Power to X
Alliance

System efficiency of renewable energy in cars – e-fuels, e-gas, green hydrogen, battery

Agenda

01 RE system efficiency: dependent on RE location, seasonal use and energy conversion

02 Efficiency chains of different PtX paths in comparison to BEVs

01

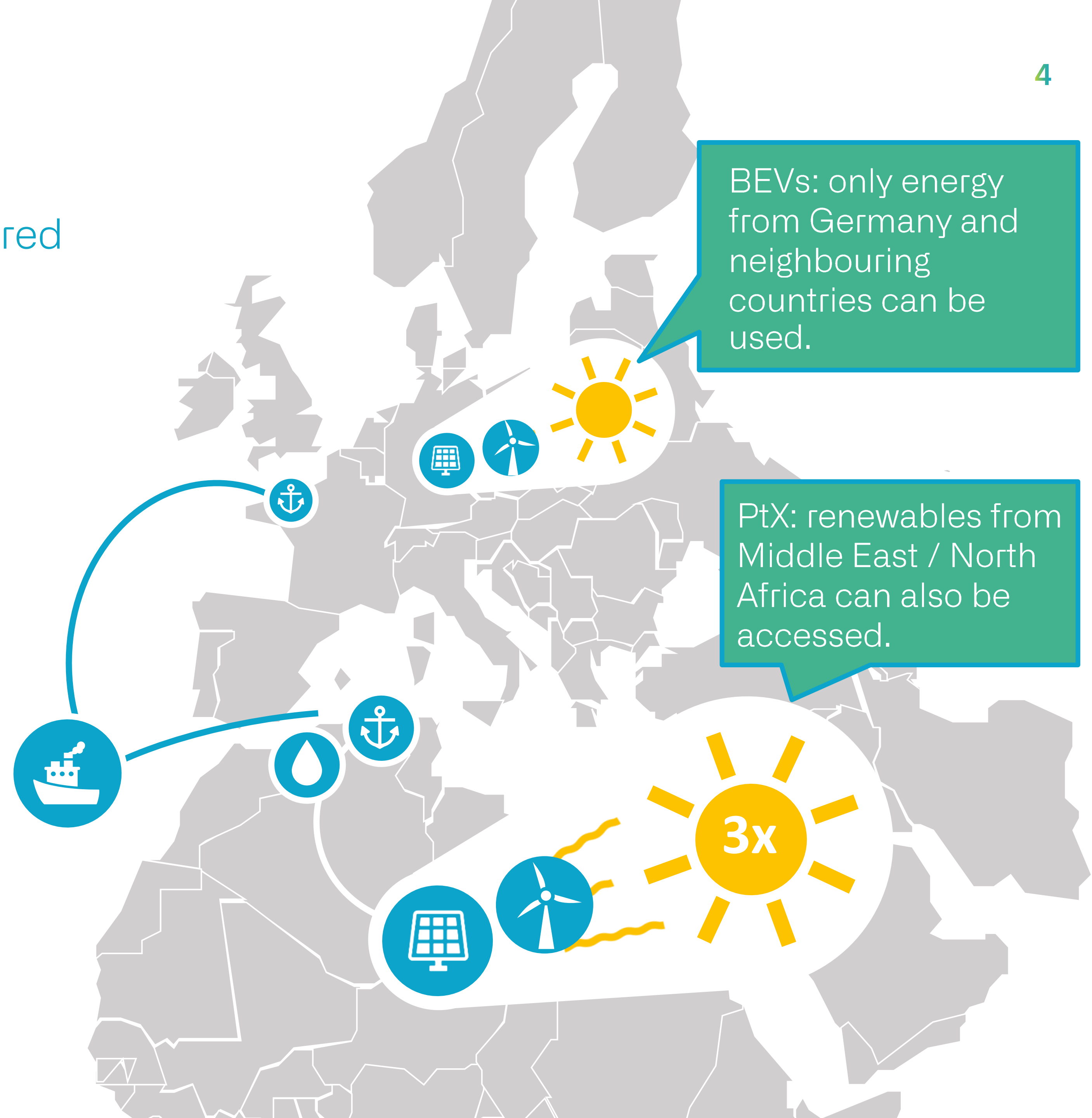
RE system efficiency: dependent on RE location, seasonal use and energy conversion

