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Hydrogen Workshop

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How to ensure H_2 quality without increasing H_2 analysis cost?

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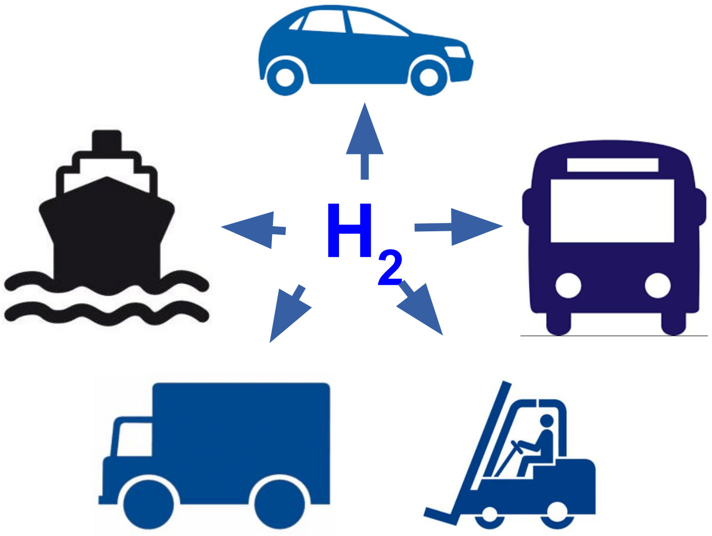
Outline

1. Regulation
2. Cost of H_2 analysis
3. Quality assurance
4. Ex: SMR supply chain
5. Conclusion

1- Regulation

- Alternative Fuel Infrastructure European Directive (AFI) is applicable since January 2018
- Each European country has to translate this directive in national regulation

- Impurities in H_2 for fuel cell vehicles shall be in agreement with EN 17124 and ISO 14687
- **EN 17124: Hydrogen fuel — Product specification and quality assurance — Proton exchange membrane (PEM) fuel cell applications for road vehicles will be published in November 2018**



1- Regulation

Component	ISO 14687 -2 µmol/mol	ISO 14687 (new) EN 17124 µmol/mol
Helium	300	300
Nitrogen	100	300
Argon	100	300
Methane	/	100
Oxygen	5	5
Carbon dioxide	2	2
Carbon monoxide	0.2	0.2
Water	5	5
Total Hydrocarbons (non methane)	2	2
Total Sulfured compounds	0.004	0.004
Ammonia	0.1	0.1
Formaldehyde	0.01	0.2
Formic acid	0.2	0.2
halogenated compounds	0.05	0.05

2 – Cost of analysis

- Between 6000 € and 11 000 € for one sample (depending of the number of samples analysed at the same time)

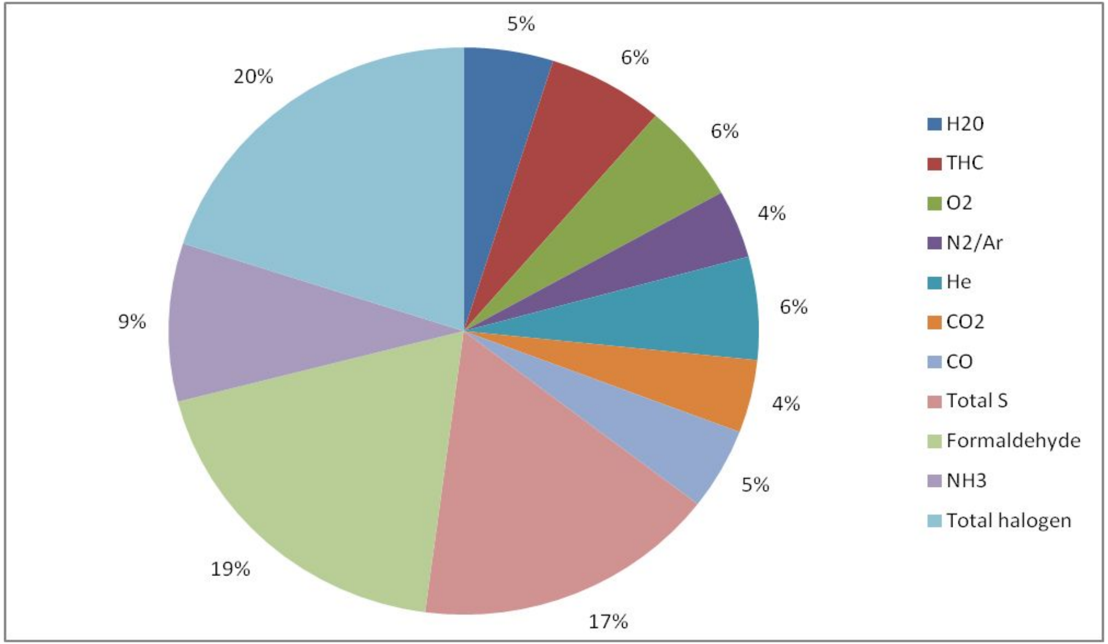
Cost for sampling could be added also (around 4000 €):

