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Energy analysis of hydrogen refueling stations

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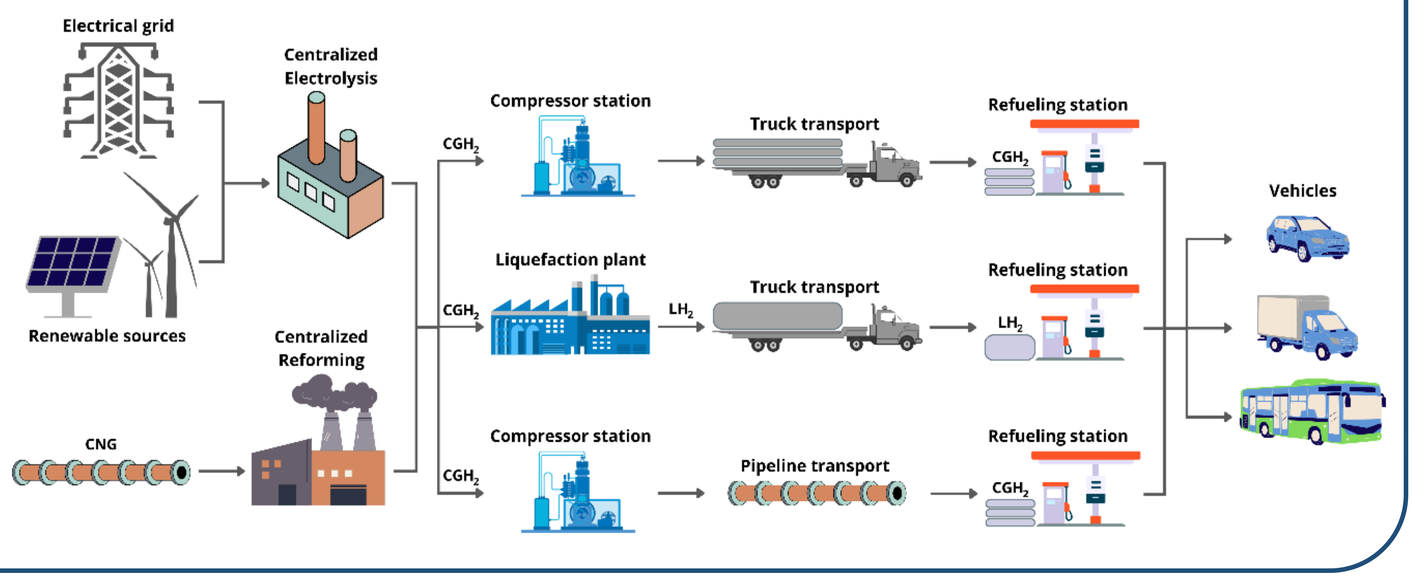
Introducction

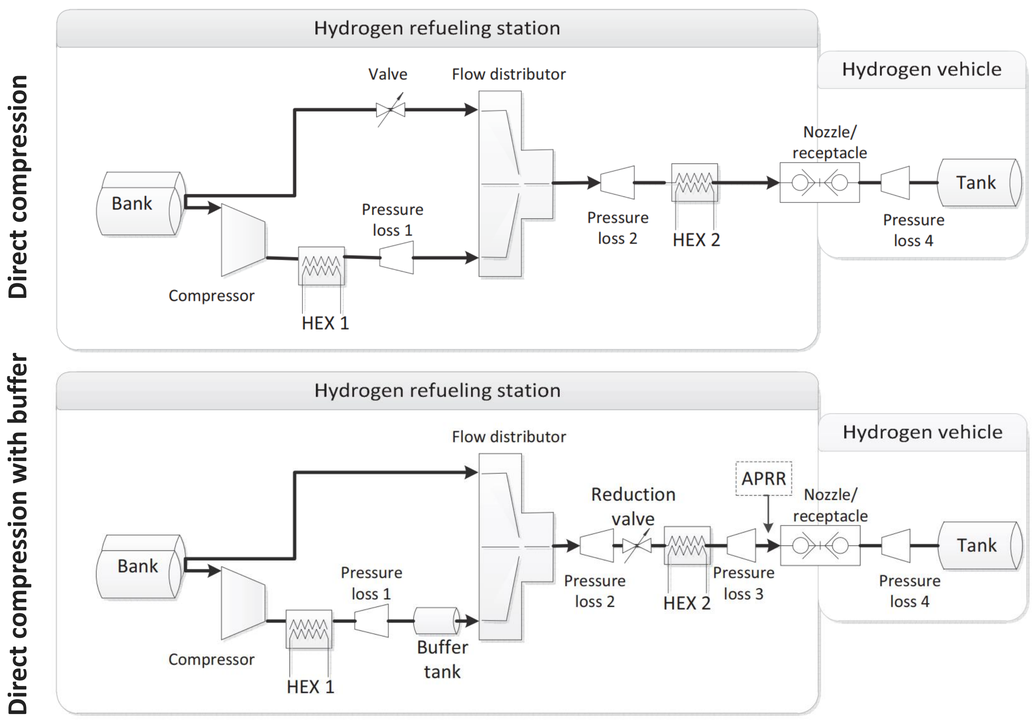
The main objective of this study is to analyze the energy consumption of the refueling process of a vehicle tank at a hydrogen refueling station. For this purpose, the operation of the different current hydrogen refueling station (HRS) designs (direct compression, compression with buffer and cascade compression) has been analyzed, distinguishing according to the type of supply (pipelines, compressed hydrogen or cryogenic hydrogen) and the dispensing pressure (350 or 700 bar).