Power to X Allianz

Energy ≠ Energy

PtX products enable access to EE favoured sites and RE import

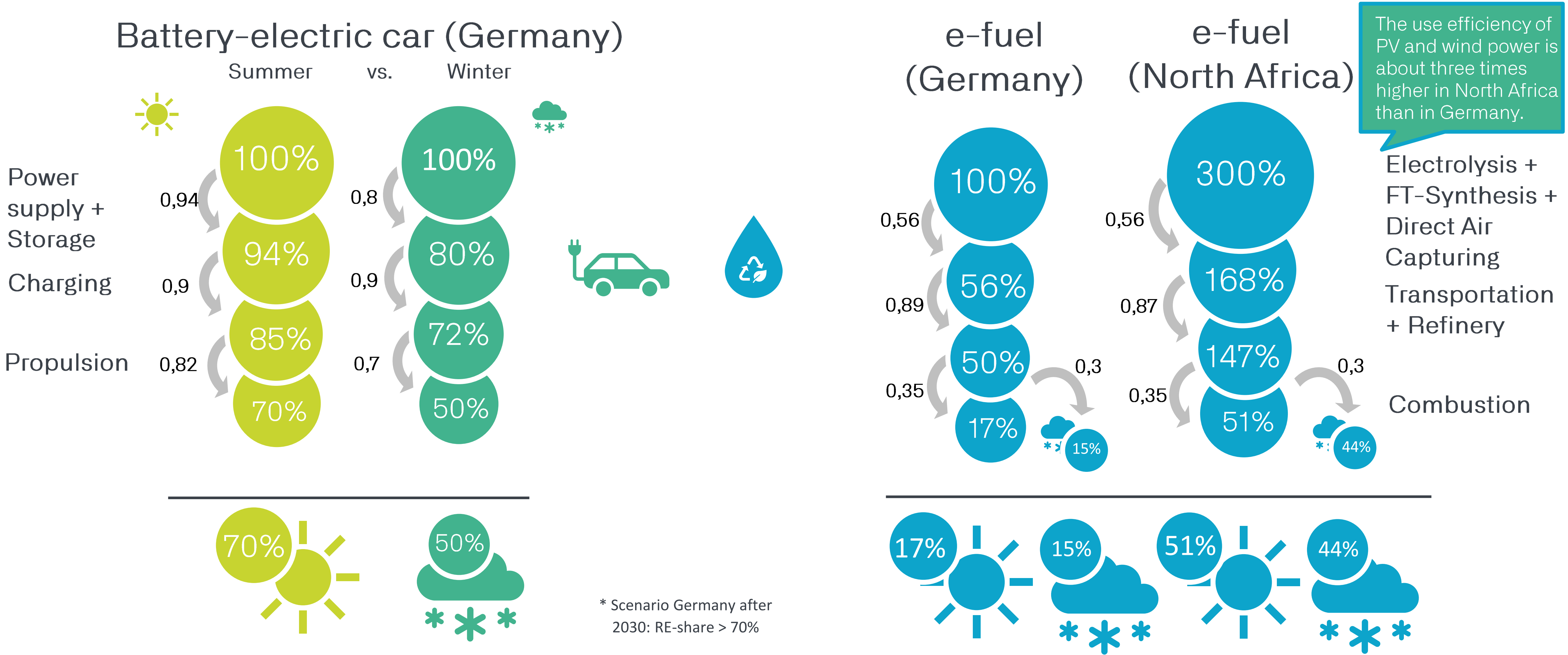
- RE production from sun/wind
- Production of e-fuels
- Shipment at the place of production
- Transportation
- Landing & Refining



*Simplified illustration.

Use efficiency of sun and wind in Germany* and favourable locations (e.g. North Africa)

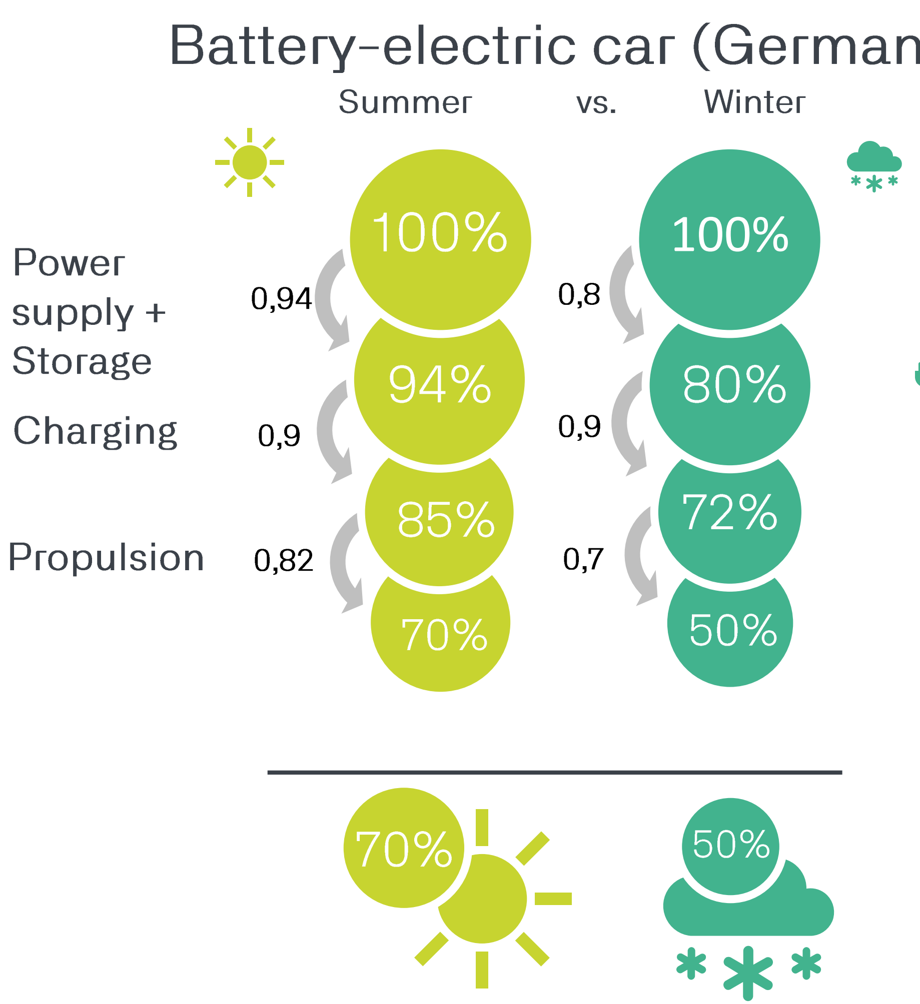
The RE use efficiency depends on the location of RE production, the seasonal use & the type of drive-train

