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Working conditions in hydrogen production – a Social Life Cycle Assessment

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Executive Summary

Social impacts of novel technology can, parallel to environmental and economic consequences, influence its sustainability. By analyzing the case of hydrogen production by advanced alkaline water electrolysis from a life cycle perspective, this paper illustrates the social implications of the manufacturing of the electrolyzer and hydrogen production when installed in Germany, Austria and Spain. This paper complements previous environmental and economic assessments, which selected this set of countries based on their different structures in electricity production. The paper uses a mixed method design to analyze the social impact for the workers along the process chain. Appropriate indicators related to working conditions are selected on the basis of the UN Agenda 2030 Sustainable Development Goals. The focus on workers is chosen as a first example to test the relatively new Product Social Impact Life Cycle Assessment (PSILCA) database version 2.0. The results of the quantitative assessment are then complemented and compared through an investigation of the underlying raw data and a qualitative literature analysis. Overall, advanced alkaline water electrolysis is found to have least social impact along the German process chain, followed by the Spanish and the Austrian. All three process chains show impacts on global upstream processes. In order to reduce social impact and ultimately contribute to Sustainable Development, policymakers and industry need to work together to further improve certain aspects of working conditions in different locations, particularly within global upstream processes.

Keywords
Social life cycle assessment, hydrogen, life cycle thinking

Contribution to Industrial Ecology
I Introduction

In order to steer decision-making, not only environmental, but also social impacts of production and consumption are decisive. The growing importance of these aspects triggered a broadening of the traditional life cycle approach and has resulted in many studies [c.f. e.g. Dreyer et al., 2006, Jørgensen et al., 2007, Reitinger et al., 2011, Traverso et al., 2016] concerned with the development of a common methodology. In 2009, the work of a UNEP/SETAC working group culminated in the publication of guidelines for Social Life Cycle Assessment (SLCA) [Andrews et al., 2009], which have been used as a basis for case studies and further methodological development. Nevertheless, the guidelines have not yet resulted in a commonly accepted framework as is available for environmental LCA studies. One approach to conduct a comprehensive SLCA analysis is the use of a quantitative social database, ideally followed by a case-specific analysis of company data to verify generic data results, known as the hybrid approach [Singh & Gupta, 2017].

In the present study, quantitative analysis through PSILCA is the main method to depict social impacts. However, in order to compensate for the abstraction inherent in quantitative studies [Johnson & Onwuegbuzie, 2004], a complementary assessment is also conducted analyzing the raw data as well as additional literature. The main reason for this mixed-method design is to pay tribute to the complexity of social phenomena and incorporate strengths of, both, quantitative and qualitative research designs. The complementary approach seeks to elaborate, enhance and further illustrate the results of the quantitative approach.

This paper presents a case study analysis of the social impacts of industrial hydrogen production using alkaline water electrolysis (AEL), including the manufacturing of the electrolyzer and hydrogen production. The environmental [Koj et al., 2017] and economic [Kuckshinrichs et al., 2017] dimensions have already been investigated. Therefore, this paper completes the sustainability assessment of AEL hydrogen production by adding the social dimension, specifically for the stakeholder group workers.

In the assessment of novel technologies participation of stakeholders is not given; therefore, applying the hybrid approach is not possible. The analysis here is conducted using the Product Social Impact Life Cycle Assessment (PSILCA) database, which constitutes a new tool in database driven SLCA. The new database provides a more comprehensive tool than its predecessor, using more indicators and an updated dataset. Database driven SLCA follows the specifications for Type I SLCA by aggregating inventory indicators into subcategories and further into stakeholder categories, as described in the SLCA guidelines [Andrews et al., 2009]. Following, the quantitative results ground the complementary analysis where PSILCA results are set in relation to the underlying data and additional empirical findings on the identified issues.

