

**Africa Solar Hydrogen
Project (ASHyP) -
Solar2Hydrogen system
design and contribution to
decarbonization for the
COP27**

Master pack

October 2022

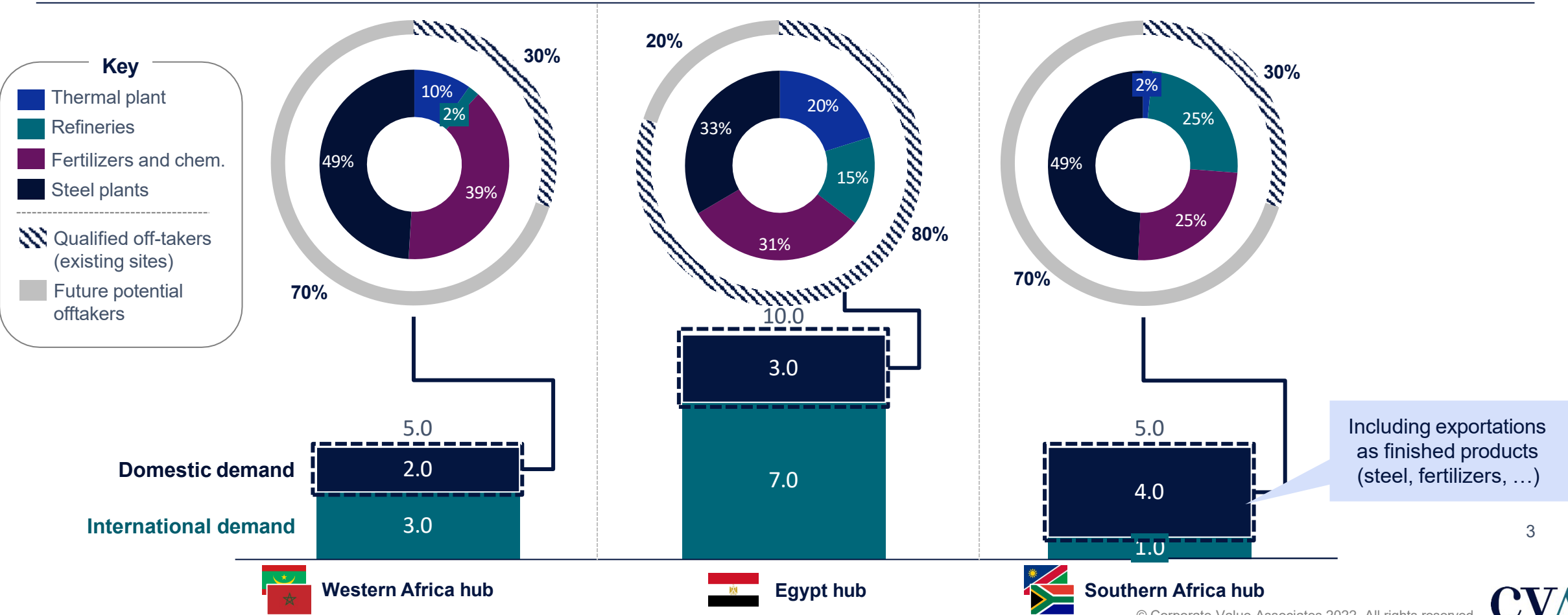
Agenda

- 1. African H2 hubs system design – Demand equation to address – 2030 and 2035**
2. African H2 hubs system design – Design and sizing of the 3 hubs
3. African H2 hubs system design – Resulting costs for the 3 hubs
4. Value creation impact

H2 demand equation to address by hub – Vision 2030

A potential H2 demand of ~20Mt/y in 2030 in the 3 areas, shared between domestic demand (~45%) and exportation (55%); the domestic demand will concentrate around green steel materials and commodities (~40%) and green fertilizers and chemicals (~30%)

