (Mutalik et al. 2009) The group must also coordinate its use of terminology, choose its units and agree on how to collate results. They must produce datasheets in standard ways, read them in the same manner and employ their information as intended by the group. Without coordinating all of these different parts, the social infrastructure cannot establish shared metrology successfully.

Social infrastructures are ubiquitous. Infrastructures are found in all parts of what they enable. Without mechanisms for coordinating and ordering people, social communities could not exist. Consider language, which permeates every human society. Language is a social infrastructure insofar as it coordinates human interactions, such as exchanges of ideas. People employ language to order the things they encounter (including each other), the events they witness and carry out, and the forms of understanding that they produce. In certain ways, language is the ultimate social enabler, since it supports nearly every other aspect of collective human existence.

If a standardised metrology is to operate throughout synthetic biology, its social infrastructure has to be just as pervasive. A standard measure will require that a critical mass of synthetic biologists commit to it and practice with it. Only if its concepts and its terms are found in labs across the field and if it forms part of synthetic biology training can a measure become an accepted, routine part of community practice. If successful, standard measurements operate like black boxes. They are transferable, interchangeable and comprehensible across different contexts.

Social infrastructures are important and valuable. Social infrastructures enable the forms of coordination and ordering that collective human existence requires. As such, social infrastructures are not simply important and valuable; they are fundamental and necessary. Their importance to standardisation is no less crucial. In fact, standardisation itself can be understood as a form of social infrastructure. It is a form of social coordination that enables other things, such as groups, objects and practices. It draws people together in new ways by creating new commitments to share. It strengthens communities that already exist by adding new ties the bind members together.

The social infrastructures necessary for standardised metrology serve crucial ends beyond their immediate technical tasks. Standard measures require community coordination and ordering, and so they create new ties between members of the groups. That is, by organising people to create shared units and measurements, synthetic biologists will also strengthen their field's unity. (Schyfter, 2015) As with BioBricks and SBOL, standardised metrology makes collaborations across groups easier. Social coordination creates the measure and the forms of talk and practice necessary to use it. Those serve as a platform for collaborative work. Finally, the social infrastructures help situate objects like genetic constructs and organisms within the field's form of quantitative understanding.

Social infrastructures are difficult to see. Even more so than electrical power grids, social infrastructures are transluscent. Unlike power stations, electrical towers and wall sockets, social infrastructures are not composed of physical parts. One cannot point to language or grab hold of a tradition. Social coordination does not exist as does a telecommunications satellite and its existence is so widespread and encompassing that it can't 'be found' as a distinct object. Moreover, people tend not to reflect on what is routine or taken-for-granted. People don't ponder language in everyday life. People talk. It is difficult for a person to distance herself from such routine activities, particularly as they enable her moment-to-moment social existence. In many ways, standardisation operates invisibly, and is designed to do so. When measuring distance with standard metric units, an engineering does not reflect on why or how metres exist. She measures.

Standardised measurement in synthetic biology displays the same characteristics. 'Agreement' regarding what measures to use does not exist physically, and so cannot be seen. The community's trust in the metrology, a type of coordination necessary to keep the standard in place, is also not 'seeable.' If synthetic biologists choose a shared form of making and recording measurements, they will carry out the 'black-boxing' that makes all infrastructures translucent. A researcher who orders a standard promoter from a fabricator may have access to a quantification of its strength, but not to everything that made the measure possible. Most importantly, standardised metrology relies on group confidence. Methods, tools and measures, if accepted as standard, are employed; they are not pondered. So long as the metrology enables successful work, little attention will be given to the social infrastructures that enable the metrology.

Social infrastructures break. Standards remain operational because the group coordination upon which they depend remains undisturbed. That coordination is no more invulnerable to change and disfunction than are technological infrastructures. Social infrastructures exist as part of continuously changing societies. Social orders do not remain static but are transformed and eventually replaced by others. Languages change over time and across space. Meanings are discarded or modified, some words are lost and others born, and existing vernacular gives way to new talk. Complete breakdowns in social coordination and ordering are rare, but when unexpected or contradictory events occur, reflection on social infrastructure becomes possible. The breakdown provides an opportunity for people to consider the workings of what they normally take for granted and to think about what correct errors entails.

5. SEEING WITH INFRASTRUCTURES

The social infrastructures conceptualisation is useful as a different perspective from which to understand and examine the standardisation project in synthetic biology. It brings to the fore issues not routinely examined or even recognised by those making and using standards. Among these are political implications of standardisation.