As mentioned previously, SLCA can steer business and political decision-making as well as investment decisions, because socially unsound investment can lead to the loss of credibility and profits. In addition, social implications of hydrogen production can also be decisive for
supply chain decisions for manufacturing industries using hydrogen as input. In times of socially responsible supply chain management, sound knowledge of supply chains and documentation of social implications can be a determining factor for economic success.

Since there is not one established methodology how to conduct Social LCA yet recent years have brought up a wide variety of different tools. Another example of database driven SLCA is the Social Hotspot database which has, for example, been employed to identify the social implications of a concentrated solar power plant [Blanca et al., 2017]. Some authors have also developed alternative tools specific to a particular case study at hand. Siebert et al. [2018] developed “RESPONSA”, a regionally specific tool for SLCA in the context of the German wood-based bioeconomy. Another way to use SLCA methodology is as one of the components of Life Cycle Sustainability Assessment (LCSA). Within this context Traverso et al. [2012] combine the LCSA methodology with the dashboard of sustainability to apply the Life Cycle Sustainability Board to a group of hard floor coverings. Even though these are only a few examples of the use of SLCA, it shows the variety of methods used to assess social implications of products.

II Methods

The SLCA guidelines [Andrews et al., 2009] identify five relevant stakeholder groups: workers, local communities, society, value chain actors and consumers. In order to reduce complexity, the scope of the present case study is limited to the stakeholder workers as a first example, in particular to the working conditions under which industrial hydrogen production takes place in the EU. The stakeholder group workers was chosen because it is described by most indicators within PSILCA, representing a solid data basis to test the new database. The improvement of working conditions has been defined as an objective for Sustainable Development within the UN Agenda 2030 [United Nations, 2015b]. The core of this agenda are the 17 Sustainable Development Goals (SDGs), with which the global community wants to “mobilize efforts to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind” [United Nations, 2015a].

The SDGs were also integrated into the work of the International Labour Organization (ILO) to derive key areas for working conditions that need to be addressed in order to ensure Sustainable Development [ILO, 2016]. As indicator selection for SLCA is still a contentious issue this case study uses the six ILO key areas (Table 1) as a basis [Hunkeler, 2006, Kühnen & Hahn, 2017, Lehmann et al., 2013]. Table 1 further illustrates the connection between the key areas and the impact categories in PSILCA 2.0.
In order to quantify the social impact along the AEL hydrogen production chain in Germany, Austria and Spain as well as their upstream supply chains, the PSILCA 2.0 database is used [Eisfeldt & Ciroth, 2017]. The database is based on a multi-regional input/output database called Eora [Lenzen et al., 2012, Lenzen et al., 2013], which enables a global mapping of supply chains on the sectoral scale, following the idea of life cycles. Information on social and socio-economic issues is collected from global statistical agencies and internationally recognized organizations, e.g. World Bank, ILO, WHO. The raw data collected from these agencies is risk assessed on an ordinal scale and implemented into the database. The connection between societal impact and input/output data is established through the use of an activity variable, here, worker hours. PSILCA 2.0 currently provides data on 66 indicators for five stakeholder categories, taken from the UNEP/SETAC guidelines [Andrews et al., 2009]. The results in PSILCA 2.0 are given in medium risk hours per impact category, computed by the different characterization factors assigned to each ordinal risk level and the share of impact of each sector along the supply chain. Impact categories are used to condense 66 indicators into 42 meaningful categories. The analysis in PSILCA is always comparative, meaning that medium risk hours are not measured on a particular scale but can only be assessed in comparison to other results.

The technical process chain starts with the manufacturing of an alkaline water electrolyzer in Switzerland. The assembled electrolyzer is then transported to its final destination in either Germany (Berlin), Austria (Vienna) or Spain (Madrid). The hydrogen production is assumed to take place over 20 years in each location with a replacement of cell stacks after ten years. Further details and technical specifications can be found in Koj et al. [2017]. The inventory in PSILCA 2.0 is inserted in monetary terms per 1 kg hydrogen produced (see supplementary material).

