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JadeWeserPort Wilhelmshaven

APPLICATIONS OF HYDROGEN & FUEL CELLS IN SHIPPING

RESEARCH FINDING

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SHIPPING EMISSIONS INVENTORY

	ICCT (million tons)		
	2013	2014	2015
CO_2 Emissions	910	930	932
SO_x Emissions	10.355	10.361	10.457
NO_x Emissions	18.426	18.398	19.062
PM Emissions	1.475	1.504	1.492

MARPOL Annex VI is strictly followed to have the air pollution under control limits.

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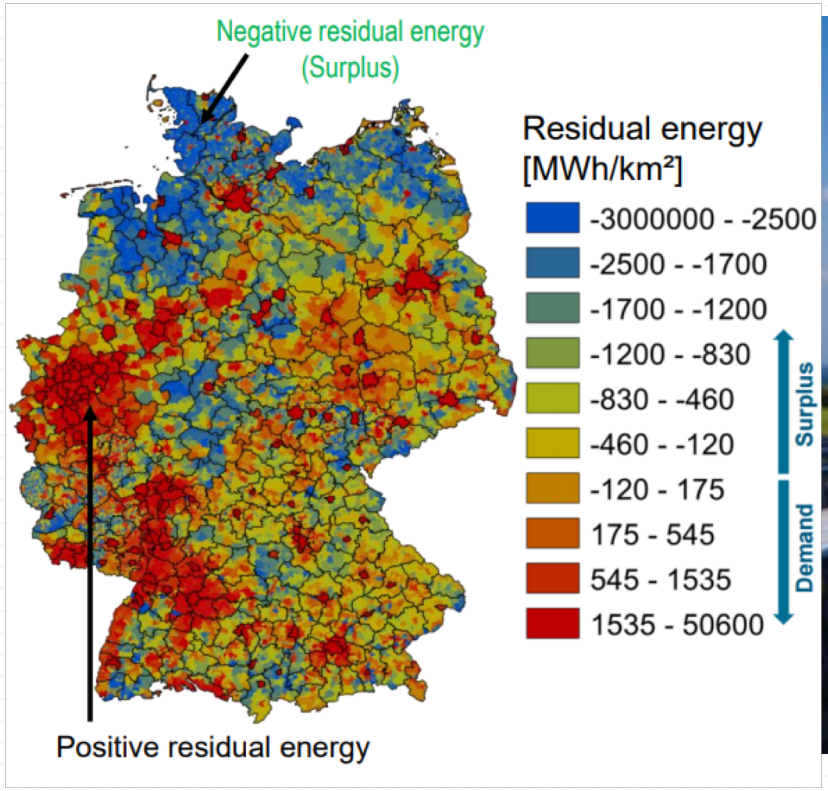
ADVANTAGES OF USING HYDROGEN