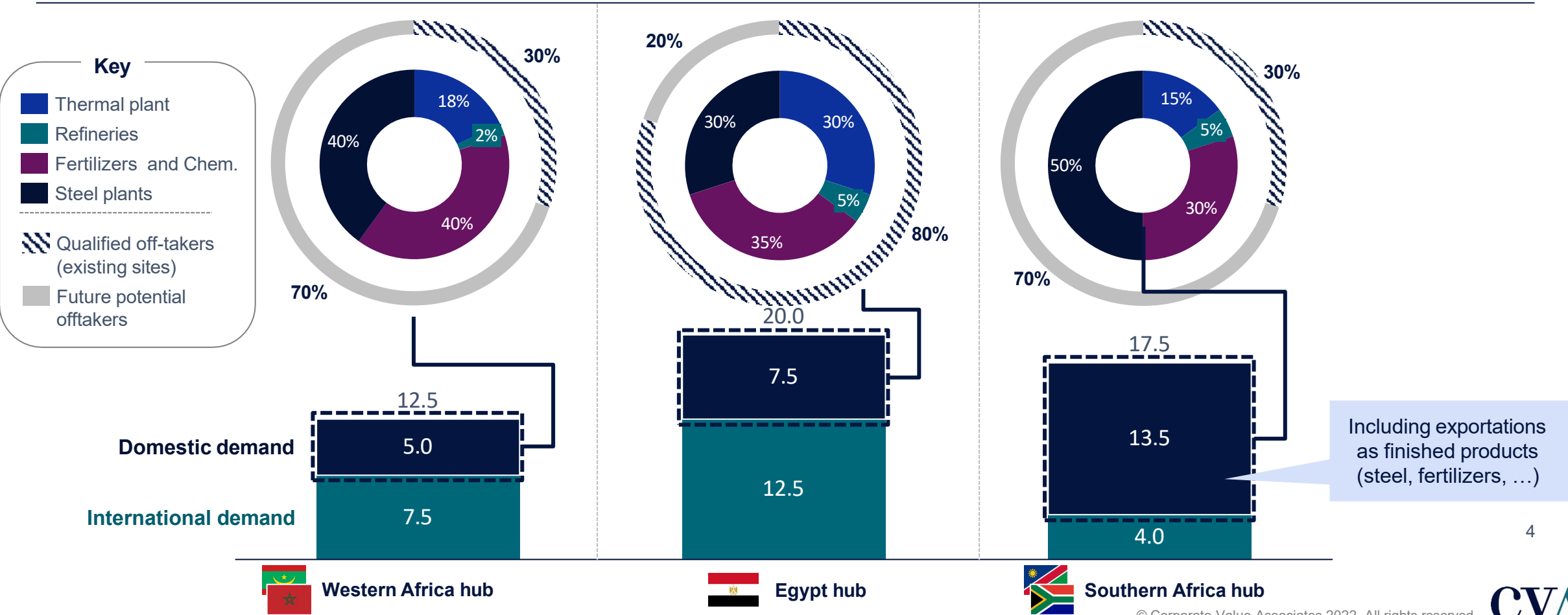
Estimated potential green H2 demand in 2030 and breakdown by sector (Mt/y)