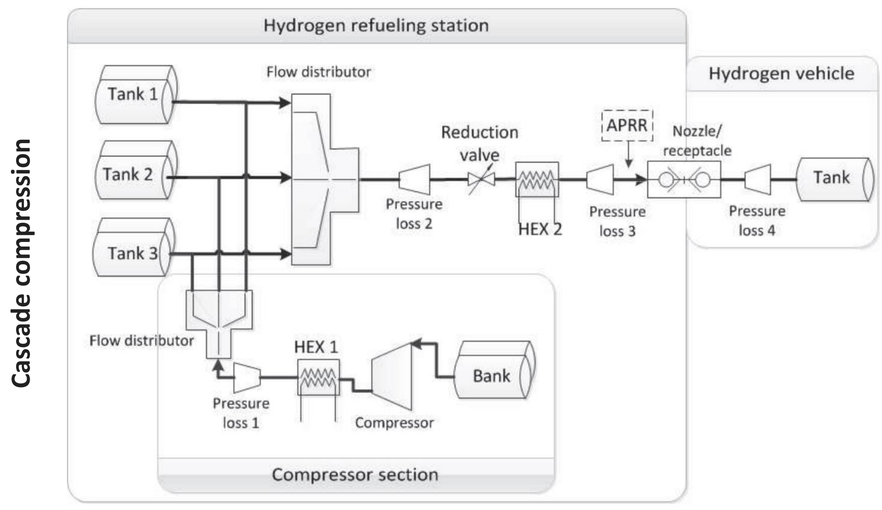
Subsequently, a thermodynamic model was developed in EES and Simscape to obtain the energy consumption of a hydrogen refueling station based on the Heavy-Duty Refueling Station Analysis Model (HDRSAM) and the Hydrogen Refueling Station Analysis Model (HRSAM) developed by Argonne National Laboratory (ANL). Then, the most common HRS scenarios with given starting conditions are presented. Finally, the results obtained by the proposed model and the HDRSAM are evaluated and compared.



Objectives Materials and Methods

The main objective is the calculation of the energy demand of hydrogen compression, in different scenarios. The thermodynamic properties of hydrogen have been analyzed and compared with different models. A detailed analysis of the changes in temperature pressure and hydrogen flow rate of hydrogen during refueling both in the vehicle tank and in storage at the RHS has been done.



