International Conference on Green Hydrogen 2023

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LEO-Blend

One Step towards Hydrogen Distribution in CNG Pipelines

Contact: **Dr. Hubert Mäncher**
MAGNUM LEO-Pipe GmbH
Schwanheimer Str. 151
64625 Bensheim
Germany

e-mail: Hubert.Maencher@magnum.de
Phone: +49 173 690 6037
www.magnum.de

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Company Introduction – Fields of Technology

- MAGNUM was founded in 1987 as an engineering service provider.
- Based on many years of experience several emerging products and solutions were developed.

Fuel Cell Technology

Test Systems **Milan FC Midi / FC Maxi**

for fuel cells PEM, HT-PEM, DMFC, SOFC, Electrolyzers, batteries etc.

Milan test systems are 2023 transferred to **iASYS Technology Solutions Pvt. Ltd.**, Pune, India

Pipeline Monitoring

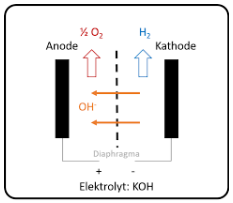
Computational pipeline monitoring system **LEO-Pipe®**

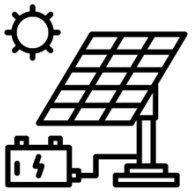
Leak detection and localization systems for pipelines according to TRFL and API standards

The Company **MAGNUM LEO-Pipe GmbH** continues the well established product line **LEO-Pipe®** of pipeline monitoring systems.

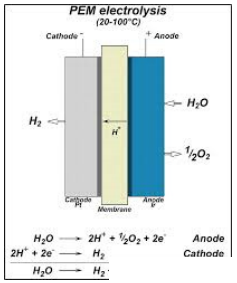
Green Hydrogen Sources and Sinks

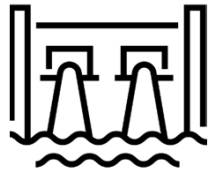
Wind power



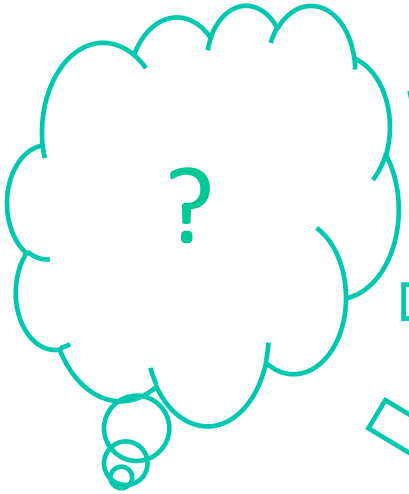


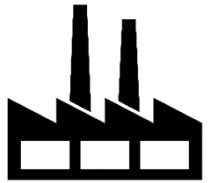
Solar power





Hydro power





Industry

Buildings

Transportation

Special Hydrogen Distribution Pipelines

Special Hydrogen distribution pipelines

Well established distribution of Hydrogen among the industry in Nord-Rhein-Westfalen, Germany

- Hydrogen supplier and owner of the grid: Air Liquid
- Customers:
  - Steel processing
  - Chemical industry
  - Pharmacy
  - etc.