For the complementary assessment, PSILCA results in terms of risks are compared to the raw data used as well as other official statistical data from national as well as international (e.g. ILOstat, Eurostat, OECD) agencies. The assessment is then complemented by a literature anal-
ysis of publications specific to the conclusions drawn from the quantitative assessment. Literature used includes scientific, peer-reviewed publications as well as results from studies conducted by recognized organizations specialized in a particular key area.

III Results

III.1 PSILCA results

The results of the PSILCA analysis for workers show that hydrogen production in Austria entails, in sum, most risks, followed by Spain and Germany (Table 2). In order to derive at condensed conclusions upon which to base the complementary literature analysis, a comparison of risks on each impact category is necessary.

Tab. 2: Results of selected impact categories, in medium risk hours (numbers have comparative value)

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Germany</th>
<th>Austria</th>
<th>Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fair Salary</td>
<td>5.46</td>
<td>7.73</td>
<td>2.30</td>
</tr>
<tr>
<td>Gender wage gap</td>
<td>5.47</td>
<td>31.94</td>
<td>7.96</td>
</tr>
<tr>
<td>Trade unionism</td>
<td>25.75</td>
<td>18.46</td>
<td>43.89</td>
</tr>
<tr>
<td>Association and bargaining rights</td>
<td>6.54</td>
<td>16.48</td>
<td>1.81</td>
</tr>
<tr>
<td>Weekly hours of work per employee</td>
<td>0.26</td>
<td>0.48</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Source: own calculation IIEK-STE 2018

Overall, Weekly hours of work per employee shows the least amount of risk whereas Trade unionism seems to be an issue in all three locations investigated. On the remaining impact categories the results show large differences between the locations.

For the Austrian process chain, the impact categories Gender wage gap and Association and bargaining rights raise particular concern. 61% of all working condition risks are domestic, meaning they come from sectors within Austria. Particularly striking is the high amount of risk of the Gender wage gap in comparison to the other sites. However, these risks cannot be associated with any particular Austrian sector. In terms of Association and bargaining rights, the Public administration sector entails a large share of risks; however, it has to be kept in mind that this sector is dominated by civil servants, who often forfeit their right to strike through their employment contract. Other upstream locations negatively associated with the Austrian process chain are India and China; India in particular with respect to Trade unionism and Fair Salary.
Risks in upstream processes in India and China also play a key role in the German process chain. In contrast to Austria, only 36% of the working condition risks in the German process chain are domestic. These mostly stem from the impact categories Trade unionism and Weekly hours of work per employee. Fair Salary and Gender wage gap show upstream effects in India whereas Association and bargaining rights are an issue in China. On the sectoral level, results are highly differentiated, meaning that there is no substantial risk that can be attributed to any particular sector.

In the Spanish process chain 77% of risks are domestic. While overall risks in the different impact categories along the Spanish process chain are comparatively small, Trade unionism contributes 65% to the total amount of domestic risks. Consequently, the assumption can be made that worker representation in Spain is comparatively weak. At the same time Association and bargaining rights show low risk levels. Therefore, there seems to be an imbalance between representation of workers in trade unions and the way in which the right of collective bargaining and the right to strike are organized. Further evaluation shows that association and bargaining issues prominently stem from upstream processes in China. Pursuant to the other two locations, the process level data shows a highly differentiated distribution of risks.
Concerning global hotspots (upstream locations that exhibit high amounts of risks) India and China are clearly identified in all three process chains. All three show that Fair Salary is an important issue in India whereas in China Association and bargaining rights raise particular concern (c.f. Table 3)

Working conditions are determined by remuneration, workers’ representation and Weekly hours of work per employee. From the PSILCA results it can be assumed that the amount of work is rather unproblematic while fair and decent remuneration constitutes a bigger problem. Within the upstream processes taking place in India the risk for indecent salaries is high. In Spain and Austria women and men are on average not paid equal salaries. While this issue is less pronounced in Germany it is not negligible. In order to initiate change, channels of communication between employees and employers need to be available. Trade unions and the ability to bargain collectively are part of these communication channels. The results above support the idea that worker representation in the form of trade union membership is overall limited.

