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Energy Transition Future with Hydrogen as a Sustainable Energy Source

–a practical application analysis from today's perspective –

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Abstract— *Renewable Energy Sources (RES) and efficiency improvements are the key factor for future energy transition. The huge amounts of fossil fuel that are burned daily through human activities and demand by the growing world population, change dramatically our environmental situation on earth in the coming decades. RES like Wind, Solar, PV, Hydro and efficiency improvement in our energy infrastructure can solve our future energy dilemma on earth. Hydrogen (H_2) as a green sustainable secondary energy carrier can help moving in the energy transition future. The objectives of the article demonstrate with two technical applications the possible impact and important issues using Hydrogen (H_2) as a green secondary energy source. Energy conversion processes, sustainability, production processes and key applications for H_2 fuel, are the scientific aspects.*

Methodologically a primary energy model is used to show the efficiency chain from Well to Wheel or Room and possible consequences for environmental, economic and technical issues. Practical Hydrogen applications will be analyzed and compared with today´s technology. Out of this analysis general issues can be derived for a possible energy transition future using H_2.

The result of the analysis shows the critical factors for the transition process working with H_2 as a renewable and sustainable energy carrier.

Keywords— *Energy Transition, Sustainablility, Green Hydrogen, FC Cars, Fuel Cell Heating.*

I. INTRODUCTION

Anthropogenic greenhouse gases which results from burning fossil energy sources like coal, gas, and oil through human activities on earth are changing our climate since the industrial revolution in the 1850[th] [1]-[7]. The world's population is increasing by over 50% since 1960[th] to the present of 7.44 billion people [8]. At present more than 413 ppm CO_2 concentration in average is in the air [9]-[10]. CO_2 is the second most important greenhouse gases which influence our global warming process and therefore our live on earth in different ways [11]-[18]. Since the start of the industrialization in the 1850[th] the CO_2 emission increased over 40% [19]. The amount of burning fossil energy sources in 2018 is more than (10.500 Million tons oil equivalent). The amount of CO_2 in 2018 was nearly 40 Gt CO_2 [19]. The reference year 1990 (Kyoto year) the amount on CO_2 increased over 60% to today's figure [19]. The IPCC global warming scenario in 2018 shows the curves in which direction we are moving. In December 2015 all member states signed a climate change agreement in Paris. The aim is to limit the temperature increasing over 2 K (2°C scenario) [20,21]

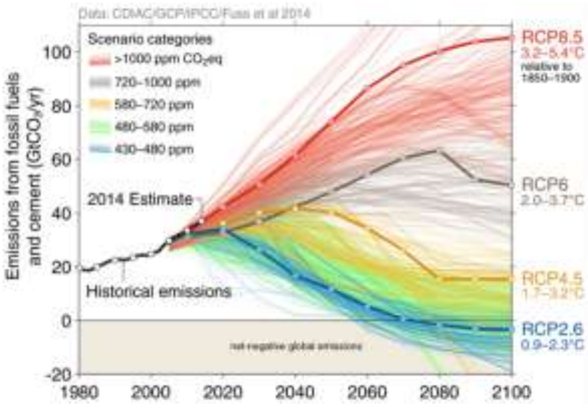

Fig. 1. CO_2 and Ambient Temperature scenarios

The consequences for increasing the CO_2 concentration are [14]-[18]:

- *higher global temperature*
- *higher water evaporation*
- *melting of glaciers and North-South Pole*
- *sea level rise*
- *significant increase in rainfall*
- *activity with storm and floods*
- *Expansion of desert areas*

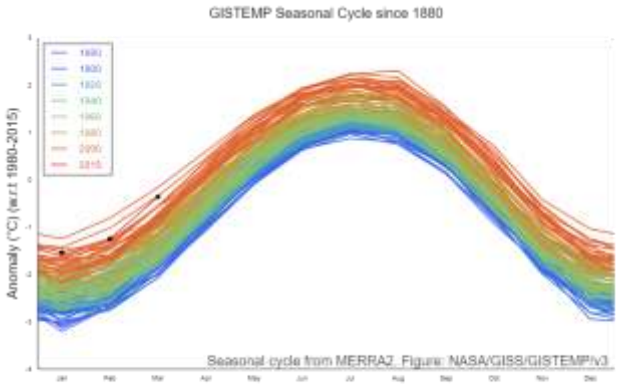

Fig. 2. Temperature changes from 1880 to today

Fig. 2 shows the temperature anomaly since 1880 to 2019. The temperature anomaly is changing constantly since 1880 through the ricing CO_2 emissions worldwide.

Fig. 3 shows the amounts of primary energy used in 2018

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[22-25].