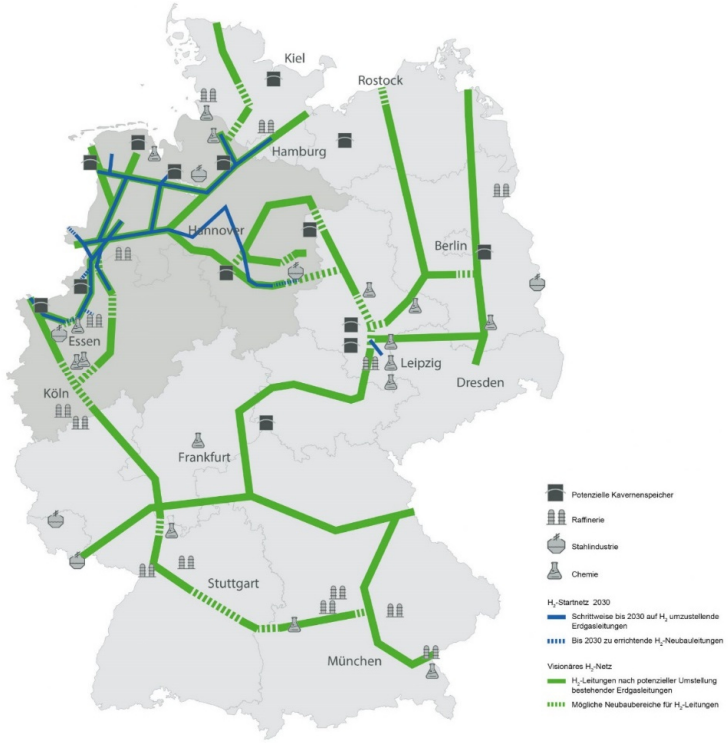
100% Compatibility with Hydrogen

- Suitable steel
- Selected equipment

Migration of CNG- to H2-ready Grid

Special Hydrogen distribution pipelines

H_2-Startnetz 2030



Disclaimer: Bei der Karte handelt es sich um eine schematische Darstellung, die hinsichtlich der eingezeichneten Speicher und Abnehmer keinen Anspruch auf Vollständigkeit erhebt.

Condition:

- Compatible pipeline material
- Compatible equipment
- Organic growing grid

Time Horizon:

- Plan shows „Start grid“ until 2030
- Finalization in decades

What about using existing CNG-pipelines

Long distance network in Germany

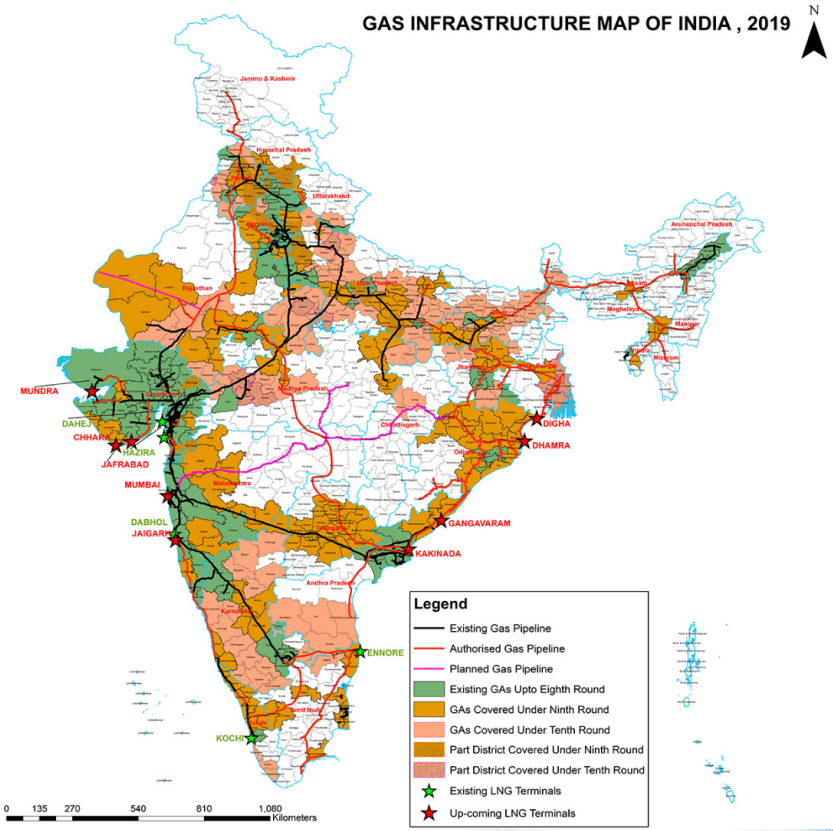
Source: FNBGas. Link: Fernleitungsnetz - FNB GAS (fnb-gas.de)

Chances:

- Quick approach saving prescious time
- Saving cost of construction
- Saving value of existing infrastructure

Odds:

- Blended instead of pure gas
- Risk of incompatibility



Source: Government of India, Link: Natural gas Pipelines - Ministry of Petroleum And Natural Gas (mopng.gov.in)

Challenges of Hydrogen in Pipelines

Special Hydrogen distribution pipelines

If we choose …

… the right material (steel no. xyz)

… the right equipment (compressors, valves etc.)