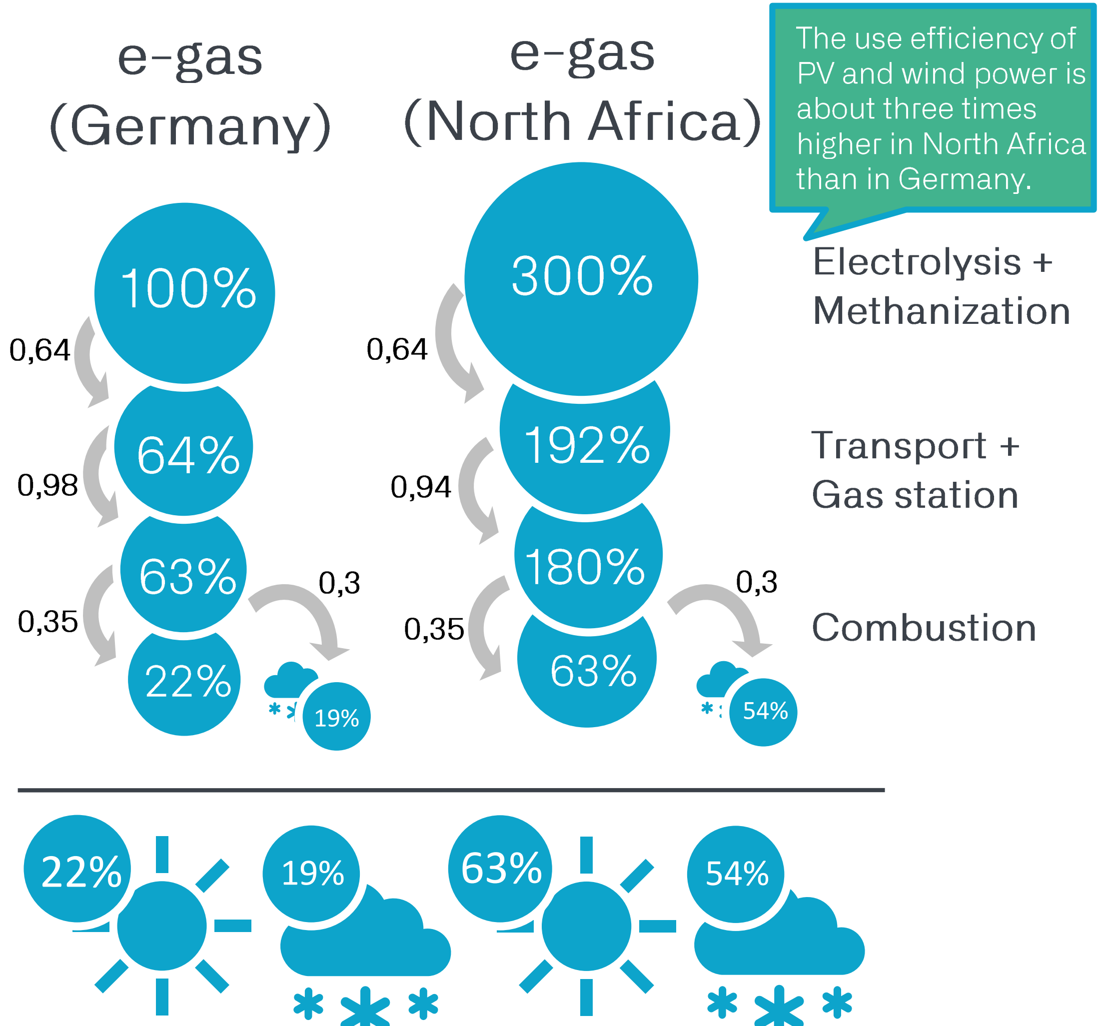


* Scenario Germany after 2030: RE-share > 70%

Use efficiency of sun and wind in Germany* and favourable locations (e.g. North Africa)

The RE use efficiency depends on the location of RE production, the seasonal use & the type of drive-train





* Scenario Germany after 2030: RE-share > 70%

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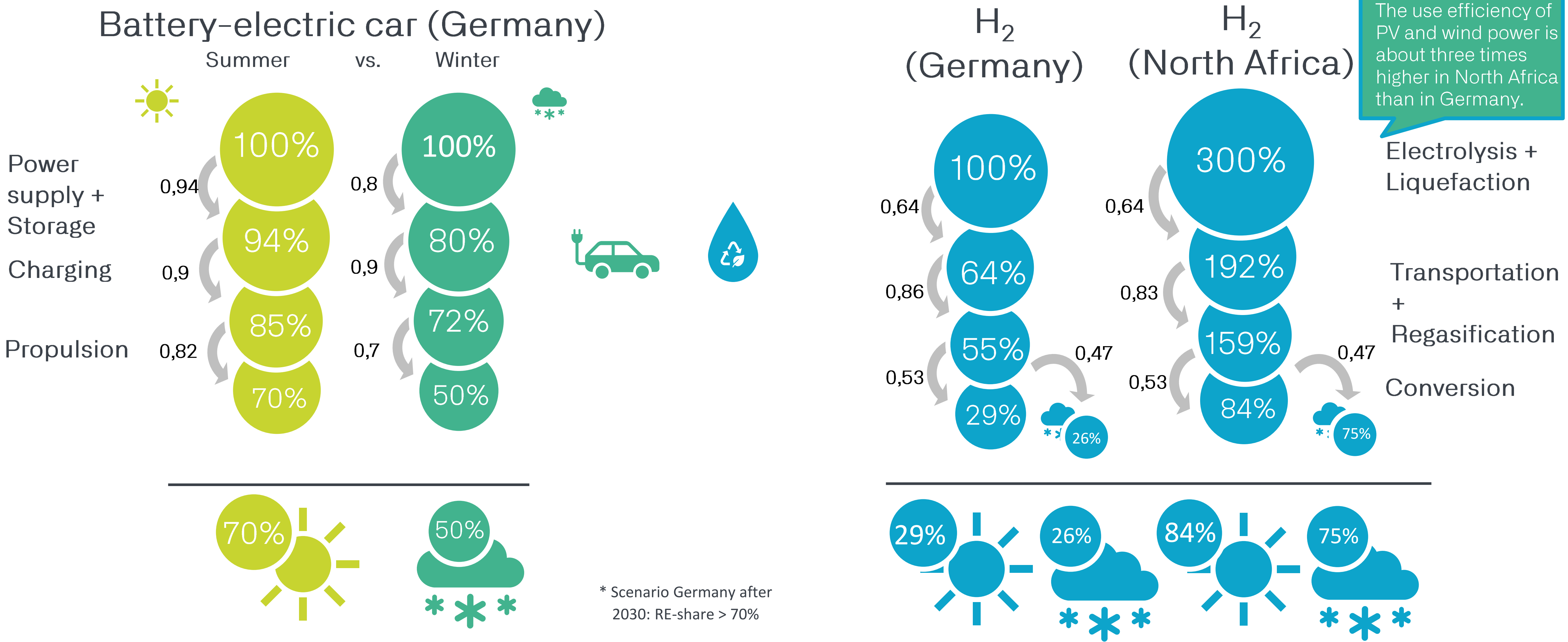
Use efficiency of sun and wind in Germany* and favourable locations (e.g. North Africa)