1. Hydrogen is a great storage medium, that could help RE systems to become self-contained solutions.



3743.2 GWh of electricity was curtailed pursuant to Section 14 of Renewable Energy Act (EEG) in 2016

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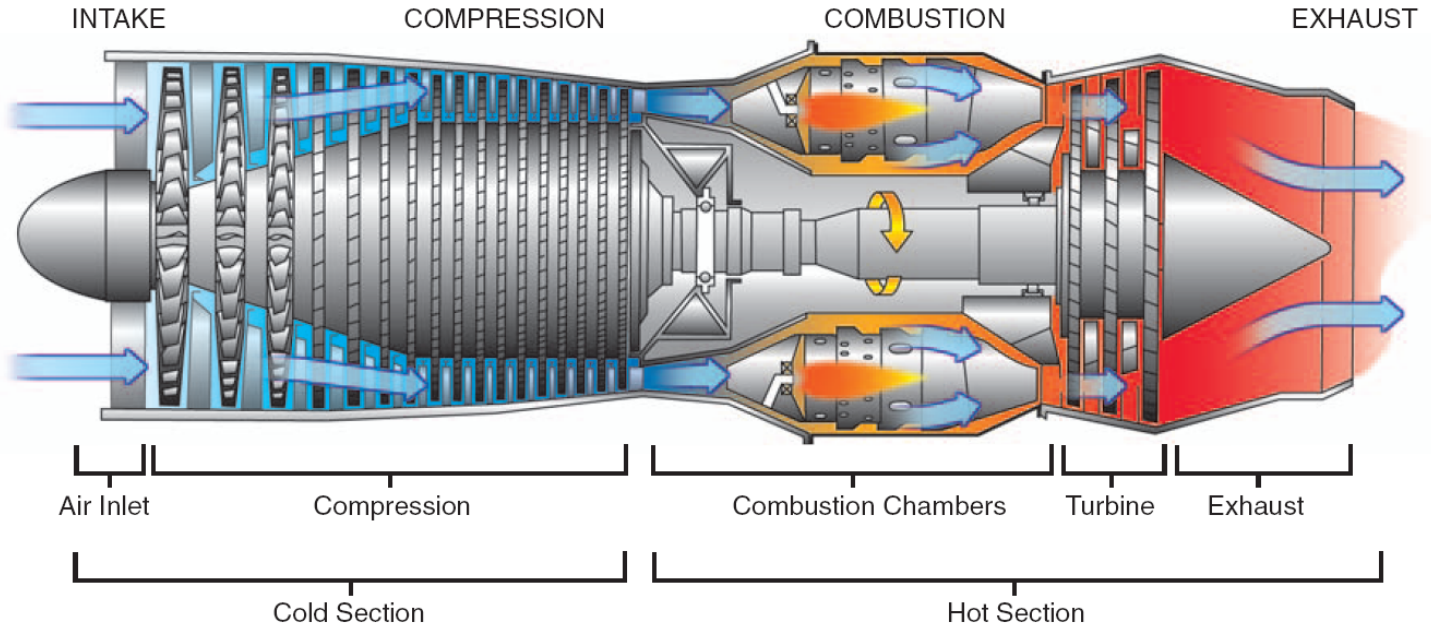
ADVANTAGES OF USING HYDROGEN

2. Produces less emissions when burned in Hydrogen ICEs or Gas turbines



NOx **could be reduced** with high air to fuel ratio – **No** SOx, PM emissions

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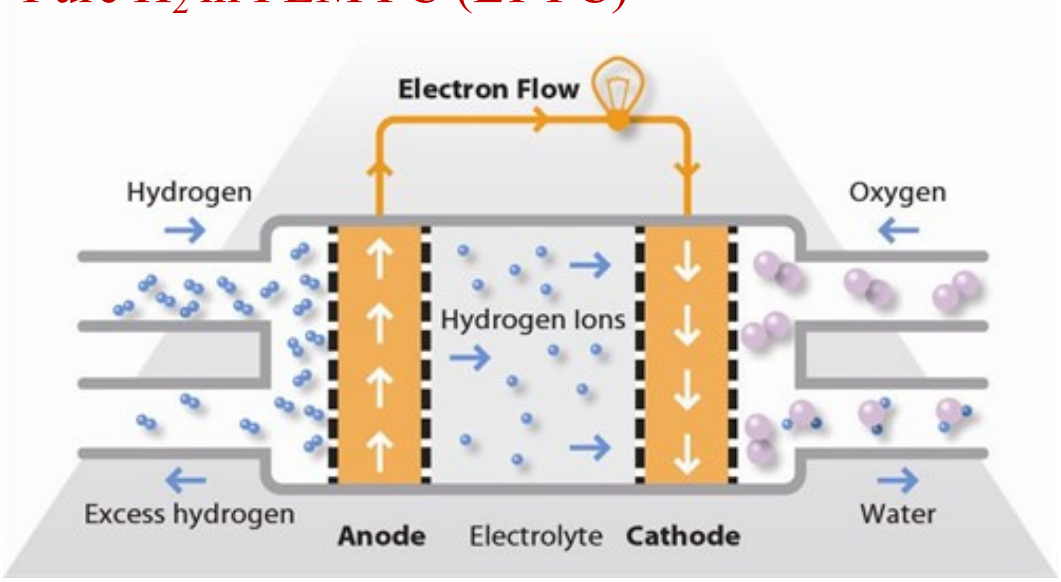
ADVANTAGES OF USING HYDROGEN

3. Produces zero- to low- carbon emissions in Fuel cells

Pure H_2 in PEM FC (LT-FC)