… the right operation, monitoring, safety means

→ there is no (additional) challenge

Reference: special networks of Air Liquide is operated since decades

Reference : MAGNUM has allready applications of LEO-Pipe at Hydrogen pipelines

What about „ifs“ and „buts“ if we mix Hydrogen into existing CNG pipelines?

- Right material – compatibility is currently widely unknown
  - Incompatibility may harm the material of underground pipelines
  - and thus destroy an existing infrastructure
  - Demage could be huge and disastrous
- Right equipment – may be replaced for big money
- Right operation – can be trained
- Monitoring – subject of this presentation
- Safety means – some work todo, e.g. the monitoring

Estimations of the compatibility **vary from 0% to 100% (Hydrogen in CNG)**
Expert talk about **15% to 25%** as a viable risk and reasonable for a start

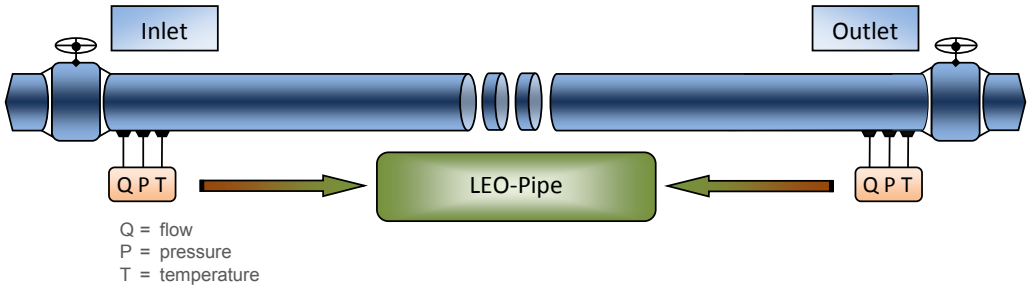
Question:

Who knows the actual distribution and concentration in complex grids with

- Several suppliers at different places
- Some extraction points where Hydrogen is regained out of the blend

Solving the issue by Computational Pipeline Monitoring

Principle arrangement of **C**omputational **P**ipeline **M**onitoring (CMP)

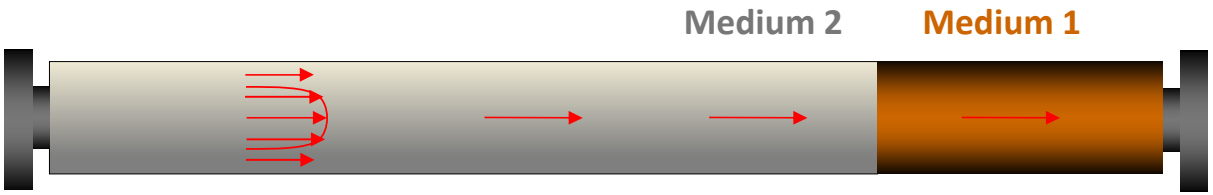


"Computational Pipeline Monitoring (CPM) means a software-based monitoring tool that allows the pipeline dispatcher to respond to a pipeline operating anomaly that may be indicative of a commodity release" (API 1130)

- Conventional measuring devices (P, Q, T)
- Algorithmic approach

Solving the issue by Computational Pipeline Monitoring

Pipeline Monitoring by RTTM Method – Theory



Data: Density, viscosity, compressibility, etc. as f (p,T)