The renewable energy amount was only a small portion of the total primary energy usage. For a global energy transition from fossil to renewable energy world a lot of efforts must be taken.

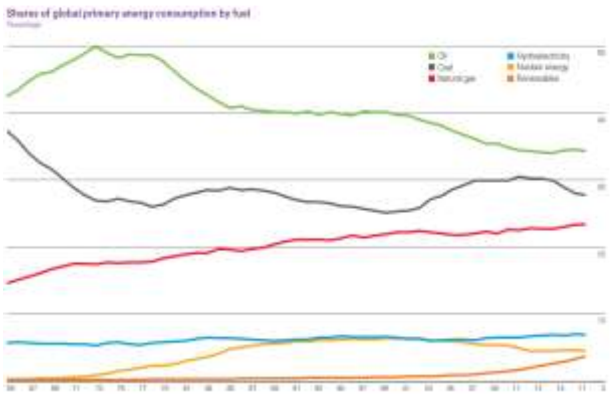

Fig. 3. Worldwide Primary Energy shares [22]

II. Sientific Aspects

A. *Energy Concept*

To analyze and understand how energy is converted, the different energy sources like primary, secondary, final and usable energy terms must be defined. The Sankey diagram shows the concept of Energy sources which is used in this article (Fig. 4).

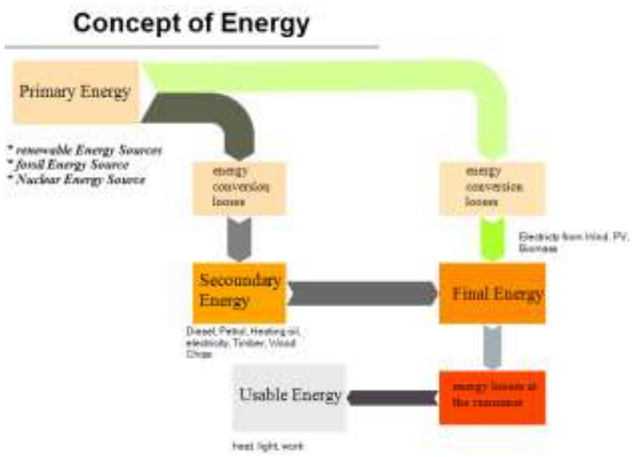

Fig. 4. Concept of Energy sources (own contribution)

B. *Energy Efficiency*

The dilemma with nearly all energy sources are conversion losses from an energy type to another [26], also the distribution losses for power cables in the different AC high voltage grid systems. As an example, the German grid system has a total length of 1.7 Million km (high and low voltage power lines) and has more than 70.000 transformer system between [27-30]. The transaction costs (energy losses) are huge and are payed from all electricity users. 6 % of these electrical generations are distribution losses. With 0,04 € /kWh produced energy this amount is more than 1.560 Mio €/a.

Tab. I shows the efficiency of different energy conversion systems [26, 27]

TABLE I: Efficiency Conversion Process Today

Energy conversion systems	Efficiency
Geothermal power plant	10 %
Parabolic trough power plant	15 %
Solar cell	15 %
Fuel cells (electricity + heat)	80 %
Wind generators	45 %
Nuclear power	30-40 %
Coal generators	30-45 %
Solar panels	70 %
Combined cycle power generator	60 %
Wood gas power plant	80 %
Hydro generators	80 %
CHP Combined heat and power	90 %

Changing energy types is mostly connected with the loos of the quality of energy. The energy of a system or of heat flow transported energy can be divided into two parts (exergy/anergy).

Exergy is the ability to do work, the anergy, however, is the amount of energy, which (except possibly for heating) is of no use and cannot be converted into work [26].

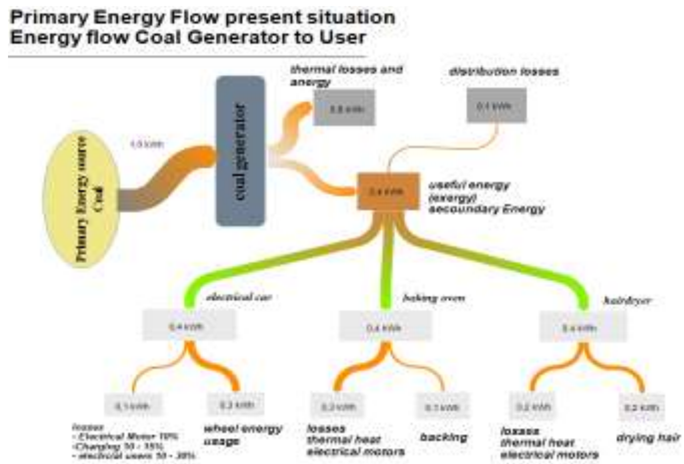

Fig. 5. Primary Energy flow (own contribution)

C. *Sustainability vs. Permanence*

The aim of the energy transition is a permanent (for all time) renewable energy supply. Carl von Carlowitz defined in the 1750th sustainability as an exact definition *law of conservation* of wood inventory [31]. Today's definition of sustainability is subjective because of the term in the definition "to meet their own needs". In our fast-paced world, "to meet their own needs" be changed frequently by governments, depending on political interest.