The RE use efficiency depends on the location of RE production, the seasonal use & the type of drive-train



* Scenario Germany after 2030: RE-share > 70%

02

Efficiency chains of different PtX paths in comparison to BEVs

Use efficiency compared across countries

RE green power mix Germany

	Full load hours (annual share [1)])	Share of installed capacity Germany[1)]
	20% (= 1.721 FLH)	48%
	35% (= 3.034 FLH)	6%
	11% (= 1.011 FLH)	41%
	37% (= 3.208 FLH)	5%

Average system efficiency

18%

Source: „Erneuerbare Energien in Zahlen“ (BMWi, 2018)

PtX-wind farm Iceland

Full load hours[2,3)]

(= 5.800 FLH)

=

System efficiency

(100% Wind)

66%

PtX-wind farm Chile / Patagonia

Full load hours [2,3]

(= 6.500 FLH)

=

System efficiency

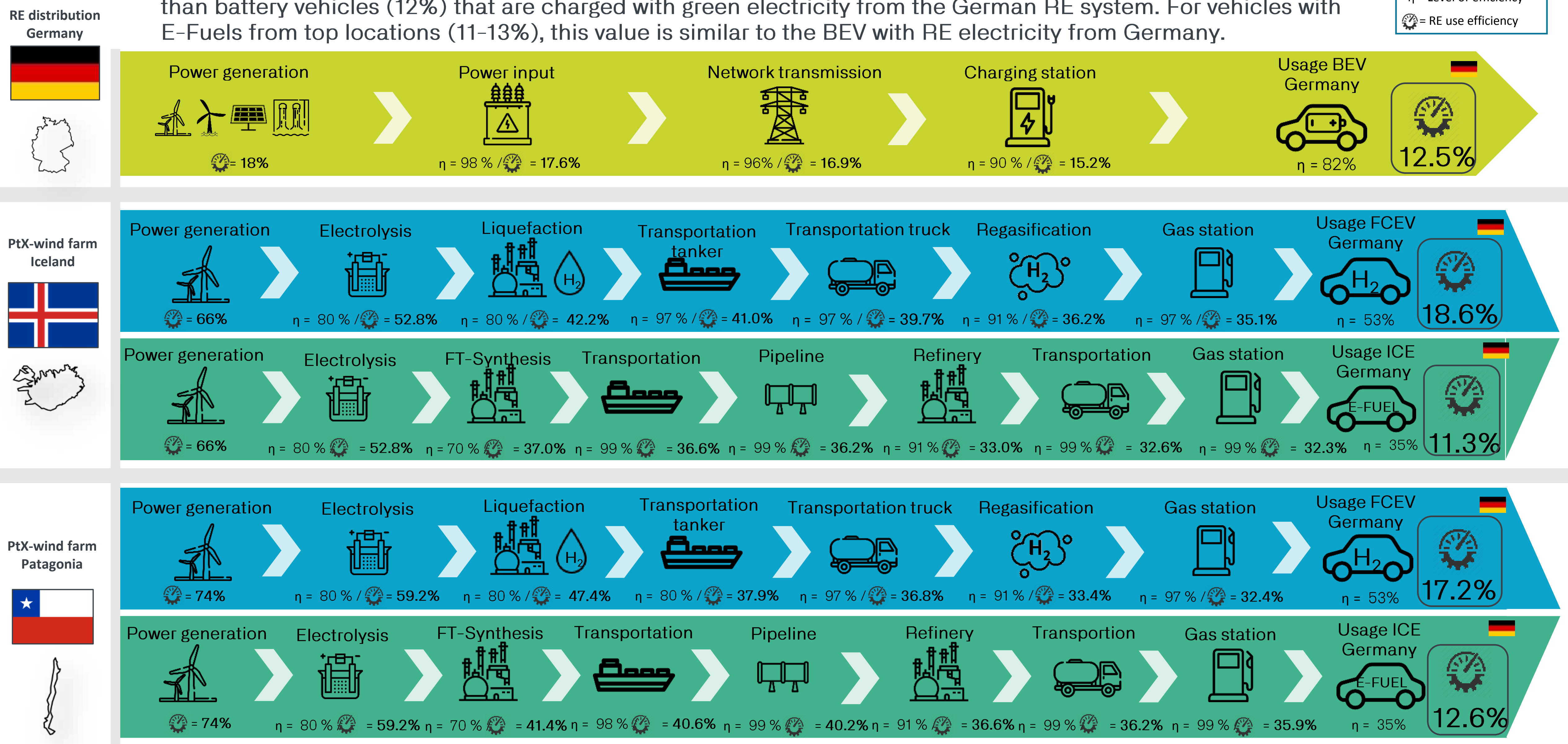
(100% Wind)