Mass balance: $$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho u) = 0$$

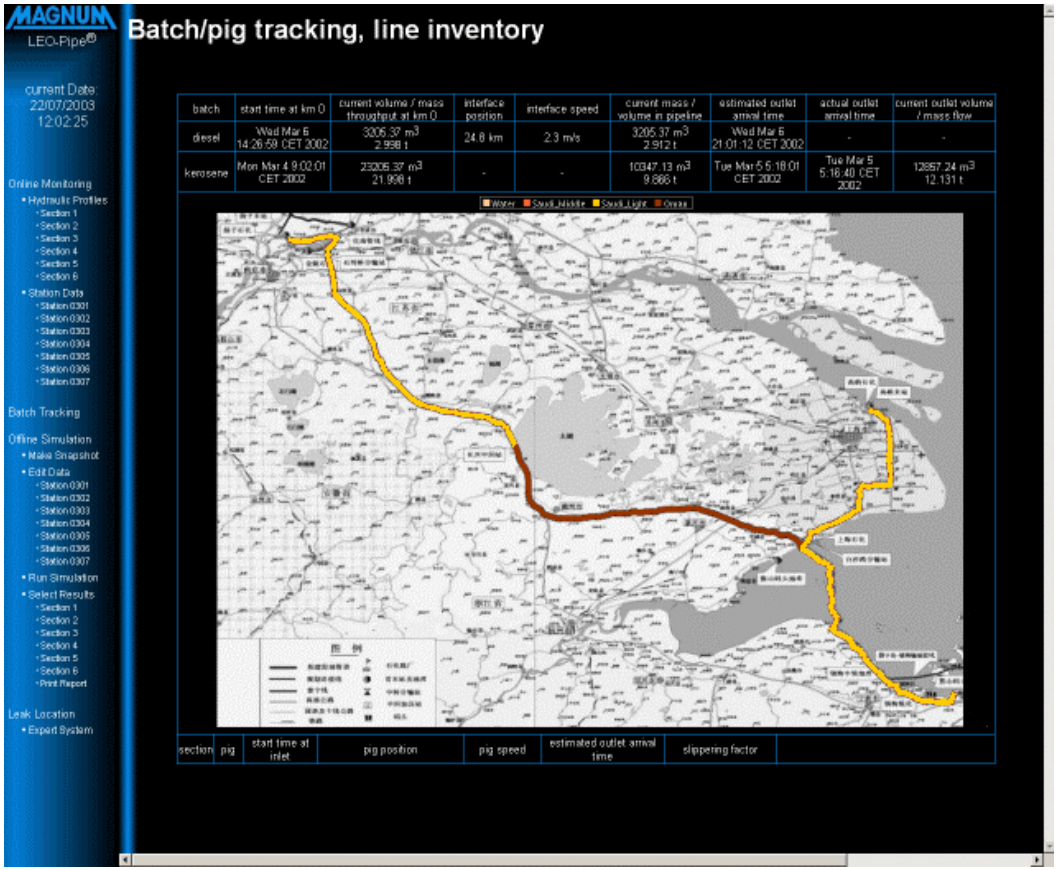
Momentum balance: $$\frac{\partial}{\partial t}(\rho u) + \frac{\partial}{\partial x}\left(p + \rho u |u|\right) + \frac{\lambda \rho}{2D}|u|u + \rho g \frac{\partial z}{\partial x} = 0$$

Energy balance: $$\frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} + \frac{\Phi_{FR}}{\partial x} - \frac{\Phi_{CV}}{\partial x} - \frac{\Phi_{HC}}{\partial x} = 0$$

Based on pressure, temperature and medium properties the system simulates the flow profile.

Solving the issue by Computational Pipeline Monitoring

Liquids in pipelines allow batch tracking



Batch tracking means for example:

Yellow Batch A
(one ship from middle east)

Red Batch
(crude oil from Russia)

Yellow Batch B
(one ship from Northern Sea)

Behavior of Blended Gases

Of course two or more gases will NOT stay seperate

- Gas is highly compressible – Pipelines function also like a storage
- Even if inserted in batches gases will mix
- Hydrogen will creep and distribute in CNG