From the analysis four conclusions about the social implications of AEL hydrogen production regarding workers can be drawn:

1. Trade union membership in Western Europe is limited.
2. Chinese association and bargaining rights are insufficient.
3. Western European women, particularly in Austria, experience wage discrimination.
4. India’s salaries are inadequate to lead a decent life.

III.2 Complementary assessment

In order to elaborate, enhance and further illustrate the results of the PSILCA assessment a complementary assessment of underlying data and a qualitative literature analysis are conducted. The following section is structured according to the conclusions drawn from the PSILCA results.

1. Trade union membership in Western Europe is limited.

The overall decline in trade union density in Europe in the past thirty years is easily verifiable by statistics [Visser, 2016]. The PSILCA results reveal Trade unionism as the impact category with highest overall risks along AEL hydrogen production process chains. The impact category refers to the membership in trade unions measured against the total number of workers that could potentially be members. The risk for low membership is highest within the Spanish chain, followed by Germany and Austria. In order to assess the situation within Western Europe the share of domestic risks is decisive. A detailed analysis shows that Trade unionism risks are 85% domestic in Spain, 48% in Germany and 18% in Austria. This result supports the conclusion that trade union membership in Western Europe is limited.

In order to investigate the reasons behind these results the initial step is to look at the raw data used in the PSILCA calculation. The risk assessment in PSILCA is based on “trade union
density” taken from the ICTWSS database [Visser, 2016]; lower trade union density is translated to higher risk. The PSILCA authors advance the idea of trade union density as “a proxy to get an overall impression of association culture in different industries and countries” [Eisfeldt & Ciroth, 2017]. In other words, trade union density alone is not able to indicate whether or not freedom of association and bargaining are protected within a country; the social and political context always has to be considered.

While the raw data confirms the PSILCA results, setting them in the social and political context requires a look at the historical development of trade union membership in each country. According to the ICTWSS database, trade union density between 1985 and 2013 declined by 25 percentage points to 27 % in Austria, by 17 percentage points to 18 % in Germany and increased by 4 percentage points to 17 % in Spain. These numbers are puzzling when compared to the PSILCA results, as a 1 percentage point difference in raw values (17 - 18) between Germany and Spain leads to an 18 point difference in medium risk hours (25.75 – 43.89), despite the fact that the quantity of input, e.g. the amount of electricity needed, is the same in all process chains. While there are many factors contributing to this difference, one of them is the price of electricity, which is 25 % higher in Spain than in Germany (see supplementary material). Another factor are the different worker hours attributed to each sector within the PSILCA database, which depict the relevance of impacts caused by a particular process in terms of the amount of labor needed for production.

Another interesting aspect revealed by the results above is that while in Austria and Germany trade union density shrank, Spain experienced a growth in membership. This phenomenon might mostly be explained by historical developments. While Austria and Germany belong to a group of countries characterized by long-standing traditions of social partnership [Gumbrell-McCormick & Hyman, 2013], Spain, as well as other countries that experienced monocratic regimes in the second half of the 20th century, tend to be more adversarial towards strong industrial relations, which explains the overall lower trade union density [Hamann, 2011]. Whereas in Austria and Germany, trade unions between 1985 and 2013 used to include 33-50 % of the wage earners in employment (trade union density), Spain’s proportion has never risen above 18 % [Visser, 2016]. Therefore, the observed increase in Spanish trade unionism is not symbolic for vivid industrial relations; rather, the data since 1985 includes the reestablishment of trade unions after the Francoist period and the subsequent but slow increase in membership. Additionally, the institutional and organizational structures in Southern Europe show weaknesses to foster high levels of trade union densities [Lima & Artiles, 2011]. Rather, Lima and Artiles [2011 identified different forms of social partnerships, such as tripartite social pacts and company-level negotiations, which nonetheless are powerful enough to initiate political momentum.