74%

Calculation of RE use efficiency (car summer operation, PtH_2, PtL)

Fuel cell vehicles that run on hydrogen from favourable locations can achieve a higher RE use efficiency (17-19%) than battery vehicles (12%) that are charged with green electricity from the German RE system. For vehicles with E-Fuels from top locations (11-13%), this value is similar to the BEV with RE electricity from Germany.

η = Level of efficiency
= RE use efficiency



Use efficiency compared across countries

RE green power mix Germany

	Full load hours (annual share [1])	Share of installed capacity Germany[1]
Onshore wind	20% (= 1.721 FLH)	48%
Offshore wind	35% (= 3.034 FLH)	6%
Solar	11% (= 1.011 FLH)	41%
Hydro	37% (= 3.208 FLH)	5%

Average system efficiency

18%

Source: „Erneuerbare Energien in Zahlen“ (BMWi, 2018)

PtX-wind farm Morocco

Full load hours[4]

(= 5.000 FLH)

=

System efficiency

(100% Wind)

57%

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Calculation of RE use efficiency (car summer operation, PtG)

Vehicles powered by SNG from favoured locations can achieve a similarly high RE use efficiency (11.0%–12.0%) as electric cars (12.5%) charged with green electricity from the German RE system.

η = Level of efficiency
= RE use efficiency

RE-distribution Germany

Power generation	Power input	Network transmission	Charging station	Usage BEV Germany	
= 18%	η = 98 % I = 17.6%	η = 96 % I = 16.9%	η = 90 % I = 15.2%	η = 82%	12.5%

PtX-wind farm Morocco

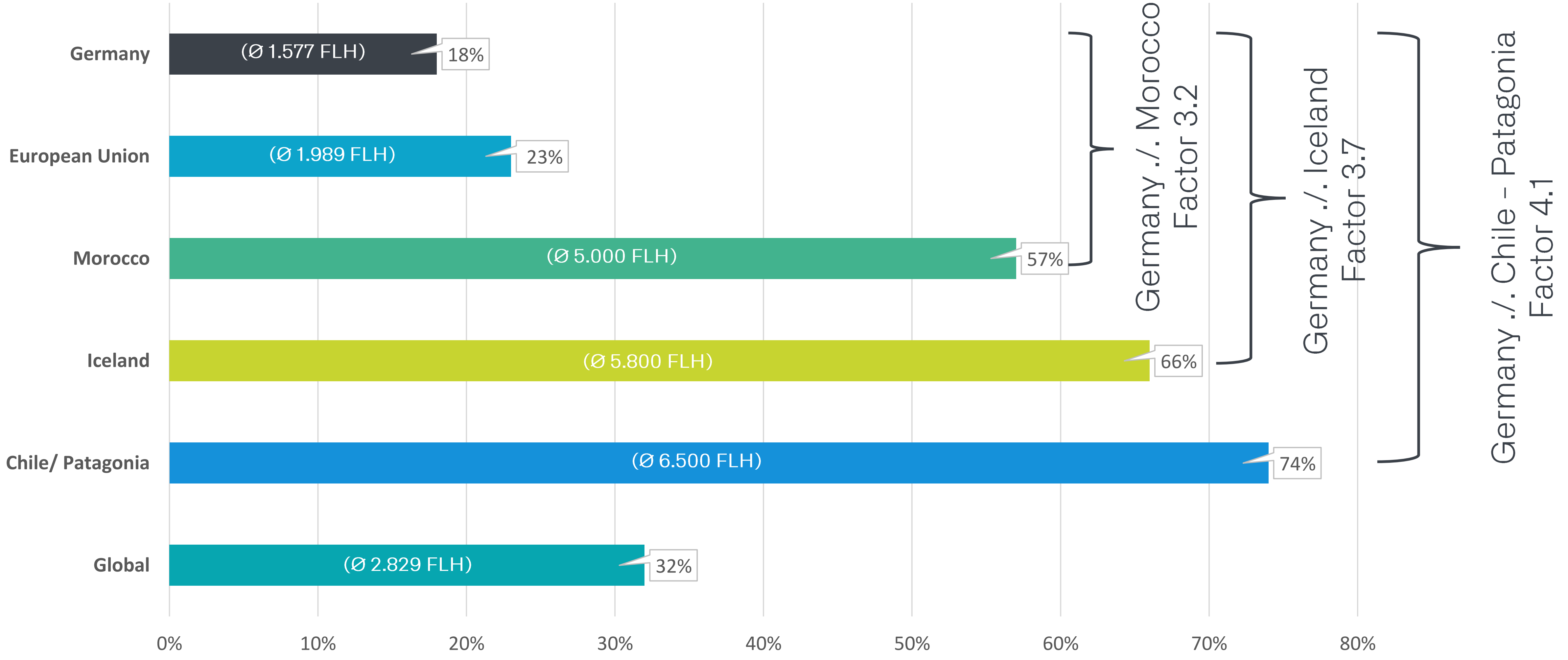
Power generation	Electrolysis	Methanization	Liquefaction	Transportation	Regasification	Pipeline	Gas station	Usage SNG Germany	
= 57 %	η = 80 % = 45.6%	η = 80 % = 36.5%	η = 90 % = 32.8%	η = 99 % = 32.5%	η = 99 % = 32.2%	η = 99 % = 31.9%	η = 99 % = 31.5%	η = 35%	11.0%