Weightings and evaluation criteria are determined by the appraiser. Both processes based on *subjective* assessments. Under today's definition of sustainability (see ISO 14000 and Brudtland definition) no physical benchmarks are possible for the implementation of an energy transition.

The concept of sustainable triangle for the energy transition will only work if the criteria are of permanence will be used. Fig. 6 shows the three-pillar model and precedence model of sustainability.

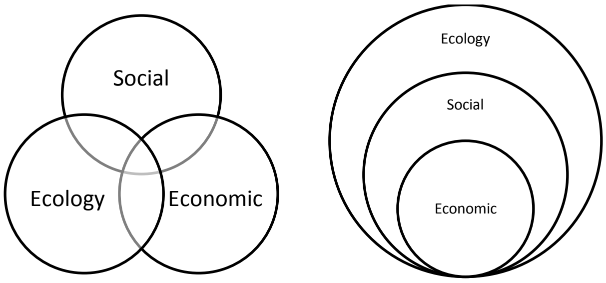

Fig. 6. Sustainability Models

In the three-pillar model, all three areas are considered equally important and with equal rights. The basic message of sustainability can only be achieved with simultaneous consideration of all three areas.

In the priority model, individual areas in your relationship and dependency on each other are seen. The basic message of this model is no economy without a society, no society without ecology.

D. Hydrogen Technologies

Table II shows the different ways for producing hydrogen today [32]-[37]. Today's H_2 production is mostly done through fossil energy sources in the chemical industry. H_2 produced out of a fossil energy source will increase the CO_2 amount. To have a permanence energy source, H_2 must be produced out of a renewable source (see Fig. 9).

TABLE II: Type of H_2 Production Sources

Process	Fuel type	Efficiency	CO2 impact
Thermal reformer	CH4	< 80%	Huge impact
Atrial oxidation	Fossil	< 80%	Huge impact
Kvaerner process	Fossil		Little impact
Electrolysis fossil	Fossil	< 70%	Huge impact
Steam reformer	Biomass	< 80%	Carbon neutral
Electrolysis	PV/Wind	< 80%	No impact

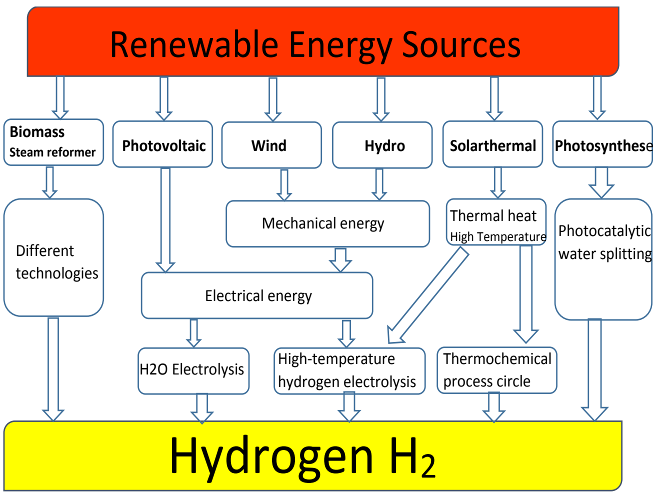

Fig. 7. H_2 Production process with renewable energy sources

Table III shows the different present application for H_2 fuel. Today´s H_2 is mostly used in industrial processes (fertilizer, solvents, plastics).

Future H_2 Applications for an energy transition are FC systems and energy special conversion processes.

TABLE III: APPLICATIONS WITH H_2 [37,38,39]

H2 Applications	Applications Examples
Stationary Systems	Fuel Cell Heating System, Fuel Cell CHP power plant operation, Electrolyze, Power generation
Mobil Systems	Cars, Buses, Ships, Lorry, Heavy goods Vehicle, Bicycles, Submarines (Military), Forklifts, Airplanes
Transportable system	Note books, Camping, Traffic control, Environmental Measurement, Cam Recorder, Portable UPS, Mobil Phones, Torches etc…

III. METHODOLOGY

For the primary hydrogen energy conversion model following parameters for calculation purpose and comparisons are essential:

- *Conversion losses, fuel cell application, fuel type, efficiency of the application, output energy type, environmental impact, energy cost, fuel cost.*

The input data´s are from Institutions, official studies, research, latest scientific publication and secondary sources. An assessment is made with the data and shown in an evaluation table.