H2 demand equation to address by hub – Vision 2035

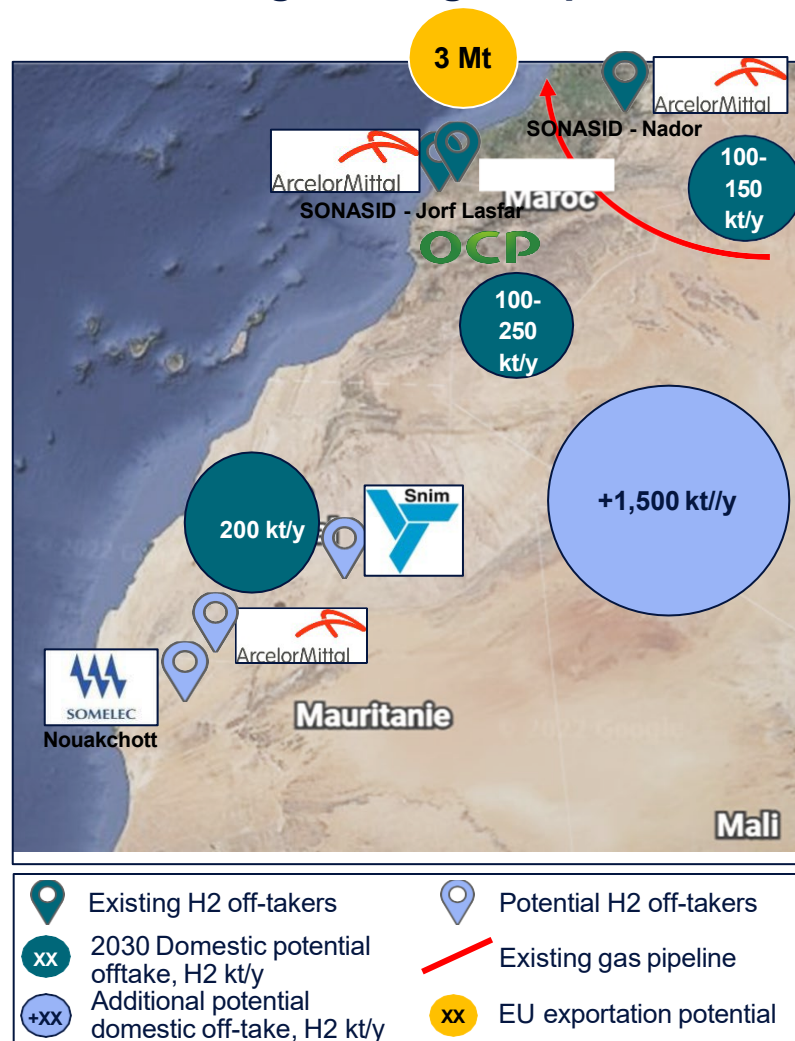
H2 demand might increase up to ~50 Mt/y in 2035 in the 3 African hubs, mainly driven by international demand and the emergence of new domestic off-takers / projects related to green gas competitiveness

Estimated potential green H2 demand in 2035 and breakdown by sector (Mt/y)



Details of key sites' H2 demand to address – Western Africa – Vision 2030

In Western Africa there is a significant future potential for domestic H2 off-take estimated up to 2 Mt/y considering existing and potential sites, as well as exportation demand (3 Mt/y)



Focus on domestic demand

	Mauritania	Morocco	Estimated potential H2 off-take volumes (2030)
Existing sites with existing or potential H2 offtake (including substitution of fossil fuels)	<ul style="list-style-type: none"> For now, no main H2 off-taker Thermal plants – assumptions of 50 kt/y in 2030 (e.g SOMELEC) 	<ul style="list-style-type: none"> 600 kt/y primary steel: 100 - 150 kt/y of H2 (e.g SONASID) Electricity generation = assumption of 50 kt H2/y (e.g ONEE) 100 – 250 kt/y H2 for ammonia (Moroccan government roadmap / e.g OCP) Local demand for other existing industries is estimated to 100 kt/y of H2 by 2030 	400-500 kt/y
Future potential H2 off-takers related to new industrial sites (announced green H2 projects and development of new facilities)	<ul style="list-style-type: none"> Primary steel production capacity: 500 kt/y of H2 (e.g SNIM/AM) Potential development: 1,5 Mt/y of ammonia which represent around 300 kt/y of H2 Transport: Assumptions of 50 kt/y in 2030 	<ul style="list-style-type: none"> Estimated to 50-100 kt/y (Moroccan government roadmap) Future development of industrial project (e.g chemicals with METHANEX) – 500 kt/y 	~ 1,500 kt/y