PtX-wind farm Morocco

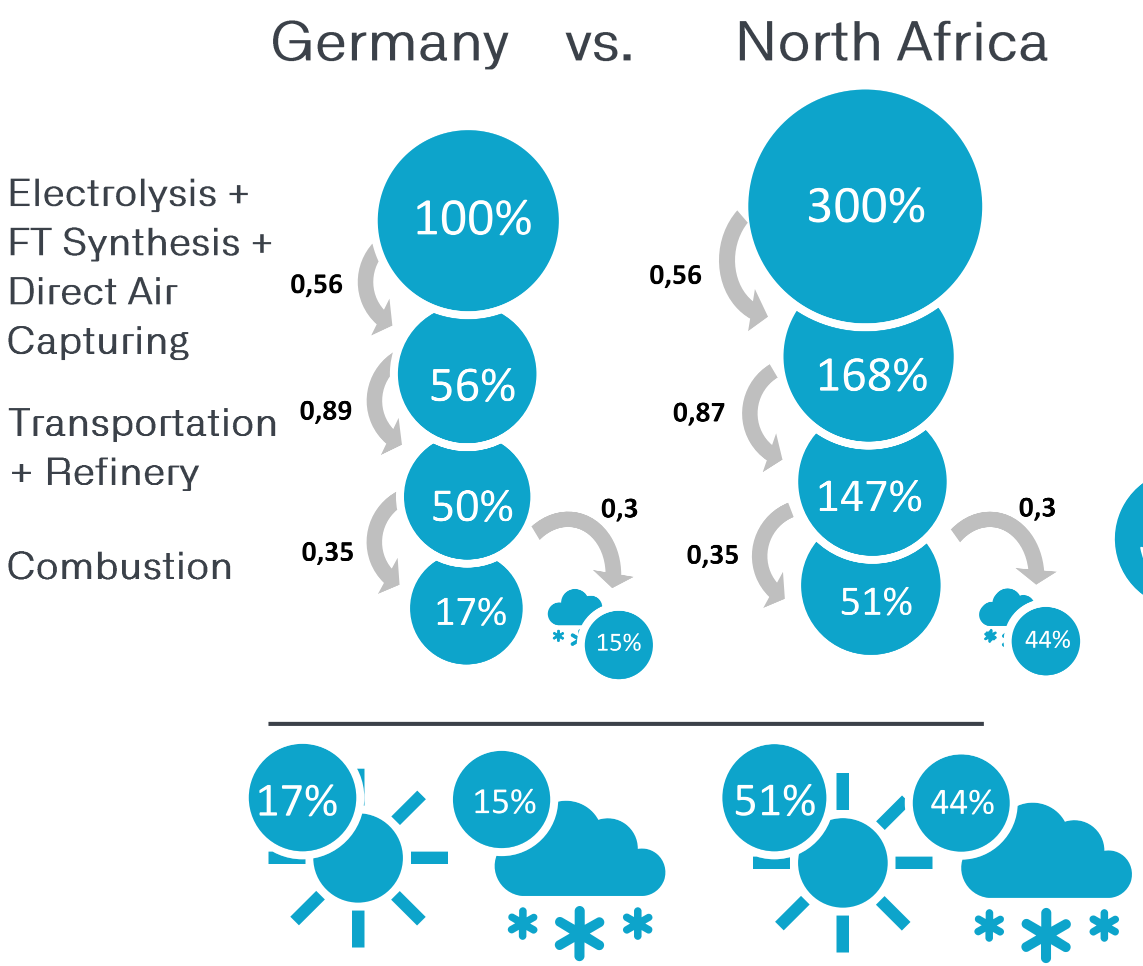
Power generation	Electrolysis	Methanization	Pipeline	Gas station	Usage SNG Germany	
= 57 %	η = 80 % = 45.6%	η = 80 % = 36.5%	η = 95 % = 34.7%	η = 99 % = 34.3%	η = 35%	12.0%