5.1 INFRASTRUCTURE POLITICS

This document has established that standardisation is more than specifications, criteria, parts, data and procedures. Standardisation is fundamentally a form of social coordination. It depends on social infrastructures, which bind groups of people together and enable their shared behaviour. Like everything social, standardisation reflects the group that brought it into being: what the group looks like, where it exists, what it does, what it needs, what it uses, what it thinks, what it wants and what it rejects. It is something “infused with social meanings and reflective of larger priorities and attentions.” (Howe et al. 2015: 548) Standards in synthetic biology reflect an understanding of what this field is meant to be, of what will make it distinct and what it will contribute.

Standards embed the field’s “choice, values, priorities, power, [and] politics.” (Timmermans 2015: 81) The social infrastructures that make standards possible can never be neutral, because humans are not neutral. What groups build is shaped by everyday dynamics of power, authority, equality, hierarchy, agency, allowances and restrictions. As a result, “one person’s benevolent infrastructure can be another person’s burdensome barrier.” (Howe et al. 2015: 556)

Standards and boundaries. All social communities involve coordination and ordering. The most fundamental order is the community itself, which has boundaries that define inclusion and exclusion. But social orders involve many other kinds of sorting, including ‘sorting out people.’ (Hacking 1999) Social orders situate people in particular places, such as by incarcerating convicted felons in prisons. Orders place people within different hierarchies, such as those that distinguish different ranks in a military and those that give regulators authority over the regulated. Orders sort out people by the allowances given and the restrictions placed. Only some people can certify legal contracts, and only some must abide by rules of medical practice.

But again, the most fundamental ‘sorting out’ involves placing a person inside or outside the collective. As a result, no social community can circumvent sorting out people. The same is true of standardisation. As a form of social coordination and ordering, standardisation involves establishing groups of people joined together by their commitment to certain standards. Some of those groups are huge and implicit, such as the group of people who make use of metric standards. Others are smaller, clearly defined and strictly overseen, such as the community that uses standard tools and procedures to monitor air traffic. In both cases, ‘those who follow standard X’ is a group. And so, matters of inclusion and exclusion are at the heart of standardisation. How those are created and implemented, who does so and why they do so are concerns no less important than the technical specifications that define a standard laboratory process or biological part.

Standards and hierarchies. Standardisation also involves ordering by hierarchies. Different parties have different abilities and permissions to establish, certify and reconfigure standards. These include governmental agencies, international bodies and professional societies. In other cases, authority over standards and the power of standards themselves comes from "research groups, funding agencies, and their widespread implementation." (Timmermans 2015: 90) Researchers may be required to follow some standards in order to participate in certain projects or to gain financial support for their work. They may also be expected to follow specific standards because their community accepts no other ones. In all of these cases, ordering by hierarchies forms a basic part of the social coordination needed to make standards possible.

Hierarchies suggest a third form of ordering people. In order to sustain social coordination, members of the group have to keep themselves and others 'in line' with those things that define what it is to be a proper member of the group. Busch writes that the real power of standards consists of their ability to define rules that members of the group have to follow. (2011) In this way standards establish what normal practice and normal objects look like. To say that something is normal is "descriptive *and* prescriptive." (Ureta 2014: 371) Someone who fails to follow a standard is acting incorrectly by not following group order. But not everyone will be able to comply. Some will lack the resources to do so or will be restricted by other rules. In some cases, standards will not satisfy local needs or fail to serve local work. In all of these cases, people will be excluded based on the particular form given to the standard.

Standards and built-in politics. Boundaries, hierarchies and other kinds of politics are 'built-in' to the things that a community makes, including its standards. This form of politics is difficult to see because it involves many things that appear apolitical or that seem to be strictly technical decisions.

When designing standards, a community will rely on certain of its principles. For instance, researchers will make sure to satisfy "technical values such as efficiency and innovation." (Shilton 2017: 251) Other technical values, such as efficacy and reliability, will also be used to guide standardisation. These will help ensure that the standards produced satisfy the technical requirements of the field. However, social values like "security, privacy, and resource democratization" also form part of technological design processes. (ibid.: 251) Those designing an electrical infrastructure may be motivated to ensure that everyone in a region is served equally by the system and that nobody enjoys privilege in terms of access to the infrastructure. Such choices might reflect values such as equality and fairness, and a commitment to ensuring that all parts of a society advanced together. Building values into technologies most often happens without awareness. What people take to be normal, including shared values, shapes the trajectory taken during design and the decisions made at different points.