Within the SDGs, the goal related to trade unionism targets the protection or establishment of the right to form social pacts and trade unions. Even though the analysis above shows declining numbers in union membership, this does not necessarily indicate a deterioration of rights within the respective countries. As mentioned above, the PSILCA assessment of trade unionism should always be interpreted within a wider context. In addition, future databases
could also include measures of social pacts beyond trade unionism in the traditional sense to depict a more differentiated image of the circumstances.

(2) Chinese association and bargaining rights are insufficient.

Within all three process chains investigated, Chinese association and bargaining rights are characterized by high levels of risk. Out of the total risks within this impact category 60 %, 23 % and 81 % could be assigned to China in the German, Austrian and Spanish process chain respectively. Even though the share in the Austrian chain is comparatively low, the conclusion that association and bargaining rights in China are problematic still holds true.

Taking a look at the structure of the impact category Association and bargaining rights in PSILCA reveals that it is composed of three indicators: Right to Strike, Right to Collective bargaining and Right of Association. The raw data for all three indicators is provided by the ICTWSS database [Visser, 2016]. The ICTWSS database provides different assessments for the market sector and the government sector; however, for China, the assessment is the same for both sectors. According to the ICTWSS database the Right of Collective bargaining in China can be exercised with minor restrictions, whereas the Right of Association is burdened by major restrictions and there is no Right to Strike in China [Visser, 2016]. For association and bargaining rights to properly function and establish dialogue between employers and employees all rights would have to be granted. The situation in China; however, seems problematic and requires further investigation.

Even though trade union membership is not part of the impact category Association and bargaining rights its close connection makes it seem appropriate to include considerations of trade unionism in China in this discussion. While formally trade unions, in the form of the All-China Federation of Trade Unions (ACFTU), have existed since the beginning of the 20th century, they have primarily acted as an extension of state policy into the workplace [Chan & Hui, 2014]. Until recently, trade union activities rarely ensured more than the legal minimum requirements for labor standards [Chan & Hui, 2014]. In response to rising social conflicts since the early 2000s labor market institutions have begun to change; however, their effectiveness is often still questionable. Lee et al. [2014 attest to the changes that reached their first culmination in the Labour Contract Law in 2008, which “seeks to enhance employment protection by encouraging indefinite-term contracts”. Chan and Sio-Ieng Hui [2013 observe the emergence of state-led collective bargaining, which is characterized by negotiations held between the enterprise and the ACFTU. Lee et al. [2014 demonstrate indications that a hybrid representational structure is emerging due to new election practices for company union committees, which no longer consists solely of management representatives but also include “rank-and-file workers”.

In Puddington and Roylance [2016, Freedom House reports on severely restricted rights of association and harassment by state officials and the police in China. Despite the positive developments and efforts also by state authorities, Chan and Sio-Ieng Hui [2013 determine that major obstacles for association and bargaining rights still remain. Whereas the one-party-state is concerned about a loss of control over its workers, foreign investors fear a surge of labor
costs, which would force them to either raise prices, and possibly loose costumers, or relocate their production facilities. This effect reinforces the pressure felt by state officials to keep rather restrictive measures in order to keep foreign investors content.

Overall, association and bargaining rights in China have seen some progress due to increased international visibility and corresponding pressures with respect to human rights issues; however, limiting factors remain. In terms of investment decisions, the fact that China’s regulations on workers’ rights have been rarely enforced has played a decisive role in its economic success and in attracting foreign investors [Aaronson, 2010]. However, in the future, it might be possible to steer investment towards improving working conditions. For such changes to occur, international investors need to be willing to prioritize social sustainability over economic profit. In how far this kind of strategy would be effective in improving workers’ rights is very difficult to predict and could ultimately also result in the opposite effect of workers being laid off because of investments withdrawn.