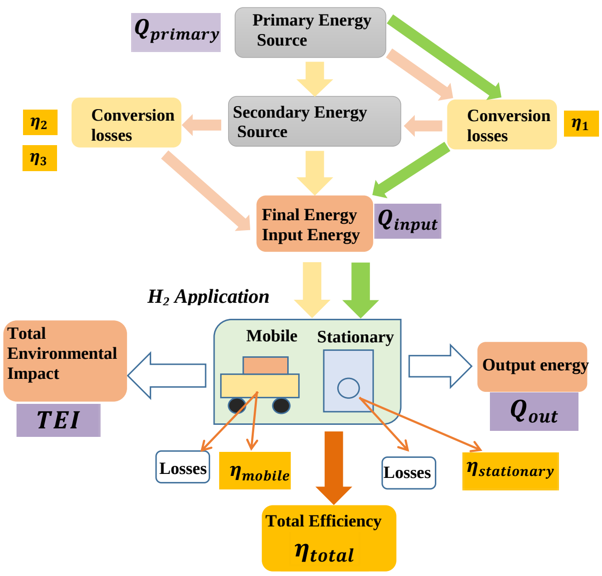

Fig. 8. Primary Hydrogen Energy Model (own contribution)

Energy Input

$$Q_{input} = Q_{primary} * (\eta_1) * (\eta_2) * (\eta_3) * \ldots (\eta_x) \quad [1]$$

η_x = *conversion losses*

Output Energy

$$\dot{Q}_{out} = \sum Q_{out_1} + \sum Q_{out_2} + \cdots + \sum Q_{out_n} \quad [2]$$

Efficiency

$$\eta_{h2} = \frac{\sum Q_{out}}{\sum Q_{input}} \qquad \eta = \frac{\dot{Q}_{out}}{\dot{Q}_{input}} \quad [3]$$

Total efficiency

$$\eta_{total} = (\eta_1) * (\eta_2) * (\eta_3) * \ldots (\eta_x) * \eta_{application} \quad [4]$$

$$\eta_{total} = \frac{Q_{out}}{Q_{primary}} \quad [5]$$

Total Environmental Impact (TEI)

$$TEI = Q_{primary} * CO2cf \quad [6]$$

PEU = Primary Energy Unit, CO2cf = CO_2 conversion factor
TEI = Total Environmental Impact

For calculation purpose different process efficiency are used (see Table IV). For CO_2 impact Table V shows the present standard factors from GEMIS Database

TABLE IV: Efficiency Chain

Processes	Efficiency %
Fossil production (well)	0,9
Electrical generation (Germany)	0,4
Distribution losses (Power Cables/Transformer	0,9
Hydrogen production	
Hydrogen production electrolysis	0,8
Reformer (CH4)	0,8
Steam Reformer	0,8
Biogas Steam Reformer	0,8
Pressure raised Hydrogen	0,9
Liquid Hydrogen	0,7
Application	
Fuel cell car (Input to Wheel)	0,45
Electrical vehicle (Input to Wheel)	0,75
Petrol/Diesel car (Input to Wheel)	0,20
Fuel Cell Heating (55% electrical/45% thermal)	0,9

Table IV shows he average efficiency for different energy conversion systems.

TABLE V: Environmental Impact Factors [40]

Energy Source	CO2 equivalent factor
Electricity	0,565
Coal	0,82
Heating oil	0,32
Gas	0,25
Diesel	0,33
Petrol	0,288
Pellets	0,027
PV	0,02–0,05
Wind	0,01–0,02

Source: GEMIS 4.95

Table V shows the calculations factor for CO_2 in kg emissions per kWh energy.