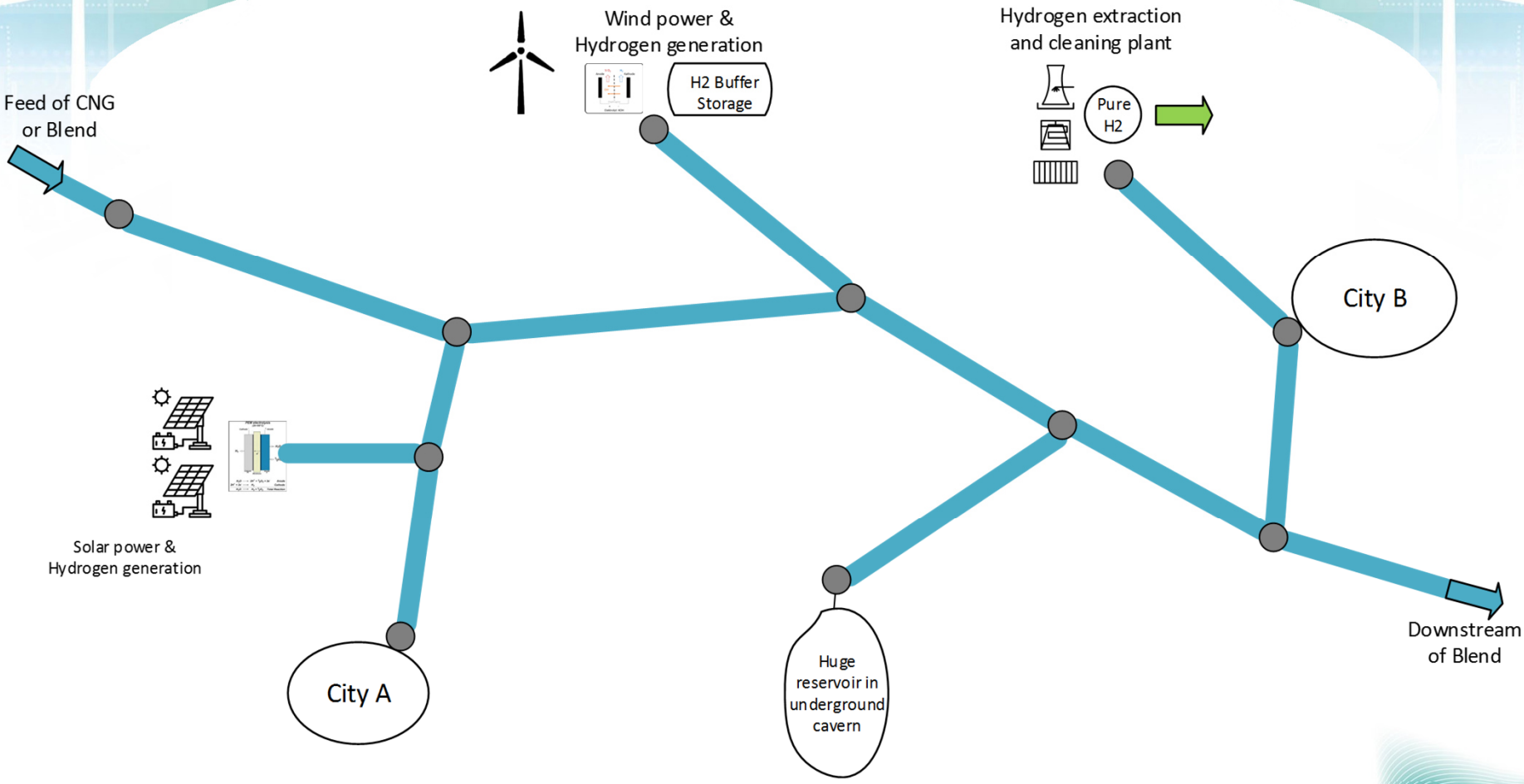
In intended applications

- Production of Hydrogen will be varying over the day and depending on weather conditions
- Hydrogen will be inserted in flowing CNG at injection points
- Hydrogen may be extracted by seperation plants (e.g. for filling stations)