In order to achieve Sustainable Development in line with the SDGs labor rights need to be granted universally. In this respect, China still has to overcome some political and societal hurdles. Due to the size of the country and the number of workers affected by the labor right standards, Chinese improvements will largely determine the success of the SDGs.

(3) Western European women, particularly in Austria, experience wage discrimination. The unequal remuneration of men and women undermines the thought of solidarity enshrined in the SDGs. As the PSILCA results of the case study show the issue is particularly severe along the Austrian process chain. Further investigation additionally reveals that 87% of these risks are found within Austrian sectors. Domestic risks along the German and Spanish process chain amount to 17% and 75% respectively, keeping in mind that the absolute risk along the Spanish process chain is four times smaller than along the Austrian.

The rather unexpected PSILCA result provokes questions about the underlying raw data. Gender wage gap in PSILCA 2.0 is determined using “mean nominal monthly earnings of employees by sex and economic activity (local currency)” [Eisfeldt & Ciroth, 2017], which is available in the ILOstat database [ILOstat, 2014]. A general issue with using monthly data is the fact that it is not able to control for effects like part-time work, which can exacerbate results. One way to control for this effect is to use hourly earning statistics.

The European Commission finds that a high wage gap is usually characteristic of a highly segregated labor market or one “in which a significant proportion of women work part-time (e.g. Germany and Austria)” (EC, 2017). In Spain, the overall female employment rate only amounts to about 51%, compared to 67% in Austria and 70% in Germany; however, those Spanish women in employment work less often in part-time than their female colleagues in Austria and Germany. While in Austria, 46.9% of female employees work part-time [STATISTK AUSTRIA, 2014], with 47.6% even more do so in Germany. In relation to previously presented results this means that part-time work cannot be the only explanation for the large medium risk hours discrepancy between the two countries.
Two additional labor market effects that should not be underestimated with respect to the gender wage gap are the so-called “glass ceiling” and “sticky floors”. The “glass ceiling” phenomenon refers to the highest part of the wage distribution. Only very few high-level managerial and CEO positions around the world are filled by women. Research by Hurley and Choudhary [2016] confirms that years of education, number of children and the size of the company in terms of number of employees play a determining role in the probability of the CEO being female, at least in the largest publicly traded firms in the USA. Another important factor for the discrepancy between male and female remuneration is the sectors in which women work. Christofides et al. [2013] confirm this phenomenon as also being true for the European labor market. The “sticky floor” phenomenon refers to the lowest part of the wage distribution, meaning that it is very difficult for minimum wage and low wage earning women to improve their social standing. Christofides et al. [2013] find that twelve out of 26 European Union member states show evidence of the “sticky floor” phenomenon. The authors also investigate the effects of institutions and work-family reconciliation policies on the gender wage gap, finding that generous and well-structured work-family reconciliation policies positively influence the gender wage gap in many of the countries considered [Christofides et al., 2013]. While Germany shows both effects, Austria is only characterized by “sticky floors” and neither of the phenomena can be observed in Spain [Christofides et al., 2013]. However, the reason for this result is most likely found in the fact that women participating in the workforce in southern Europe are more concentrated in the high-wage jobs [Claudia Olivetti & Barbara Petrongolo, 2008].

The raw data in the ILOstat database is collected on country level. Consequently, data is often collected from different sources. For Austria, the ILOstat database uses administrative records, whereas German data is taken from household income/expenditure surveys and the Spanish number stems from establishment surveys [ILOstat, 2014]. While a detailed investigation of the differences between these sources is beyond the scope of this research, the different ways to collect and compute data could certainly contribute to the large discrepancies in PSILCA results.