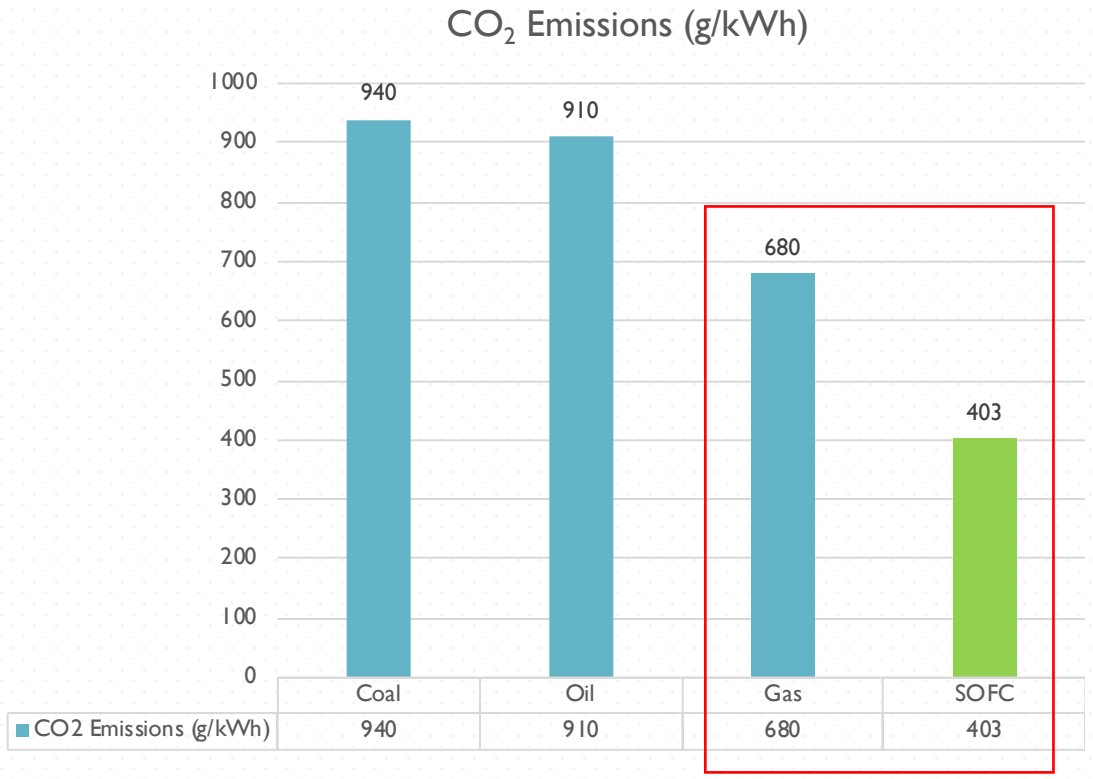


Anode Reaction: $2\ H_2 \rightarrow 4\ H^+ + 4\ e^-$

Cathode Reaction: $O_2 + 4\ e^- + 4\ H^+ \rightarrow 2\ H_2O$

Overall Reaction: $2\ H_2 + O_2 \rightarrow 2\ H_2O$

H_2 from Internally reformed Natural gas in a SOFC



No NOx or PM – **Insignificant Amount** SOx emissions

ADVANTAGES OF USING HYDROGEN