- Man power
- Sampling device cost
- Transport from HRS to laboratory

- few analytical service labs are available in Europe

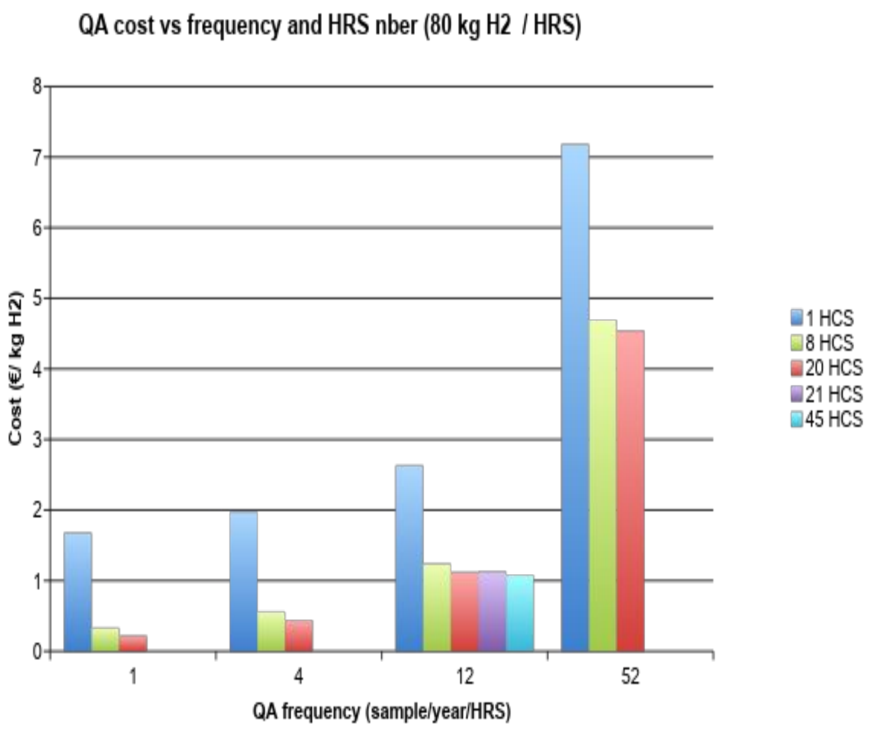
2 – Cost of analysis

Repartition per impurities (ISO 14687-2)



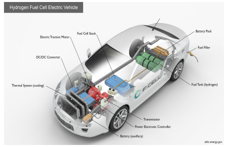
Total S + Formaldehyde + Total halogen = 50 % of the cost

2 – Cost of analysis



- QA cost is impacted by
  - Number of HRS and volume of H2 per HRS
  - Number of analysis per year and per HRS (QA frequency)
  - The number and type of elements to analyse
- Maintenance cost & CAPEX lower with high number of HCS and independent of the QA frequency
- **Labour and other running costs for sampling and analysis is the most contributing part** of the total QA cost (above 8 HRS)

3 – Quality Assurance



FCEVs:

- Make sure the H2 supplied will not damage the vehicle or affect its performance

H2 providers:

- Make sure the required specifications can be guaranteed, at an acceptable cost.

Define a QA scheme acceptable by all parties:

- Use the risk assessment for quality assurance of H2
- According to ISO:IEC Guide 73: definition of risk assessment is Combination of the probability of an event and its consequences

3 – Quality Risk Assessment

- **Objective:**
  - For each H_2 source : Evaluation of the risk if there are impurities above their threshold value
  - Evaluation of measurement to implement quality assurance of HRS
- **Risk assessment methodology according to ISO:IEC Guide 73**
- **3 fundamental questions:**
  - What might go wrong: which event can cause the impurities to be above the threshold value?
  - What is the likelihood (probability of occurrence) that impurities can be above the threshold value?
  - What are the consequences (severity) for the fuel cell car?