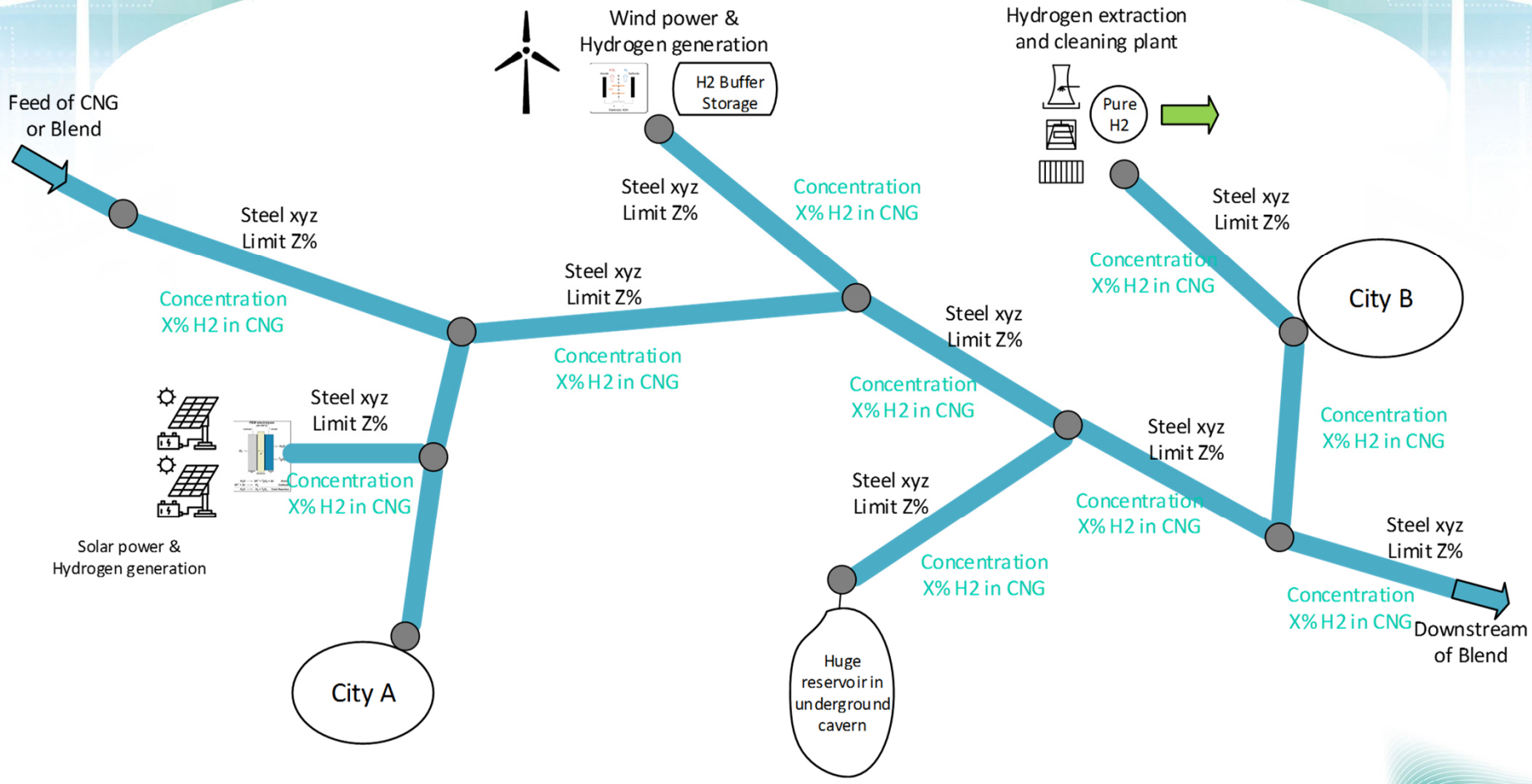
It allways ends-up with a blend of Hydrogen in CNG

- That is different at every point of the grid
- Changing depending on input and extraction