4. Hydrogen could be blended with natural gas to reduce emissions, without the need to modify the domestic burners.

Blending ratio: **20–30%** H_2 to **70–80%** Natural gas

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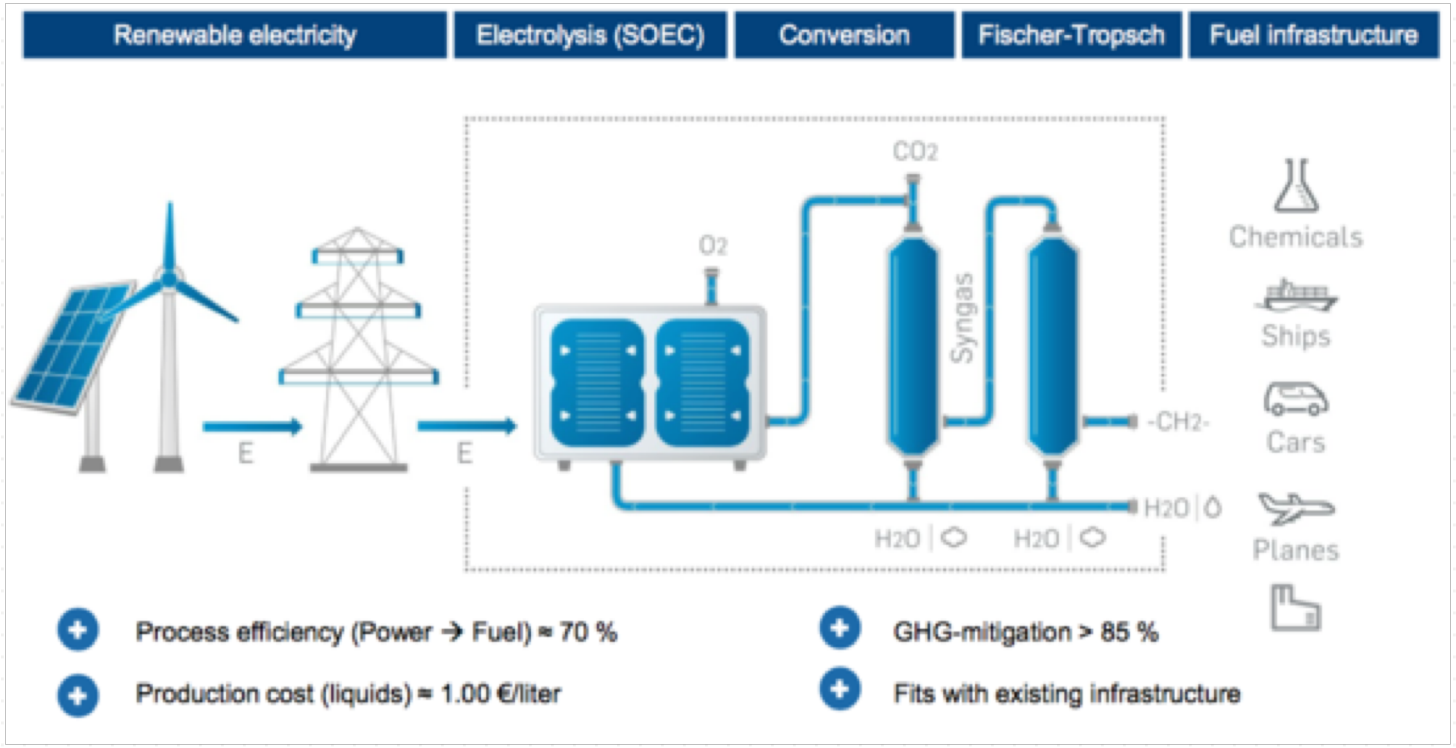
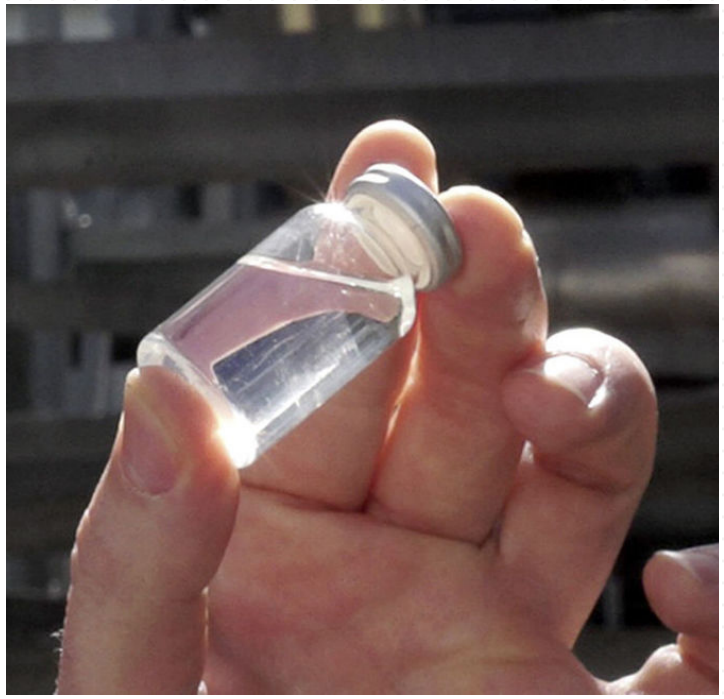
ADVANTAGES OF USING HYDROGEN