IV. Research Analyse And Results

A. Energy analysis

Primary world energy consumption shows Fig. 9

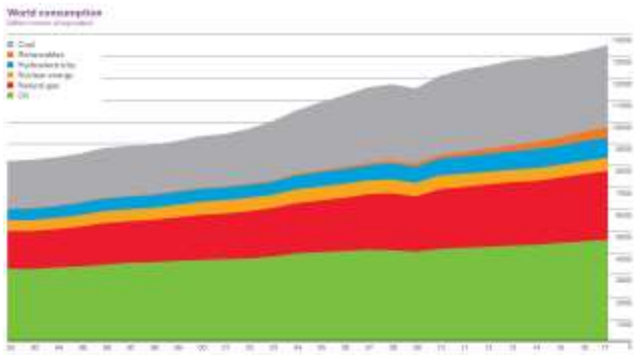

Fig. 9. Primary Energy usage [22]

The todays worldwide Primary energy usage is around 14.000 Mill. tones oil equivalent, and increasing steadily [22 - 24]

In Germany 2018, 12.900 Petajoule on primary energy are used [29,30]. The energy policy strategy in Germany for 2020 and 2050 are 20% and 50% less fossil primary energy usage through energy savings, higher efficiencies and renewable energy sources. Fig. 10 shows the primary energy sources in Germany since 1990.

Since 1990 the primary energy amount is only reduced slightly. The RES is increase from 3 % to over 14% in the last 18 years.

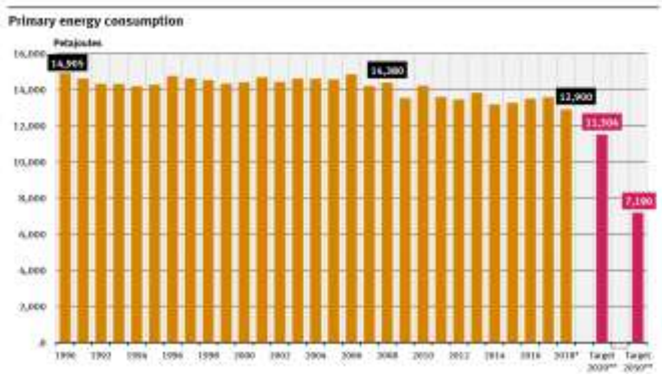

Fig. 10. Primary Energy Sources in Germany

Fig. 11 shows the primary energy mix in Germany in 2018 [29]. 14 % of the primary energy comes from a renewable energy source.

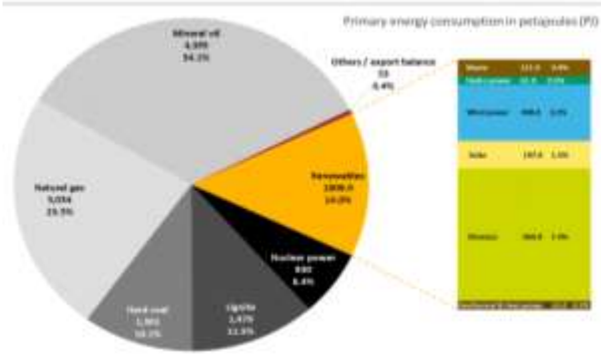

Fig. 11. Primary Energy Mix in Germany 2018

Moving to an energy transition a precise analysis is necessary. This should be split in the different energy sources for possible substitution with RES. The energy sectors electricity, mobility and thermal energy must be viewed holistically. This includes a new view of an energy infrastructure. The most crucial point for an energy transition lies in the renewable energy sources. The demand for renewable energy has grown exponentially in the last 10 years. As a result, we are able to generate energy equal to or even cheaper than conventional power plants in most of the world's energy markets [41, 42]. This trend continues and will make future solar energy the cheapest source of energy.

To supply the three energy sectors with energy in the future, energy sources will be needed that can be used holistically in the sectors. This energy source can ideally be hydrogen, which is made from different renewable energy sources. Due to the ever-lower energy costs of renewable energy sources, the production of hydrogen with these sources is economically and environmentally feasible. There are already numerous examples here, especially in the Power to X applications. The future market for hydrogen applications has huge market potential, as different studies show [43].

B. Efficiency and Environmental Aspects using H_2

For the research analysis a standard power generator driven with a fossil source is used. Wind and PV for a RES will be used. The application example is a H_2 driven fuel cell car and stationary Micro CHP system. The well to wheel research shows the efficiency chain in Table IV. One Primary Energy Unit in kWh (PEU) is the base of the calculation. The environmental impact is based on PEU and the CO_2 conversion factor (see Table V).

C. Case Study Mobility Sector

In the mobility sector over 80% of the energy source are fossil fuels (Gas/Oil). These case studies shows the use of H_2 in a FC Car with the efficiency chain well to wheel. The basis of the calculation is the primary energy unit. This PEU is normalized to one unit in kWh. This unit is required to move the wheel. For each PEU a special amount of CO_2 emissions are polluted. This total environmental impact (TEI) is calculated, depending of the primary energy source over the CO_2 equivalent figure. The efficiency chain goes from the primary energy source back to all efficiency conversion process up to the application self.