Thermal plants



Fertilizers



Steel



Refinery

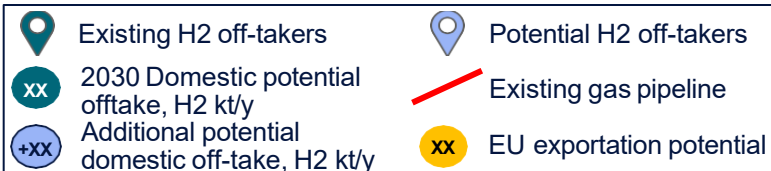
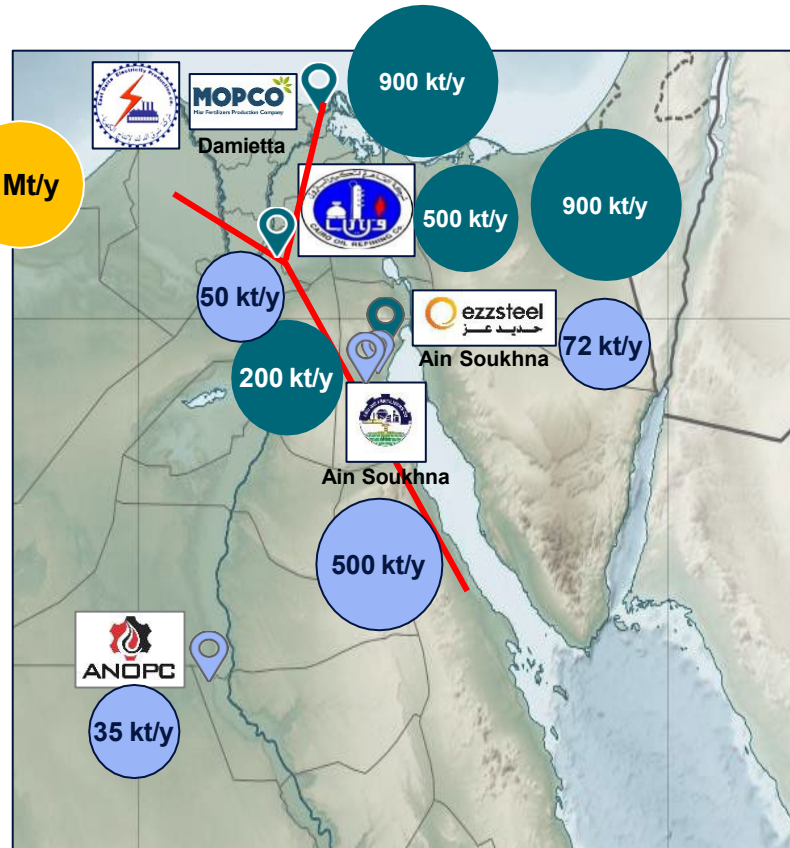


Chemicals

Details of key sites' H2 demand to address – Egypt – Vision 2030

In Egypt, the existing potential for H2 off-take (2.5 Mt/y), combined with a potential domestic development (up to 0.6 Mt/y) is completed by a high potential exportation demand (7 Mt/y)

Focus on domestic demand



Sources: ONNE, ArcelorMittal, World Steel Association, Moroccan government H2 roadmap, CVA analysis

Egypt						Estimated potential H2 off-take volumes (2030)
Existing sites with existing or potential offtake (including substitution of fossil fuels)	 500 kt of H2 in 2021 that could represent 700 kt/y of H2 by 2030 (e.g MOPCO)	 6 Mt primary steel in 2021, representing 800 kt/y of H2 by 2030 (e.g EZZ STEEL)	 200 kt refining products in 2021 that could represent 400 kt/y of H2 by 2030 (e.g CORC)	 80 kt of chemical products in 2021 that could represent 200 kt/y of H2 in 2030 (e.gb METHANEX)	 Consumption for electricity production I thermal plants: 400 kt/y (e.g MDEPC)	2,500 kt/y
Future potential H2 off-takers related to new industrial sites (announced green H2 project and development of new usage)	 500 kt/y ammonia and 900 kt/y of am. nitrate which represent 250 kt/y H2 (e.g ABU QIR Fertilizers plant project in Ain Sokhna)	 Potential for DRI development through development of new steel industry sites: additional 1 Mt/y of primary steel which represent 72 kt/y of H2	 3 Mt/y of petroleum products which represent 35 kt/y of H2 (e.g ANOPC petrol diesel production complex)	 2 Mt/y methanol which represent 250 kt/y H2 (e.g ABU QIR Fertilizers and HELWAN Fertilizers plant project in Ain Sokhna)	 Green H2 to substitute gas in transports in the long term – estimated to 50 kt/y	>650 kt/y