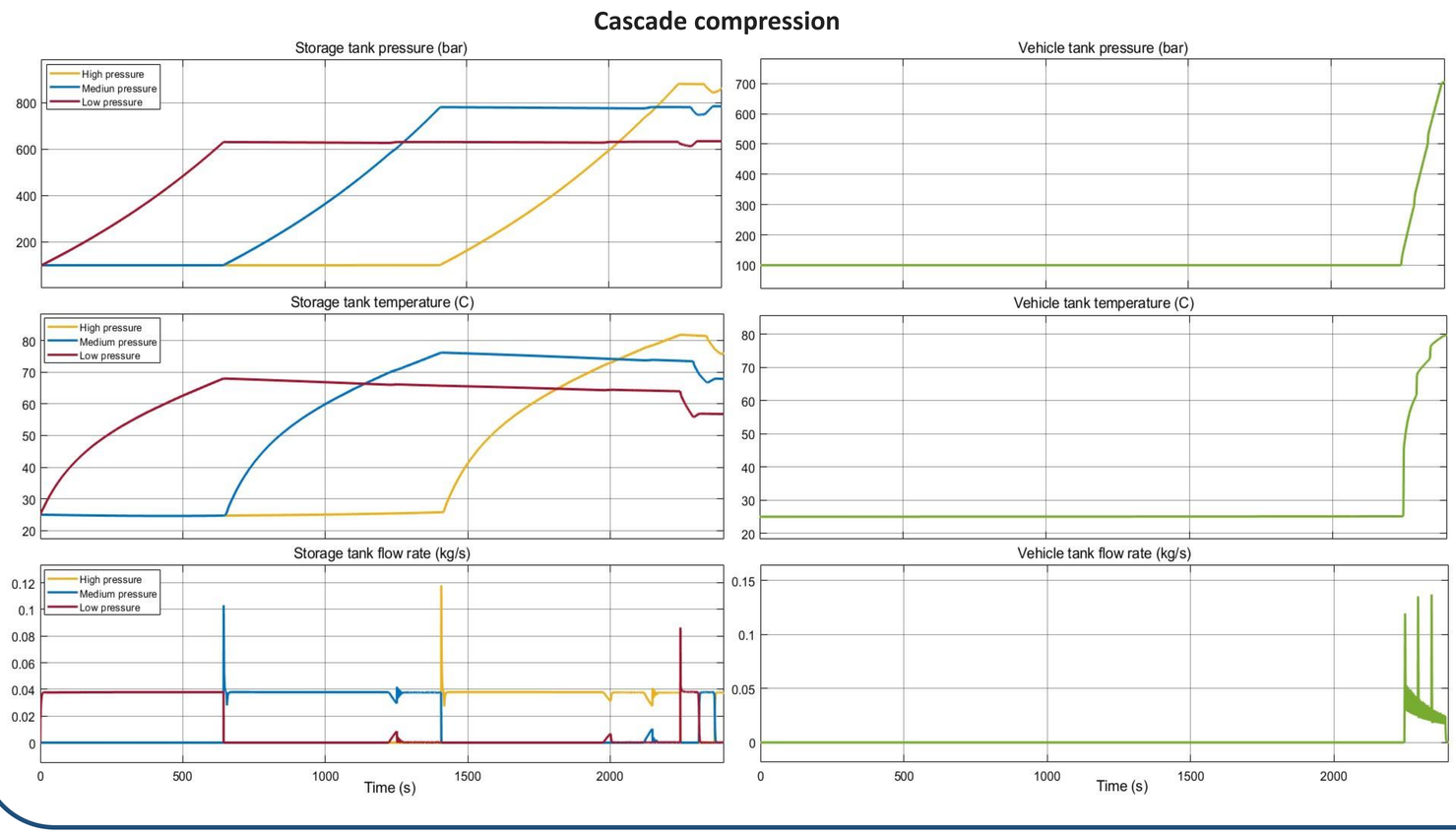


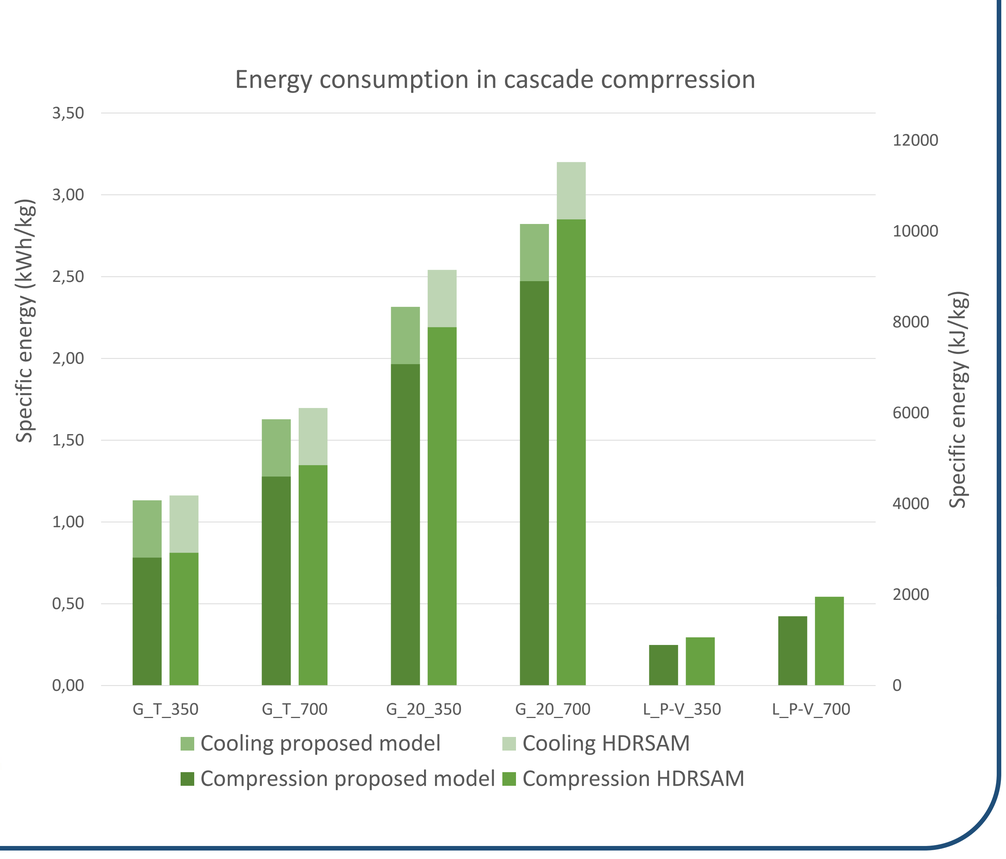
	Direct compression	Direct compression with buffer	Cascade compression
Recovery time between fuelings	Not required	Not required	Required
Storage pressure	Low	High	High
Compression pressure	Needed	Needed	Higher than needed
System complexity	Low	Low	High
Compressor control complexity	High	High	Low
Compressor size	Large	Large	Small
Refueling of vehicles with power failure	Not possible	Not possible	Possible
Follow the APRR	No	Yes	Yes
High pressure tank	Not required	One required	Various required
HRS cost and capacity	Low	Moderate	High

Results

The specific energy consumption of the refueling process of a light vehicle fuel tank (700 bar) in an HRS with cascade compression starting from hydrogen at 20 bar is 2,8-3,2 kWh/kg. If the HRS starts from tube-trailer at 147 bar then the consumption is 1,6-1,7 kWh/kg. For heavy vehicles (350 bar) starting from hydrogen at 20 bar, the consumption is 2,3-2,5 kWh/kg versus 1,1-1,2 kWh/kg starting from tube-trailer at 147 bar. On the other hand, if it is an HRS with liquid supply, the consumption is 0,42-0,55 kWh/kg for refueling at 700 barversus 0,25-0,3 kWh/kg for refueling at 350 bar. Moreover, the results (pressure, temperature and flow rate) of a HRS loading in cascade compression and refueling of a vehicle are shown.

Supply	Dispensing at 350 bar	Dispensing at 700 bar
Tube-trailer at 147 bar	G_T_350	G_T_700
Pipelines at 20 bar	G_20_350	G_20_700
LH2 trailer at -253 °C	L_P-V_350	L_P-V_700





Conclusions and Acknowledgments

Cascade compression is the most popular HRS design for the future because it is the most efficient and versatile way to refuel a fuel cell vehicle for variable demand. On the other hand, it is verified that the proposed model is valid since the results obtained deviate by less than 15% from the HDRSAM model developed by ANL. An HRS model with cascade compression has been developed using the Smiscape program, which simulates the refueling process of a vehicle and provides detailed information on the thermodynamic parameters, as well as the temperature, pressure and flow rate at each of the relevant points of the process.

References