Grid transporting Hydrogen blended in CNG



Concentration and distribution of Hydrogen in CNG grid



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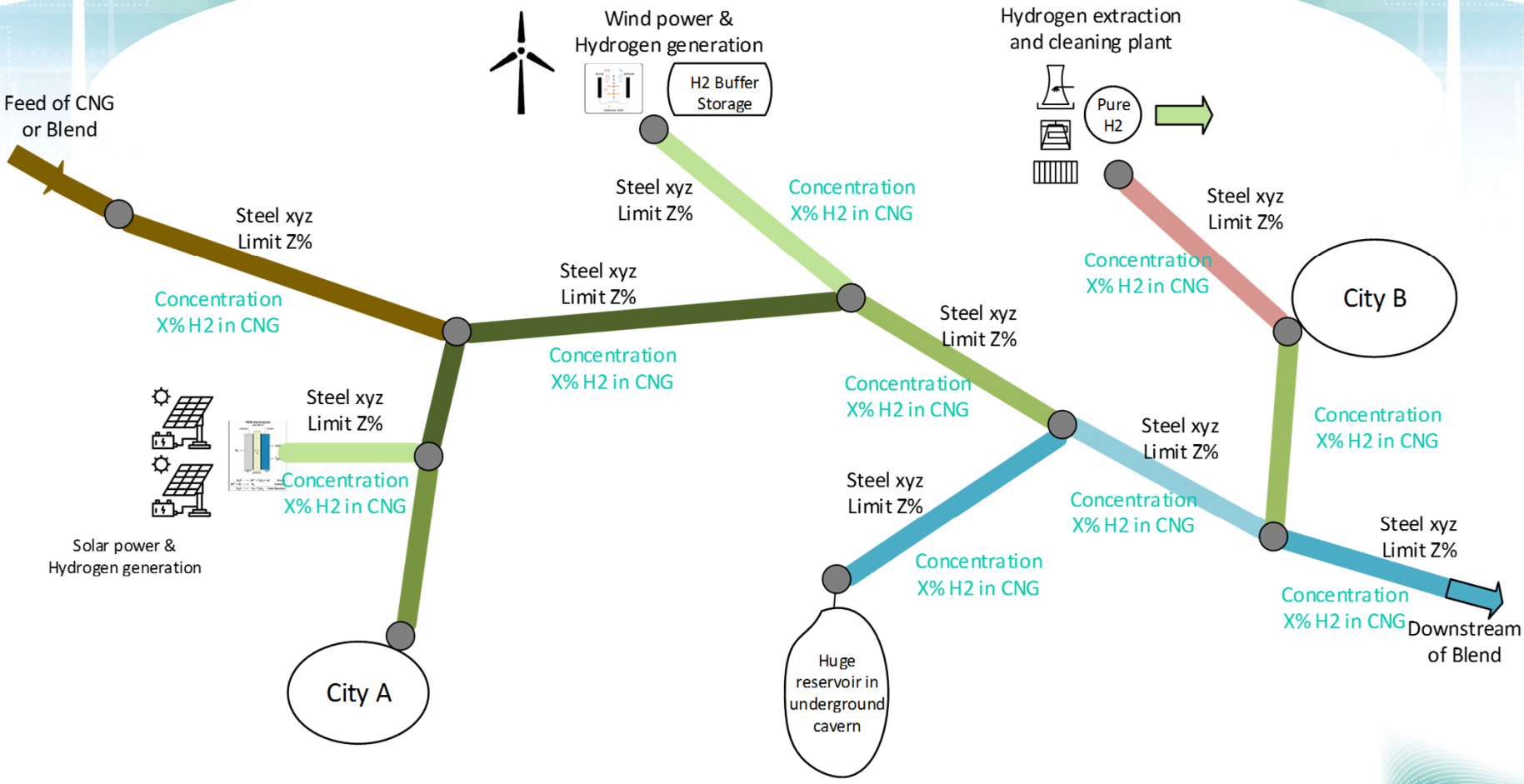