 Thermal plants

 Fertilizers

 Steel

 Refinery

 Chemicals





Thermal plants



Fertilizers



Steel



Refinery



Chemicals

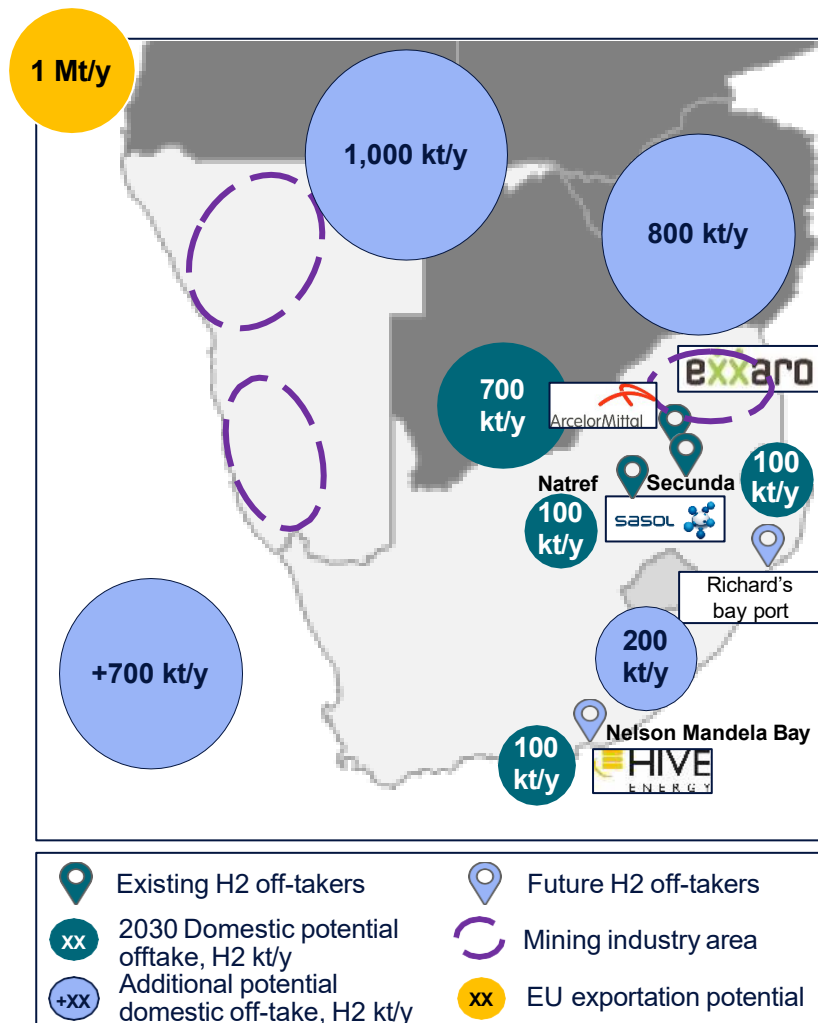
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Details of key sites' H2 demand to address – Southern Africa – Vision 2030

Domestic demand should be driven by a development of new H2 sites with announced projects (~2.5Mt H2/y), adding up to existing refineries and steel production sites (~1.5Mt)