Example 1: H_2 produced out of electricity from today's grid *(electrolyzes)*

TABLE VI: Well to Wheel Analysis FC Car

Process	**η**	**PEU kWh**	**TEI kg**
Primary energy source		8,57	0,565
Fossil energy production	0,9	7,7	
Electrical generation	0,4	3,4	
Distribution looses	0,9	3,1	
Electrolysis	0,8	2,46	
Pressure raised H_2	0,9	2,22	
Fuel Cell car	0,45	1	
Total	0,10	8,57	4.84

Example 1 shows a FC car with 1 kWh coming out of the wheel, 8,57 kWh are necessary from a primary energy side. The environmental impact is 4.8 kg CO_2 per kWh.

Example 2: H_2 produced out of a fossil energy source *(CH_4)*

TABLE VII: Well to Wheel Analysis FC Car

Process	**η**	**PEU kWh**	**TEI kg**
Primary energy source		3,4	0,25
Fossil energy production	0,9	3,1	
Reformer	0,8	2,46	
Pressure raised H_2	0,9	2,22	
Fuel Cell car	0,45	1	
Total	0,29	3,4	0,85

Example 2 shows a FC car with 1 kWh coming out of the wheel. Producing H_2 over a reformer process with a fossil gas 3.4 kWh units on gas ist necessary. The enviornmental impact is 0,85 kg CO_2 per kWh.

Example 3: H_2 produced out of a RES *PV*

TABLE VIII: Well to Wheel Analysis FC Car

Process	**η**	**PEU kWh**	**TEI kg**
Primary energy source		15,4	0,02
PV System	0,20	3,1	
Electrolysis	0,8	2,47	
Pressureraised H_2	0,9	2,22	
Fuel Cell car	0,45	1	
Total	0,06	15,4	0,3

Example 3 shows a FC car with 1 kWh coming out of the wheel. Producing H_2 over a reformer process with a PV system. 15,4 kWh units on a PV system ist necessary. The enviornmental impact is 0,3 kg CO_2 per kWh.

Example 4: H_2 produced out of a RES *Wind*

TABLE IX: Well to Wheel Analysis FC Car

Process	**η**	**PEU kWh**	**TEI kg**
Primary energy source		6,8	0,02
Wind generator	0,45	3,1	
Electrolysis	0,8	2,47	
Pressureraised H_2	0,9	2,22	
Fuel Cell car	0,45	1	
Total	0,15	6,8	0,13

Example 4 shows a FC car with 1 kWh coming out of the wheel. Producing H_2 over a reformer process with a wind generator. 6.8 kWh units on wind energy is necessary. The environmental impact is 0,13 kg CO_2 per kWh

Reference mobility

The example 5-7 shows reference cars driven with fossil energy and electrical vehicles.

Example 5: Electricity out of a RES *PV*

TABLE X: Well to Wheel Analysis electrical car

Process	**η**	**PEU kWh**	**TEI kg**
Primary energy source		6,6	0,02
PV System	0,20	1,33	
Electrical car	0,75	1	
Total	0,15	6,6	0,13

Example 5 shows a BE car with 1 kWh coming out of the wheel. Producing electricity with a PV generator. 6.6 kWh units on PV energy is necessary. The environmental impact is 0,13 kg CO_2 per kWh

Example 6: Electricity out of a fossil Source

TABLE XI: Well to Wheel Analysis electrical car

Process	**η**	**PEU kWh**	**TEI kg**
Primary energy source		4,11	0,565
Fossil energy production	0,9	3,7	
Electrical generation	0,4	1,48	
Distribution looses	0,9	1,33	
Electrical car	0,75	**1**	
Total	*0,24*	*4,11*	*2,32*

Example 6 shows a BE car with 1 kWh coming out of the wheel. Electricity comes from the grid 4,1 kWh units are necessary. The environmental impact is 2,32 kg CO_2 per kWh

Example 7: <u>*Reference*</u> Car today <u>*Diesel*</u>

TABLE XII: Well to Wheel Analysis Diesel Car

Process	η	PEU kWh	TEI kg
Primary energy source		5,5	0,31
Fossil energy production	0,9	5	
Diesel Car	0,2	1	
Total	0,18	5,5	1,72

Example 7 shows a Diesel car with 1 kWh coming out of the wheel. 5,5 kWh on PEU is necessary. The environmental impact is 1,72 kg CO_2 per kWh

D. *Result of the Energy Traffic Sector Analysis*

Table XIII and XIV show the result of the analysis.