In order to ensure fair working conditions for everyone, equal remuneration for men and women plays a key role. Even though the principle of “equal pay for equal work” has been enshrined in the EEC Treaty since 1957 [Foubert, 2017], wage discrimination remains a problem even within highly developed nations such as the EU member states. In order to change the situation for women the government as well as private companies need to improve their policies on work-family reconciliation as well as break down prejudices with respect to women in the workforce. Efforts to close the gender wage gap will improve the livelihoods of women worldwide and contribute to achieving Sustainable Development, in particular SDGs 5 and 10 on reducing inequalities.

(4) India’s salaries are inadequate to lead a decent life.
The impact category Fair Salary aims to depict the adequacy of wages for workers. The idea about Fair Salary stems from Article 25 (1) of the Universal Declaration of Human Rights which states that “everyone has the right to a standard of living adequate for the health and well-being of himself and of his family [...]” [UN General Assembly, 1948]. Within this paper the adequacy and fairness of salaries is assumed to be equal to the ability to lead a decent life. A more detailed discussion on fairness of wages is beyond the scope of this paper.

The PSILCA analysis for all three locations reveals high risks for inadequate salaries in India. The country-level analysis shows that 37 %, 24 % and 34 % of Fair Salary risks stem from India in the German, Austrian and Spanish process chain respectively. Only the Austrian process chain exhibits more domestic than Indian risk.

The PSILCA impact category Fair salary is composed of three indicators: Minimum wage per month, Living wage per month, Sector average wage per month. Risk assessment of both the sector average wage and the minimum wage is conducted in relation to the living wage. The methodology behind the living wage is based on the idea to estimate the monthly expenses for essential needs [Anker & Anker, 2013]. Looking at the raw values, the living wage in India is rather low, meaning that life in India is not particularly expensive. However, set in relation to the minimum wage the risk of inadequate salaries becomes apparent.

The data uncovers a systematic problem with setting minimum wages in developing countries. To avoid job losses and attract foreign investment, minimum wages are often set at a low level and only apply to a selected group of workers, almost always excluding informal workers [Gindling, 2014]. These peculiarities also apply to the Indian labor market, which is characterized by high level of informal employment, to which the legal provisions for minimum wages do not apply. “Increasing casualization and informalization of employment despite the continuing relatively high growth of incomes are likely to further increase the inequality between wage earners and other groups” [Papola & Kannan, 2017]. Additionally, the size of the Indian subcontinent results in large regional differences and minimum wages being set at national, state and regional level [Papola & Kannan, 2017]. While informal workers are not included in the PSILCA assessment, they play an important role in the Indian context and reveal a structural problem of the Indian labor market that is not visible when looking at the quantitative results alone.

As Verick [2017] confirms, India has not yet been able to completely translate its rapid economic growth into better working conditions. Conversely, the rapid growth has often been associated with more pronounced inequalities and “greater fragility of incomes” [Ghosh, 2011]. This phenomenon indicates issues of income redistribution. Gupta et al. [2014] confirm that “more money in the same programmes without addressing their operations and outcomes will deliver little”. Successful human development is not only a question of quantity of money but also of the quality of redistribution mechanisms. Sarkar and Mehta [2010] attest to the increasing inequalities accompanying rapid economic growth.

Due to its size and large population, India’s economic structure is highly complex. In order to distribute economic growth more evenly, political and societal barriers need to be overcome.
Sehrawat and Giri [2015 focus on increased access to banking facilities for people in rural India in order to improve their chances to benefit from economic growth. Other options for more fairness are tax reforms or targeted government spending.

While there is still a rather long way to go, India’s success in creating more inclusive growth and decent work will not only be decisive for the future of its social balance but also favorable to the achievement of the SDGs, particularly Goal 8 (Decent Work and Economic Growth).