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3 – Quality Risk Assessment

- Event : Be above the threshold value defined by ISO 14687-2 (for each impurity)
- probability of occurrence of this event for a given supply chain (production mode+ deli

Occurrence class	Class name	Occurrence or frequency	Occurrence or frequency
0	Very unlikely (Practically impossible)	Contaminant above threshold never been observed for this type of source in the industry	Never
1	Very rare	Known to occur in the Industry for the type of source/ Supply chain considered	1 per 1 000 000 refueling
2	Rare	Has happened more than once/year in the Industry	1 per 100 000 refueling
3	Possible	Has happened repeatedly for this type of source at a specific location	1 out of 10 000 refueling
4	Frequent	Happens on a regular basis	Often

Table 2 — Occurrence classes for an impurity (EN 17124)

3 – Quality Risk Assessment

- Evaluation of severity (risk) : level of damage for the vehicle (table 3 EN 17124)

Severity class	FCEV Performance impact or damage	Impact categories		
		Performance impact	Hardware impact temporary	Hardware impact permanent
0	— No impact	No	No	No
1	— Minor impact — Temporary loss of power — No impact on hardware — Car still operates	Yes	No	No
2	— Reversible damage — Requires specific light maintenance procedure ,— Car still operates	Yes or No	Yes	No
3	— Reversible damage — Requires specific immediate maintenance procedure . Gradual power loss that does not compromise safety	Yes	Yes	No
4a	— Irreversible damage — Requires major repair (e.g. stack change) — Power loss or Car Stop that compromises safety	Yes	Yes	Yes or No

a Any damage, whether permanent or non-permanent, which compromises safety will be categorized as 4, otherwise non-permanent damage will be categorized as 1, 2 or 3.

3 – Quality Risk Assessment

→ Acceptability table (table 5 of EN 17124)

		Severity				
		0	1	2	3	4
Occurrence as the combined probabilities of occurrence along the whole supply chain	4					
	3					
	2					
	1					
	0					
	Unacceptable risk ; additional control or barriers are required		Further investigations are needed: existing barriers or control may not be enough		Acceptable risk area Existing controls acceptable	

3– Quality Risk Assessment

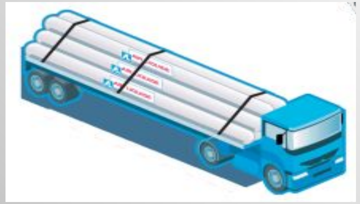
- **Step 1 : evaluation of probability of occurrence**

Must be done for each facility by a team of experts or people having the knowledge of each part of the supply chain

- **Step 2: Combined with defined severity impact on vehicle :**
- **Step 3: Establish the acceptability level for this specific case**
- **Step 4 : Define the actions to reduce the risk**
  - **Step 4.1: define the barrier to reduce the risk level to acceptable level**
  - **Step 4.2: define the critical impurities to follow according to the results of the risk assessment**

4 – example: one HRS supplied by SMR

- **Production site**
  - **SMR**



- **Transport**
  - **Tub-Trailer**

- **Point of use**
  - **HRS**

Purity analysis

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4 – example: one HRS supplied by SMR

ISO spec 14687 (new)		Supply Chain					
Contaminant	**Threshold**	**Production SMR**	**Filling center and TT transport**	**HRS**	**Compounded probability**	**Severity**	**Criticality**
Inert gases : N2	**300**	1	2	3	**3**	**1**	
Inert Gas Ar		0	0	0	**0**	**1**	
Oxygen	**5**	0	0	1	**1**	**0**	
Carbon dioxide	**2**	0	0	0	**0**	**1**	
Carbon monoxide	**0,2**	2	3	0	**3**	**2**	
Methane (CH4)	**100**	0	0	0	**0**	**1**	
Water	**5**	0	3	0	**3**	**4**	
Total sulphured components	**0,004**	0	0	0	**0**	**4**	
Ammonia	**0,1**	0	0	0	**0**	**4**	
Total hydrocarbons	**2**	0	1	0	**1**	**4**	
Formaldehyde	**0,2**	0	0	0	**0**	**2**	
Formic acid	**0,2**	0	0	0	**0**	**2**	
Halogenated compounds	**0,05**	0	1	0	**1**	**4**	
Helium	**300**	0	0	0	**0**	**1**	

Critical impurities:

N2, CO, H2O,
Total Hydrocarbons,
Halogenated compounds

To reduce the risk additionnal barriers are necessary

Quality Risk assessment is necessary to:

- ❑ Reduce the cost of analytical control of Hydrogen quality
- ❑ Maintain a high level of guarantee for Hydrogen car manufacturers and users.
- ❑ Improve the supply chain by addition of barriers to avoid introduction of impurities.

Thank you for your attention