5. Wide range of e-fuels could be derived from Hydrogen (Power to Gas, Power to Liquid)





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APPLICATIONS OF H_2 IN PORTS

1. Transportation of Goods (Road Freight)

Comparison Point	Diesel	Electric
Horse Power	500 HP	Up to 1,000 HP
Torque	1,650 ft-lbs	Up to 2,000 ft-lbs
Range	500-700 miles	Up to 500-1,000 miles
Top Speed Up Hills (6%)	20-40 MPH	65 MPH
On Descent	Exhaust & Friction Brakes	Recharging & Saving Brakes
Acceleration 0-60 MPH Under Load	60 seconds	30 seconds
Fuel Efficiency (MPG)	7.5 MPG	13 – 15 MPG
Weight	19,000 - 23,000 lbs	18,000 - 21,000 lbs

Freight Efficiency (Ton-Miles per Galon):
Nikola One Class 8 Truck is 75% more efficient than a Class 8 Diesel truck

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APPLICATIONS OF H_2 IN PORTS

1. Transportation of Goods (Rail)

250kW for traction or Power-to-grid

150 kW power for traction

2. Cargo Handling

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APPLICATIONS OF H_2 IN PORTS

3. Cold ironing (Shore-to-ship power supply)

The Surf 'n' Turf project, utilizes the green hydrogen produced by wind power on Eday Island in a fuel cell that would act "as an auxiliary power source for the inter-island ferries when they are docked in the harbor overnight."

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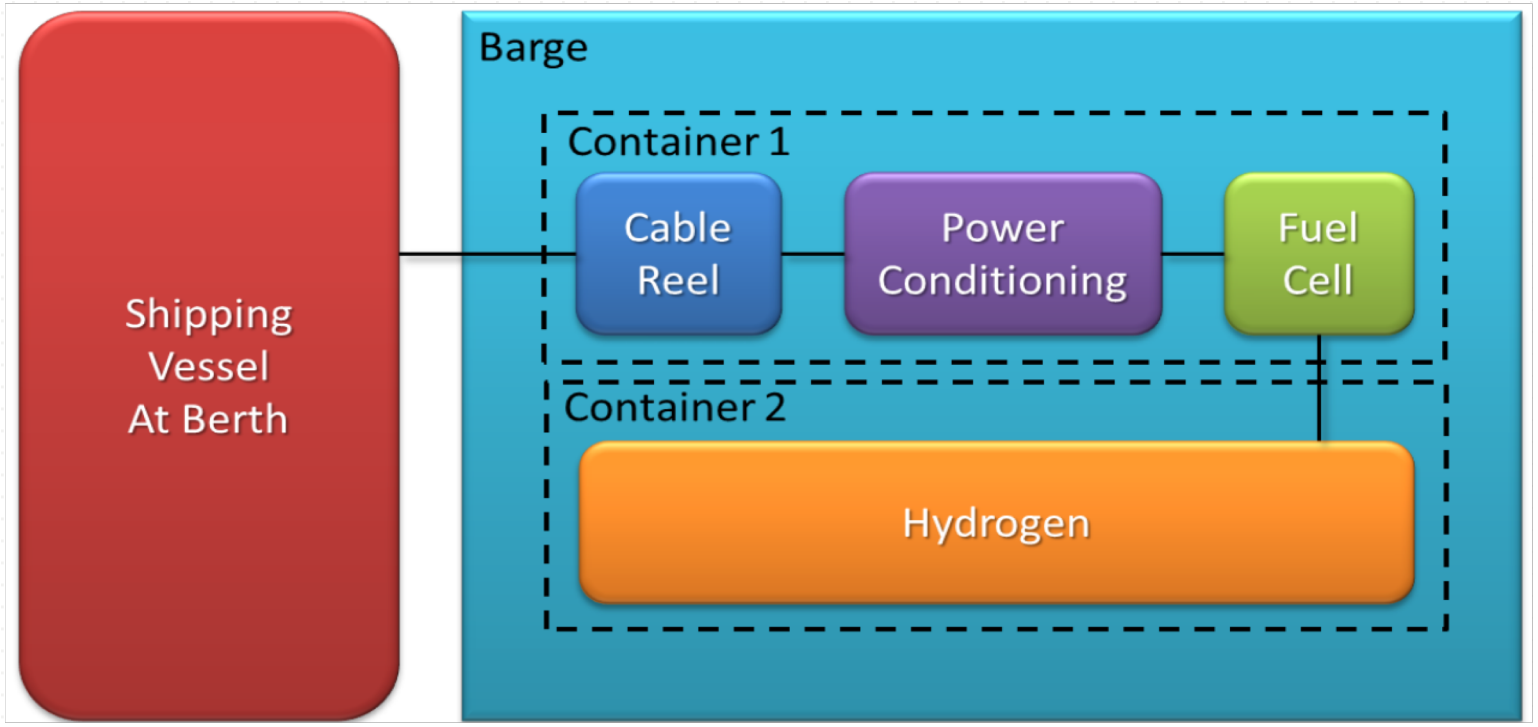
APPLICATIONS OF H_2 IN PORTS