Politics are also built-in as a result of ideas that are taken for granted, such as assumptions about potential users. All technologies, including synthetic biology standards, have users. When designing those technologies, researchers have to make assumptions about what those people and their practices will look like. Only then can designers make choices about how to configure their technologies. It is difficult to create design targets without having a clear sense of what the technology will have to do once put into use. A result is "built-in assumptions about use and users." (Timmermans 2015: 90) Standards in synthetic biology are meant to be used by certain people in certain ways. Who contributes opinions or specifications, whose opinions are valued or dismissed, who provides funding will all shape what form the standards finally take. If designers assume that the standard will never be used by a certain kind of researcher, they won't try to satisfy those researchers' needs. If they assume that all laboratories that use the standard will have certain equipment, they will effectively exclude those with more limited resources from using the standard. Such assumptions are a good example of what social perspectives of standardisation can reveal.

5.2 WHEN BUILDING AND FIXING

Standards are observed most effectively before they have been established or when they are broken. When a standard is set and in use, social infrastructures becomes translucent. Like all forms of infrastructure, it operates inconspicuously to sustain a normal condition.

When standards are still under construction, people actively discuss and debate what form they will take. Before specifications can be set, the community must reach consensus about what needs must be met and what will constitute success. Priorities, requirements, priorities and rules (among many things) have to be defined and plans must be made to satisfy them. Perfect agreement about these issues is unlikely. As a result, they may become "the object of intense political and economic debate." (Howe et al. 2015: 551) Even if producing standards does not cause such discord, the period of design and construction offers a chance to watch the heterogeneous assemblies being put together.

Repair offers a chance to watch people analysing their constructs, making sense of what caused the failure and decided how to return to normal operation. Repairing a technological artefact can involve opening it up, evaluating parts and their connections, reworking and eventually returning the system to working order. Repairing a standard involves a similar process of evaluating an assembly and making choices about what to change. In both cases, a black box has been opened and internal workings have been revealed. Failures and their repair can reveal when aspects of the assembly have changed or been broken and can reveal when components must be discarded or reconfigured. For instance, a synthetic biology standard may no longer work because of changes in the organisms being used. It is just as likely that certain groups have decided not to employ it anymore or have found a superior way of working. In both cases, elements of the heterogeneous assembly have gone askew. Failure can occur when social coordination and order cease to operate. Watching how people put those back into working condition offers insights into how a community holds itself together and what role standards can play in doing so. (Ureta 2014) It is also a chance to again observe people debating the standards. (Summerton 2004) A broken standard may be one to repair or one to discard. Disagreements and discussions can make assumptions and politics conspicuous.

Timmermans writes that when standards "produce anomalous or unexpected results, raise questions, prompt a search of solutions," it becomes possible to examine their true, complex character. (Timmermans 2015: 94) The same is the case before they have begun to produce normal results, during construction. Such instances offer those making and fixing the standards to ask questions that otherwise seem irrelevant or which seem to have self-evident answers. As one wonders what technical problems have arisen, one can ask why the assembly looks as it does and wonder if a different arrangement might work better.

6. STANDARDS, SOCIAL INFRASTRUCTURES AND BIOROBOOST

The conceptualisation presented here forms part of Work Package 4. However, it can contribute to all but one of BioRoboost's seven other Work Packages (WPs). The final section of this document offers suggestions about those contributions. Ultimately, those responsible for the other WPs must decide if and how they will employ this social perspective.

WP1 (Standards in biology, theory development. Biological metrology) concerns itself with identified existing problems with standardisation in synthetic biology, both in terms of tasks that remain unfulfilled and ones that have not been accomplished successfully. It also aims to present potential solutions. Put differently, WP1 is meant to open and examine semi-stable black boxes in synthetic biology. Its responsibilities include evaluating how the field is putting together procedures and products that can be deployed across the community with sufficient stability, transferability and functional capacity. As such, WP1 can use a social perspective to consider how standardisation problems and solutions involve community coordination and order. Standardisation weaknesses may be the result of flawed technical choices. They may also be the result of a group's inability to arrive at a consensus about the right ways to standardise. As it ponders what directions to take, WP1 can consider the role played by how people relate to each other and the effects that social hurdles can have. It can view its choices as decisions that will establish expectations and boundaries that may benefit some while posing a burden to others.