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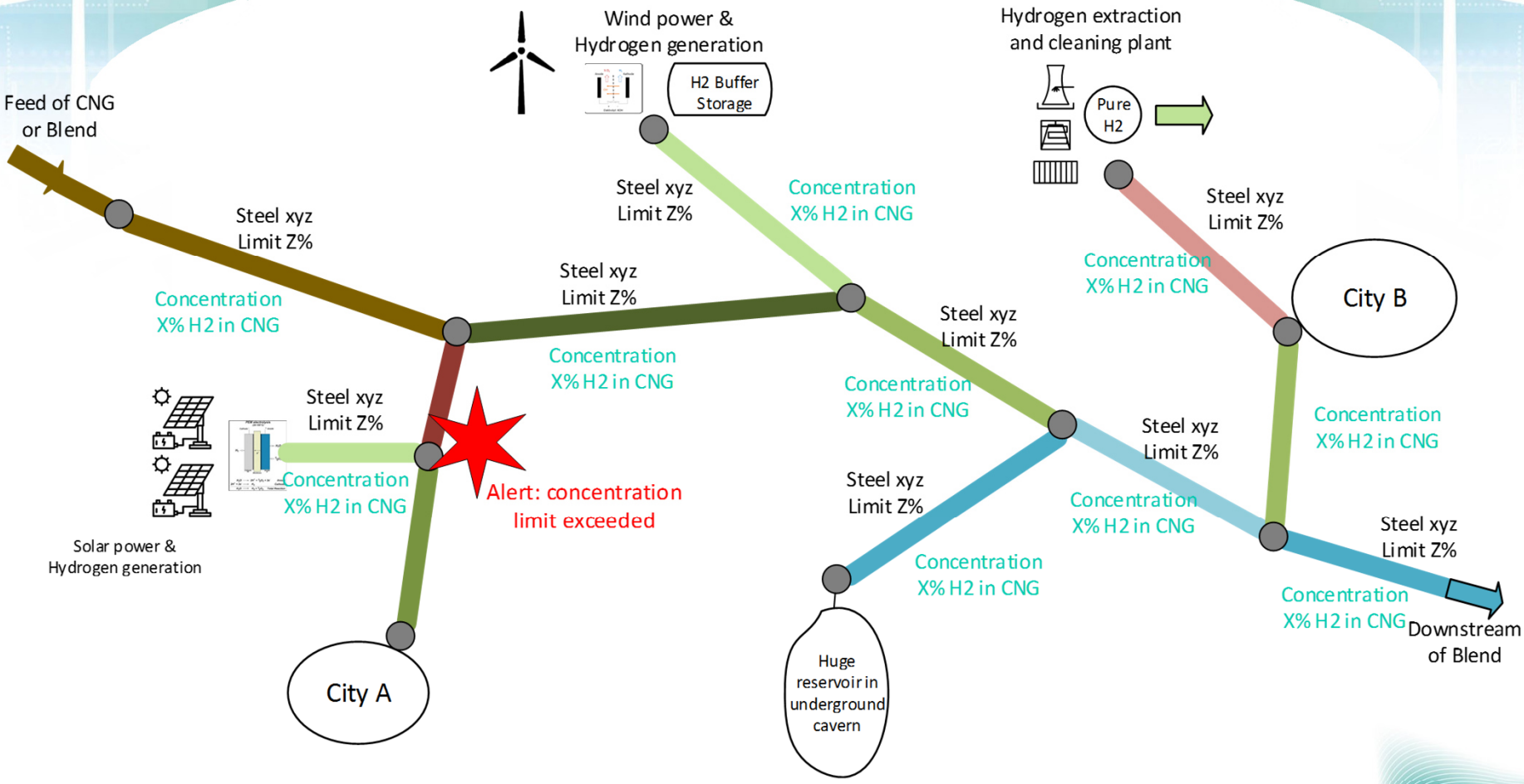

Main Features of LEO-Blend

LEO-Blend

Brings all neccessary features to monitor pipelines transporting **Blended** G**ases**

It provides observed measurements or estimates at every point of the network:

- Pressure
- Flows of
  - CNG
  - Hydrogen
- Concentration of Hydrogen in CNG
- Stored Mass of CNG and Hydrogen
- Alerts in case of
  - Leaks or pressure drops, showing time, amount, location
  - Violations showing concentration, time and duration

It furthermore provides tools for the operator:

- Support for operation and and optimization
- Statistics
- Forecasts

Established cooperation of MAGNUM in India

Fuel Cell Test Systems Milan

- Test Systems **Milan FC Midi / FC Maxi** for fuel cells PEM, HT-PEM, DMFC, SOFC, electrolyzers, batteries etc.
- 2023 transferred to and produced by **iASYS Technology Solutions Pvt. Ltd.**, Pune, India

Fuel Cell Technology

- Start-up company established in Hyderabad **Virayaa Green Energy Systems**
- Target: **Indian-made Fuel Cell Stack**
- Vehicle integration in light-weight trucks

Pipeline Monitoring

- Project preparation in India to expand **LEO-Pipe® for Hydrogen and Blend Gases**
- Leakage detection and localization
- Monitoring and balancing of Hydrogen
- Monitoring of Hydrogen concentration in CNG pipelines

Thank you for your attention.

Vamsi Krishna M.
Sree Harshi Infoway Pvt. Ltd.
#1-9-292/7, Ramalayam Street
Vidyanagar
Hyderabad-500044
India

E-Mail: vamsi@sreeharshi.com
Phone: +91 (94909) 63366

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