TABLE XIII: Environmental Analysis Result

Example	PEU	Fuel type	CO_2cf	TEI kg
1 grid	8.8	Electricity	0,565	4.8
2 CH_4	3,4	CH_4	0,25	0,85
3 PV	15,4	Electricity	0,02	0,3
4 Wind	6,8	Electricity	0,02	0,13
5 batt. (PV)	6,6	Electricity	0,02	0,13
6 batt. (foss.)	4,11	Electricity	0,565	2,32
7 Reference	5,5	Diesel	0.31	1,72

In the energy traffic analysis, the CO_2 emissions could be reduced over 90% in compare to the today´s reference car, if H_2 is produced out of renewable energy sources like Wind or PV. The PEU shows impressively how much extra energy is needed for one PEU for the application. If H_2 is produced out of fossil electricity source (Grid) the impact would be <u>*3 times*</u> higher. In example 6 a battery-powered car charged with electricity from the grid shows now environmental advantage in compare to a Diesel car.

TABLE XIV: Economic Analysis Result

Example	PEU	Fuel type	Price € kWh	Price cent per PEU
1 grid	3,1	Electricity	0,26	80
2 CH_4	3,1	CH_4	0,06	19
3 PV	3,1	Electricity	0,12	37
4 Wind	3,1	Electricity	0,08	25
5 batt. PV	1,3	Electricity	0,12	16
6 batt. grid	1,3	Electricity	0,26	34
7 Reference	5	Diesel	0,12	60

The economic calculation is dependent from the PEU. The blue columns show the energy units which must be paid for.

The analysis takes todays energy cost for PV and Wind generators (levelized cost of energy LCOE). That is depending of future innovations for standalone systems or possible decentralized filling station. The analysis will give a good view of the efficiency chain and the energy unit which must be produced and paid for.

The best price energy ratio has a reforming process out of a fossil gas CH_4. The worst price/energy ration has H_2 production out of electricity from the grid. RES Wind and Hydro would be nearly competitive to today's fossil energy price for the reference car.

E. *Household (Heating) Sector*

In the Household Sector over 80% of the energy is for thermal energy mostly driven with a fossil fuel (Gas/Oil). This example shows the use of H_2 in a Micro CHP System with the efficiency chain well to wheel (room) with different energy sources. In the calculation one unit PEU is the base to compare. For each energy unit a special amount of CO_2 emissions are polluted. The efficiency chain goes from the primary energy source back to all efficiency conversion process up to the application self. FC Heating Systems are producing 55% electricity and 45% thermal energy. For this reason there is a positive contribution if the electricity is feed in or direct used in the household.

Example 1: H_2 produced out of a fossil energy source (CH_4)

TABLE XV: Well To Room Analysis Micro Fuel Cell CHP

Process	η	PEU kWh	TEI kg
Primary energy source		1,54	0,238
Fossil energy production	0,9	1,38	
Reformer	0,8	1,1	
Fuel Cell System	0,9	**0,55** **0,45**	
Total	0,65	1,54	0,37
Electrical production grid		0,55	0,565
Negative impact			-0,31
Total environmental impact			0,06

Example 1 shows one PEU from a fossil gas in the house need 1,54 PEU kWh. The total environmental impact is 0,37 kg CO2. An additional 0.55 kWh of electricity was generated in the building. This share of electricity in a standard electricity grid would emit 0,31 kg of CO_2. Thise impact has a negagtiv effect.

Example 2: H_2 produced out of electricity from the grid

TABLE XVI: Well To Room Analysis Micro Fuel Cell CHP

Process	η	PEU kWh	TEI kg
Primary energy source		3,4	0,576
Energy conversion	0,45	1,5	
Electrolysis	0,8	1,2	
Pressureraised H_2	0,9	1,1	
Fuel Cell System	0,9	0,55 0,45	
Total	0,3	3,4	2
Electrical production grid		0,55	0,565
Negative impact			-0,31
Total environmental impact negative			1,7

Example 2 H_2 is produced out of electricty from the grid. The total environmental impact is 2 kg CO2 less 0,31 kg of CO_2 generated electricity in the building.

Example 3: H_2 produced out of Wind Energy

TABLE XVII: Well to Room Analysis Micro Fuel Cell CHP

Process	η	PEU kWh	TEI kg
Primary energy source		3,4	0,02
Wind generator	0,45	1,5	
Electrolysis	0,8	1,2	
Pressureraised H_2	0,9	1,1	
Fuel Cell System	0,9	0,55 0,45	
Total	0,3	3,4	0,07
Electrical production grid		0,55	0,576
Negative impact			-0,31
Total environmental impact negative			-0,24

Example 3 shows H_2 is produced out of a wind generator. The total environmental impact is 0,07 kg CO_2 less 0,31 kg of CO_2 generated electricity in the building.