WP2 (Chassis in SB: theory, state of the art and development of a panel of standardised biological frames) focuses on the role played by standard chasses in making broader standardisation possible. Those constructs constitute a particular kind of standardised part. As such, WP2 is involved in actualising standardisation into physical products (i.e. giving it material existence). It is responsible for creating black boxes. Like WP1, its work involves making choices. Like WP1, those choices will have ramifications for the ways in which synthetic biologists arrange their field and their practices. WP2 researchers can ask themselves why they choose certain elements to use. They can ask what kind of user they are assuming will employ their chasses. They can reflect on what their designs mean for people with access to different resources, or with limits that WP2 does not face. Ultimately, those considerations may not affect the group's decisions and its subsequent products. However, by considering what assumptions are built into its black boxes, WP2 can accomplish its work with a more encompassing understanding of how its chasses will affect the constitution of the field.

Like WP1, WP3 (Beyond bacteria: standards for yeast and mammalian systems. Auditing unmet standardisation needs) concerns itself with gaps in synthetic biology standardisation. Specifically, it explores how standardisation can be carried out on organisms that have yet to receive as much attention as bacteria. A crucial part of the WP is establishing standardisation needs that require satisfaction. Because it explores standards in relation to specific organisms, WP3 offers a chance to consider how contextual changes can affect the ways in which social groups coordinate themselves and order those things with which they work. By using a social perspective, WP3 researchers can evaluate not just what technical differences characterise the switch from bacteria to yeast and mammalian systems, but also what social differences characterise the different communities involved. Different organisms may require significantly different technical solutions; they may also require entirely different social arrangements. As it evaluates those solutions, WP3 can also evaluate what needs have been given priorities over others, why that occurred and what their solutions will demand of the community's membership.

Like WP4, WP5 (Standards, ownership and reusability. Characterizing standardization, shareability and re-usability in SBOL) is a social scientific component of BioRoboost. This document is meant to serve as a bridge between the two WPs. Most of the literature cited here concerns itself with issues like shareability, transferability and collaboration, all of which form part of WP5's goals. Moreover, WP5's focus on SBOL matches the literature's interest in information and knowledge infrastructures. Thus, the conceptualisation presented here draws on scholarship meant to examine the types of technology that WP5 explores. This document's focus on social coordination also serves WP5 due to the latter's research on shareability and ownership. Both of those are forms of social coordination, and both rely on technical, social, legal and political infrastructures. As such, some WP4 tools might be useful for WP5 research. They can also establish a platform upon which to develop discussions about the social aspects of standardisation in synthetic biology.

WP6 (Towards biosafety and risk assessment solutions. Towards full incorporation of safety relevant data and information in SB standards) examines specific social concerns. Its focuses on risk and safety and aims to develop guidance for making those considerations a central part of synthetic biology standardisation. Insofar as WP6 seeks to shape standardisation, it is involved in building black boxes. Its members thus have a chance to encourage their synthetic biology colleagues to reflect on non-technical facets of standardisation. However, risk and safety solutions involve both technical and social components. As such, WP6 has a chance to explore links between the two varieties of infrastructure discussed here. By thinking in terms of technical and social infrastructures, WP6 may be able to demonstrate how the social and the technical shape each other and operate together inside black-boxed standards. Finally, by reflecting on its own decisions, WP6 can consider what concerns and risks become the focus of the WP and what social consequences those choices have. Placing certain risks above others will invariably make some groups' concerns above others, and may even exclude certain issues entirely.

WP7 (Dissemination and Exploitation; policy analysis of biological standardisation) investigates policy concerns, solutions and implications. By exploring standardisation in relation to social institutions outside of synthetic biology, WP7 offers a chance to examine different social infrastructures. These include ones found in politics and policy, as well as social infrastructures that encompass both synthetic biology and other social institutions. This makes it possible for WP7 to consider how synthetic biologists and their standards relate to other forms of communication coordination and ordering. The WP also makes it possible to evaluate the usefulness of this social perspective when used beyond the boundaries of synthetic biology.

The social understanding of standardisation presented here is meant to be more than an abstraction. However, its utility can be evaluated only if the perspective is put to use. Those who have contributed to ideas and text to this document hope that it can expand what is already an expansive project. As noted above, a social understanding of standardisation is not meant to substitute technical viewpoints and practices. Without those, the social perspective lacks relevance. At the same time, without a social perspective, technical viewpoints and practices lack what they need to understand what standardisation entails for synthetic biology.

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