IV Discussion

The present study investigates the social impacts along the life cycle of AEL hydrogen production in Germany, Austria and Spain. The analysis showed that AEL hydrogen production is socially least problematic in Germany compared to Spain and Austria. Using PSILCA 2.0 provides new insights into the pitfalls of database driven SLCA. One of them is its limited ability to truly depict reality, e.g. statistics that exclude important proportions of society like informal workers. However, in PSILCA 2.0 the increased number of indicators and detailed result levels provides more avenues for interpretation of the complex social impacts along process chains, which balances this pitfall to a certain degree.

Due to several layers of computation in PSILCA, the concept of medium risk hours is difficult to grasp. Therefore, the approach to complement the quantitative assessment with an additional literature analysis is intended to provide more information about the meaning of the numeric results and contextualize them.

The results of the analysis are somewhat surprising; the most striking aspect being the large difference in medium risk hours between Germany and Austria, two countries that are often perceived as structurally and culturally similar. Unfortunately, the scope of this research was only able to uncover some of the reasons behind this discrepancy. Further research is needed to investigate its full extent.

In an ideal case scenario all stakeholders involved in the operation of a particular electrolyzer would be known, including suppliers. This would enable a well-informed PSILCA analysis (e.g. actual prices) as well as targeted qualitative research using interviews and surveys. In a study devoid of actual stakeholders as the one presented here such level of detail is not possible. Consequently the complementary approach is used to enrich the quantitative data as much as possible in order to create a realistic image of the circumstances. The methods used in this study are an attempt to mimic the hybrid approach of SLCA and therefore expand the methodological choices in SLCA.

Limiting the analysis to the stakeholder group workers was done to provide a focused study able to assess information in a detailed manner and provide a starting point. However, in order to fully assess the social implications of AEL hydrogen production future research should also include other stakeholder groups, also establishing a stronger connection to Sustainable Development and the SDGs.

Another limitation of the method presented here is the difference in levels of abstraction adopted in PSILCA and the literature used in the complementary analysis. Whereas in PSILCA
the technical components are used as inputs in terms of sectors, the complimentary literature uses the country level or a particular societal group as frame of reference.

V Conclusion

Overall, the analysis shows that most social risks in AEL hydrogen production can be associated with the Austrian process chain, followed by Spain and Germany. Relating back to the research question, social implications for workers across all three process chains show a high vulnerability concerning the degree of association of workers and the provision of communication channels between employees and employers, e.g. in terms of trade unions.

The approach taken in this study has shown that complementing database driven SLCA with additional information can be useful to identify weaknesses of databases and improve their ability to depict reality.

In terms of investment decisions in AEL hydrogen production some of the working conditions dealt with in this study are easier to influence than others. While Weekly hours of work and the Gender wage gap can be influenced by individual employers, larger societal issues like trade union membership are more difficult and might not even be beneficial to the investment. Nevertheless, avoiding certain producing countries completely, because of the working conditions, might be counterproductive as missing investment could lead to further deterioration of the economic situation and even more precarious working conditions. Rather, companies could steer their investment and purchasing power to push suppliers towards fair working conditions. In order to reach the Sustainable Development Goals such industry efforts need to be combined with policy developments in order to ensure the longevity of improvements. As indicated by the inclusion of fair and sound working conditions in the SDGS they build the foundation of a well-functioning economy and long-term prosperity.
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Many of the issues at the centre of public attention can only be dealt with by an interdisciplinary energy systems analysis. Technical, economic and ecological subsystems which interact with each other often have to be investigated simultaneously. The group Systems Analysis and Technology Evaluation (STE) takes up this challenge focusing on the long-term supply- and demand-side characteristics of energy systems. It follows, in particular, the idea of a holistic, interdisciplinary approach taking an inter-linkage of technical systems with economics, environment and society into account and thus looking at the security of supply, economic efficiency and environmental protection. This triple strategy is oriented here to societal/political guiding principles such as sustainable development. In these fields, STE analyses the consequences of technical developments and provides scientific aids to decision making for politics and industry. This work is based on the further methodological development of systems analysis tools and their application as well as cooperation between scientists from different institutions.

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