Example 4: H_2 produced out of PV

TABLE XVIII: Well to Room Analysis Micro Fuel Cell CHP

Process	η	PEU kWh	TEI kg
Primary energy source		7	0,02
PV Generator	0,20	1,7	
Electrolysis	0,8	1,4	
Pressureraised H_2	0,9	1,1	
Fuel Cell System	0,9	0,55 0,45	
Total	0,13	7	0,14
Electrical production grid		0,55	0,576
Negative impact			-0,31
Total environmental impact negative			-0,17

See example 3

Example 5: Micro CHP with CH_4

TABLE XIX: Well to Room Analysis Micro CHP fossil

Process	η	PEU kWh	TEI kg
Primary energy source		1,4	0,24
Fossil energy production	0,9	1,25	
CHP	0,8	**0,5** **0,5**	
Total	0,72	1,4	0,34
Electrical production grid		0,50	0,576
Negative impact			-0,28
Total environmental impact			0,06

Example 5 shows a convetional CHP driven with fossile gas. The total environmental impact is 0,34 kg CO_2 less 0,31 kg of CO_2 generated electricity in the building.

Example 6: Gas Boiler with electricity from the grid

TABLE XX: Well to Room Analysis Micro CHP fossil

Process	η	PEU kWh	TEI kg
Primary energy source		0,7	0,24
Fossil energy production	0,9	0,63	
Gas boiler	0,8	0,5	
Total	0,72	1,4	0,168
Electrical production from grid		0,50	0,576
Total environmental impact			0,74

F. Result of the Household Analysis

Table XIX and XX show the Result of the Analysis.

TABLE XXI: Environmental Analysis Result

Example	PEU	Fuel type	CO_2cf	TEI kg
1 CH_4	1,54	CH_4	0,24	0,06
2 grid	3,4	Electricity	0,576	1,7
2 Wind	3,4	Electricity	0,02	-0,24
3 PV	11,6	Electricity	0,02	-0,08
4 conv.	1,4	CH_4	0,24	0,06
5 gas boiler + grid	0,7 0,5	CH_4 grid	0,24 0,565	0,74

In the household analysis the CO_2 emissions could be reduced over 10 times lower and negative impact in compare to today´s heating systems, if H_2 is produced out of RES sources like Wind or PV. The negative impact is the result of electricity usage, either direct in the building or tariff feed in. CO_2 emissions could be nearly reduced to zero.

The PEU shows how much extra energy is needed for one PEU for the application. If H_2 is produced out of fossil electricity source (Grid) the impact would be 2 times higher.

TABLE XXII: Economic Analysis Result

Example	PEU	Fuel type	Price € kWh	Price cent/PEU
1 CH_4	1,38	CH_4	0,06	8,3
2 grid	1,5	Electricity	0,20	30
3 Wind	1,5	Wind	0,08	12
4 PV	1,7	PV	0,12	21
5 conv.	1,25	CH_4	0,06	7,5
6 gas+grid	0,63 0,5	CH_4 Electricity	0,06 0,26	17

The economic calculation is dependent from the PEU. The blue columns show the energy units which must be paid for.

The analysis takes todays energy cost for PV and Wind generators. In today´s Micro CHP systems with fuel cells a reformer is integrated. The cost (depreciation cost) for the electrolysis and pressure riser unit is not included. That is depending of future innovations for standalone systems or possible decentralized systems.

The best price energy ratio has FC Micro CHP with a reforming process out of a fossil gas CH_4 and a standard CHP system. CHP´s are more complex to calculate. Depending of the tariff feed system; running time and energy demand in the building this system today can save energy and money (38,39, 44). The worst price/energy ration has H_2 production out of electricity from the grid.

V. Conclusion

A sustainable energy transition will only work, if the physical aspect clearly identified, assessed and converted into a clear political long-term strategy with clear objectives. H_2 as an energy carrier can be used in this energy transition process as one of several RES for the chancing process. Using H_2 technology applications for the transition process, efficiency increasing of > 40 % and less environmental impact < 90 % in compare to fossil fuel sources are in present possible.

H_2 will only work in an Energy transition process with other complementary RES. This combination can make H_2 as a secondary energy carrier so interested. Economically H_2 is in compare to fossil fuel sources still more expensive. This difference will change constantly with new renewable energy technologies, learning curves and higher quantities. In present H_2 produced out of wind (and hydro) Energy is nearly competitive with today's fossil driven energy conversion systems. A clear view must be placed on today's old energy transformation processes. Efficiency potential of over 40% must be addressed and implemented. From today's perspective H_2 which is produced out of different renewable energy sources can reduce the dependencies on fossil fuels, saving CO_2 emissions and minimization the climate change in the future.

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