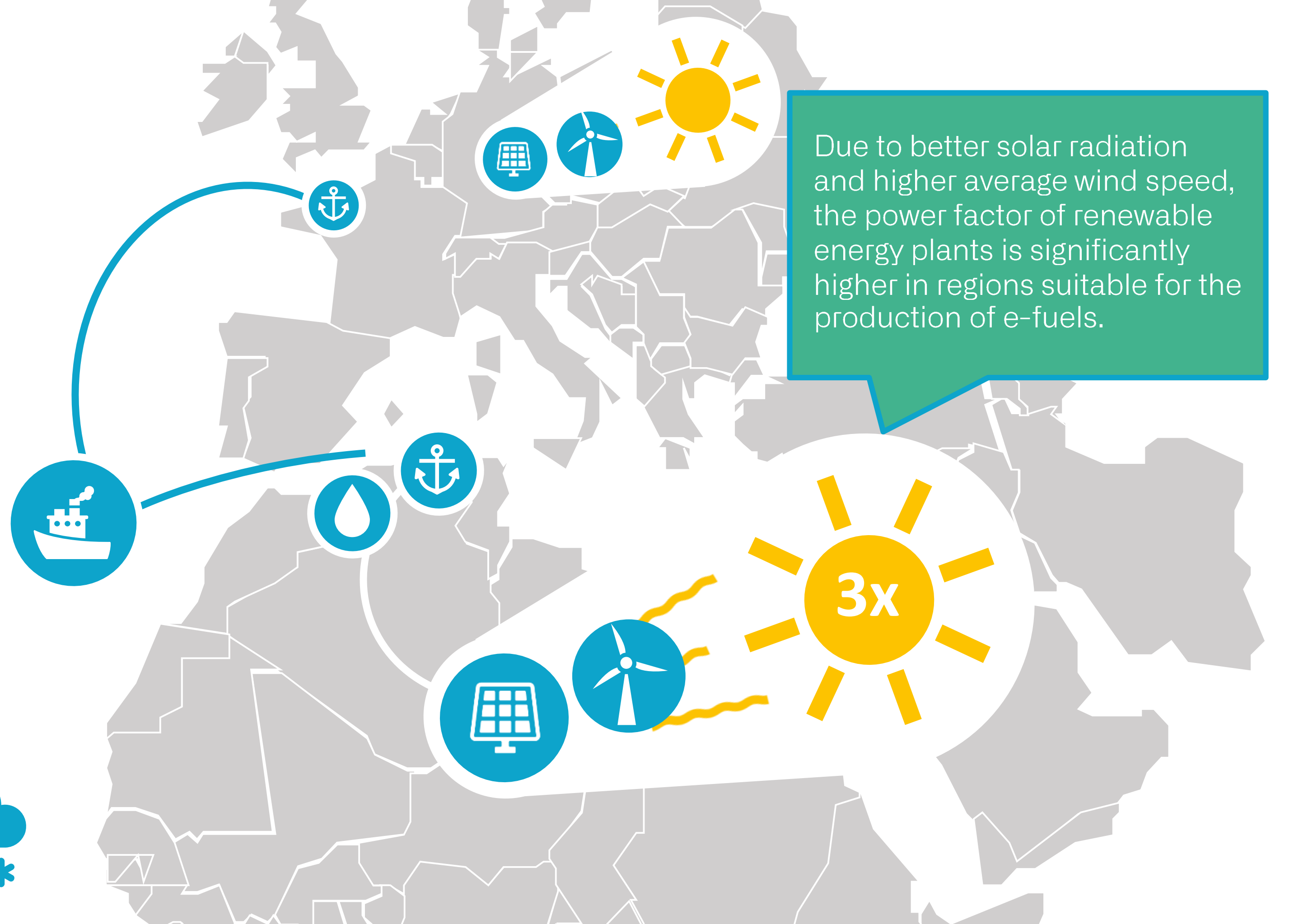
BACKUP

The different use efficiencies are based on the possible annual full load hours of RE generation plants



The RE use efficiency of e-fuels depends on the location of RE production, the seasonal use & the type of drive-train





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Yuksel, T. u. Michalek, J. J. (2015): Effects of Regional Temperature on Electric Vehicle Efficiency, Range, and Emissions in the United States. Environ. Sci. Technol., 49.

Slide „RE green power mix Germany/ PtX-Windpark Iceland / PtX-Windpark Chile / Patagonia“

Note:
Electricised biogas is deliberately not included in the system balance for Germany, as the source of biogas today is usually cultivated biomass. In the view of key stakeholders, the use of cultivated land for the production of biogas should not compete with food production (global shortage).

Footnote 1)

Bundesministerium für Wirtschaft und Energie
„Erneuerbare Energien in Zahlen – Nationale und internationale Entwicklung im Jahr 2018“

Deutschland

Erzeugungsart	Installierte Leistung	Stromerzeugung	FLH (Stromerzeugung/ Installierte Leistung)	Verteilung FLH (in %)	Installierte Leistung (von Summe 100%)
Wind (On-Shore)	53 GW	90.484 GWh	1.721 h	20%	48%
Wind (Off-Shore)	6 GW	19.467 GWh	3.034 h	35%	6%
Wasserkraft	6 GW	18.002 GWh	3.208 h	37%	5%
Photovoltaik	45 GW	45.784 GWh	1.011 h	11%	41%

Footnote 2|3)

Journal of Cleaner Production 243 (2020) 118466
„Baseload electricity and hydrogen supply based on hybrid PV-wind power plants “
Autoren: Mahdi Fasihi (Island 5.800 FLH / Patagonien 6.500 FLH)

Global Wind Atlas „https://globalwindatlas.info/“

Footnote 4)

Agora Energiewende „Future Cost of Onshore Wind“
Autoren: G.Thomaßen, M. Deutsch (Marokko 5.000 FLH)

Global Wind Atlas „https://globalwindatlas.info/“

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BEV

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Network transmission
UBA: Umweltbilanz von Elektrofahrzeugen, UBA: Klimaschutz und regenerativ erzeugte Energieträger, destatis: Monatsbilanz für die Elektrizitätsversorgung
Charging station
UBA: Umweltbilanz von Elektrofahrzeugen
Usage PKW
M. Trzesniowski: Antrieb, D. Kreyenberg: Fahrzeugantriebe für die Elektromobilität