3. Seaside Cold ironing

The main advantage; it can be moved from one berth to another, and it can also be used to power the ships in Anchorage area



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APPLICATIONS OF H_2 ONBOARD

The Application of FC depend on: The Power Requirement of the Vessel

Power Demand	Fuel Cell Application
Low (up to 500 kW)	• Total power demand (Propulsion + Auxiliary Power Supply) could be covered by 1 FC module (Example: FCS Alsterwasser)
Medium (1-5 MW)	• The total power demand could be covered by several FC modules • 1 FC module supply the bigger part of the auxiliary power.
High (5-100 MW, 1-15MW Auxiliary)	• Several FC modules supply the bigger part of the auxiliary power. • One or more fuel cell module(s) supply power to single ship sectors. (Suitable for Large passenger ships)

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APPLICATIONS OF H_2 ONBOARD

Type of Fuel Cell also depends: The Power Requirement of the Vessel

Merchant ships has a high energy demand requires more fuel storage capacity, since the alternative fuels have a lower energy content than that of Heavy Fuel Oil (HFO).

Fuel	Volume factor*
HFO	1.0
LNG	1.8
LPG	1.7
LH2	4.7
CH2 (700 bar)	8.6

* without considering the volume of the different storage technologies.

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REQUIRED DEVELOPMENT

1. **Increasing Power output of HT-FC.**
2. **Increasing the specific power (kW/kg) and power density (kW/m3)** of HT-fuel cell systems

   The weight of HT-FC is 7-19 times higher than that of diesel generator

   The volume of HT-FC is 10-15 times higher than that of diesel generator

3. **The lifetime** of FC be should be increased to 40,000 – 80,000 h to have a competitive advantage over a conventional diesel generator, that has usually service interval of about 25,000-30,000 h
4. The **prices** of the technology should drop
5. More **hydrogen infrastructure** is needed

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NO TIDE. NO LIMITS.

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THANKS FOR YOUR ATTENTION!

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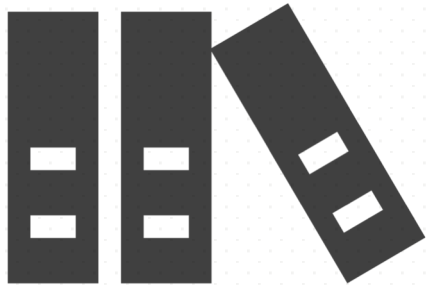

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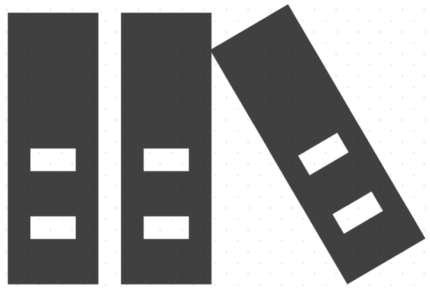

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