H2

Electrolysis
UBA: Postfossile Energieversorgungsoptionen, M. Klell: Wasserstoff in der Fahrzeugtechnik, UBA: Klimaschutz und regenerativ erzeugte Energieträger
Liquefaction
M. Klell: Wasserstoff in der Fahrzeugtechnik, Shell: Wasserstoffstudie
Transportation tanker
M. Klell: Wasserstoff in der Fahrzeugtechnik, Shell: Wasserstoffstudie, Google Maps (Entfernungen messen)
Transportation truck
M. Klell: Wasserstoff in der Fahrzeugtechnik, Shell: Wasserstoffstudie
Regasification
M. Klell: Wasserstoff in der Fahrzeugtechnik, Shell: Wasserstoffstudie
Gas station
M. Pehnt: Ganzheitliche Bilanzierung von Brennstoffzellen
Usage truck
UBA: Postfossile Energieversorgungsoptionen

E-FUEL

Electrolysis
UBA: Postfossile Energieversorgungsoptionen, M. Klell: Wasserstoff in der Fahrzeugtechnik, UBA: Klimaschutz und regenerativ erzeugte Energieträger
FT-Synthesis
UBA: Postfossile Energieversorgungsoptionen
Transportation
G. Brauner: Energetische Konversionspfade ausgewählter Energieträger im Verkehrssektor mit anschließender Erstellung des ökologischen Fußabdrucks unter besonderer Berücksichtigung des Flughafens Hamburg, Google Maps
Pipeline
G. Brauner: Energetische Konversionspfade ausgewählter Energieträger im Verkehrssektor mit anschließender Erstellung des ökologischen Fußabdrucks unter besonderer Berücksichtigung des Flughafens Hamburg
Refinery
FfE: CO-2 Bilanz des CAPHENIA-Prozesses
Transportation
G. Brauner: Energetische Konversionspfade ausgewählter Energieträger im Verkehrssektor mit anschließender Erstellung des ökologischen Fußabdrucks unter besonderer Berücksichtigung des Flughafens Hamburg
Gas station
G. Brauner: Energetische Konversionspfade ausgewählter Energieträger im Verkehrssektor mit anschließender Erstellung des ökologischen Fußabdrucks unter besonderer Berücksichtigung des Flughafens Hamburg
Usage truck
UBA: Postfossile Energieversorgungsoptionen

SNG/e-gas

Electrolysis
UBA: Postfossile Energieversorgungsoptionen, M. Klell: Wasserstoff in der Fahrzeugtechnik, UBA: Klimaschutz und regenerativ erzeugte Energieträger
Methanization
UBA: Klimaschutz und regenerativ erzeugte Energieträger
Liquefaction
UBA: Climate protection and renewable energy sources.
Transporation
UBA: Klimaschutz und regenerativ erzeugte Energieträger
Regasification
UBA: Klimaschutz und regenerativ erzeugte Energieträger
Pipeline
UBA: Klimaschutz und regenerativ erzeugte Energieträger, Google Maps (Entfernungen messen)
Gas station
U. Kramer: Defosselizing the Transporation Sector (Zukünftige Kraftstoffe)
Usage truck
UBA: Post-fossil energy supply options

Listing of the calculation method of the efficiency of use of presented RE paths, car summer operation

BEV	Performance efficiency Germany		Power input	Network transmission	Charging station	Usage BEV
	18%	Level of efficiency	98%	96%	90%	82%
		Performance efficiency	17,6%	16,9%	15,2%	**12,5%**

FCEV	Performance efficiency Iceland		Electrolysis	Liquefaction	Transportation	Transportation	Regasification	Gas station	Usage FCEV Germany
	66%	Level of efficiency	80%	80%	97%	97%	91%	97%	53%
		Performance efficiency	52,8%	42,2%	41%	39,7%	36,2%	35,1%	**17,5%**

ICE e-fuel	Performance efficiency Iceland		Electrolysis	FT-Synthesis	Transportation	Pipeline	Refinery	Transportation	Gas station	Usage ICE Germany
	66%	Level of efficiency	80%	70%	99%	99%	91%	99%	99%	35%
		Performance efficiency	52,8%	37%	36,6%	36,2%	33%	32,6%	32,3%	**11,3%**

FCEV	Performance efficiency Chile/Patagonia		Electrolysis	Liquefaction	Transportation	Transportation	Regasification	Gas station	Usage FCEV Germany
	74%	Level of efficiency	80%	80%	80%	97%	91%	97%	53%
		Performance efficiency	59,2%	47,4%	37,9%	36,8%	33,4%	32,4%	**16,2%**

ICE e-fuel	Performance efficiency Chile/Patagonia		Electrolysis	FT-Synthesis	Transportation	Pipeline	Refinery	Transportation	Gas station	Usage ICE Germany
	74%	Level of efficiency	80%	70%	98%	99%	91%	99%	99%	35%
		Performance efficiency	59,2%	41,4%	40,6%	40,2%	36,6%	36,2%	35,9%	**12,6%**

SNG (Pipeline)	Performance efficiency Morocco		Electrolysis	Methanization	Pipeline	Gas station	Usage SNG Germany
	57%	Level of efficiency	80%	80%	95%	99%	35%
		Performance efficiency	45,6%	36,5%	34,7%	34,3%	**12%**

SNG (tanker)	Performance efficiency Morocco		Electrolysis	Methanization	Liquefaction	Transportation	Regasification	Pipeline	Gas station	Usage SNG Germany
	57%	Level of efficiency	80%	80%	90%	99%	99%	99%	99%	35%
		Performance efficiency	45,6%	36,5%	32,8%	32,5%	32,2%	31,9%	31,5%	**11%**

Disclaimer

Using varying figures, for example with regard to full load hours of renewable energy sources, it is not impossible to obtain gradually deviating results for Germany as well as for the other countries listed (Iceland, Chile / Patagonia).

However, this does not affect the respective proportions and the conclusions drawn from them.

Thank you!

Danke!

Merci!

¡Gracias!

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