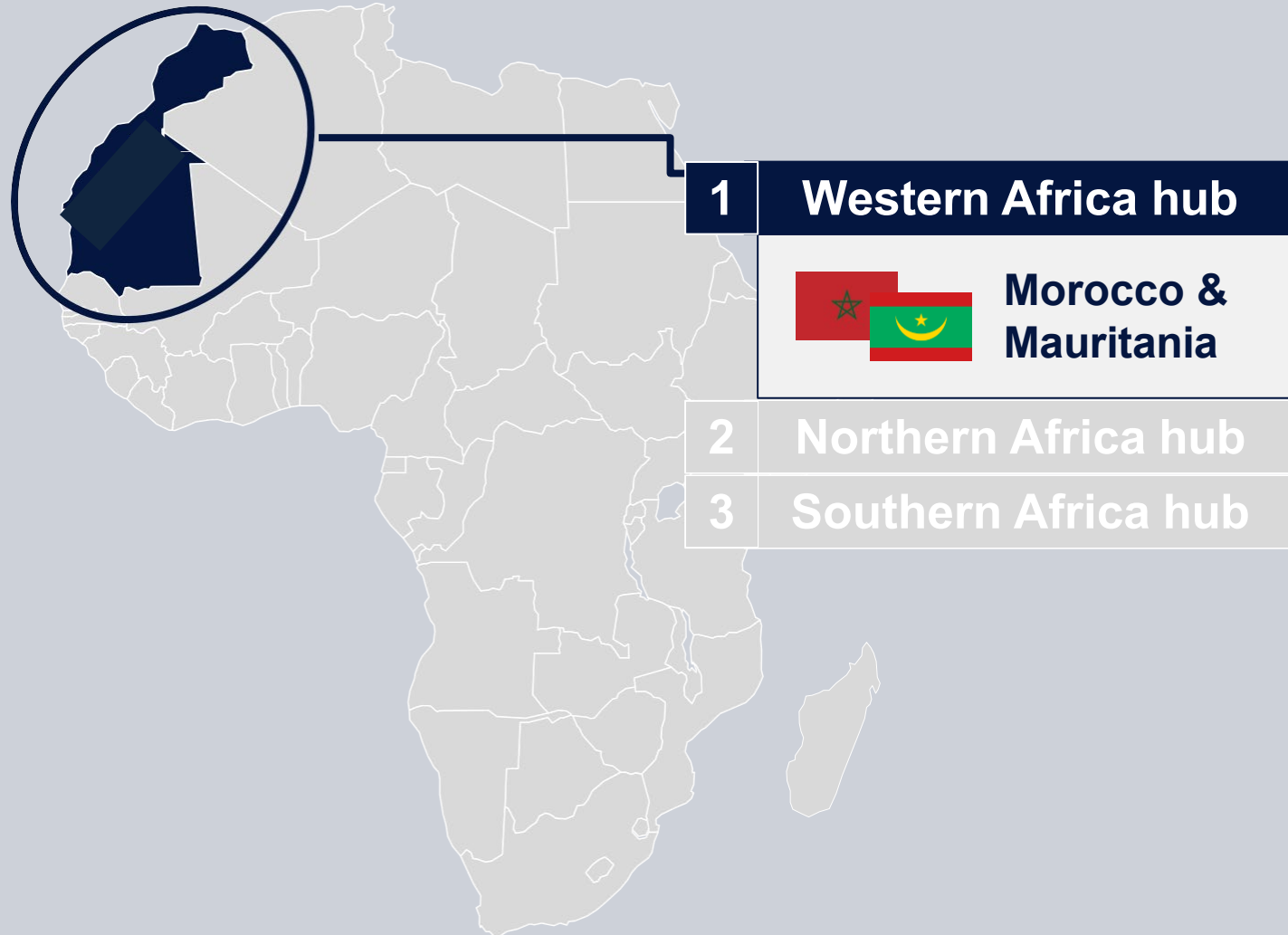
Focus on domestic demand

	Namibia	South Africa	Estimated potential H2 off-take volumes (2030)
Existing sites with existing or potential offtake	<p>Currently no main DRI, Ammonia or chemical industries with significant H2 consumption</p>	<p>Consumption of H2 by refining industry (e.g. SASOL largest refiner with 2 factories located in the North-East): 500k barrels/day representing ~140kt H2</p> <p>Overall industry: 500kt H2</p>	<p>Consumption of H2 by steel industry: Arcelor Mittal plant: 5 Mt of primary steel in 2021 representing ~350 kt H2</p> <p>Overall industry by 2030: 10 Mt of steel representing 1,000kt H2</p> <p>1,500 kt/y</p>
Future H2 off-takers related to new sites (announced green H2 project)	<p>Mining: fuel for mining trucks (mining industry represents 10% of the national GDP): 1Mt/y of H2</p> <p>Potential DRI industry development: 2 Mt/y of primary steel which represent 150 kt/y of H2</p> <p>Potential Ammonia industry development 100 kt/y of H2</p>	<p>World's largest green ammonia plant planned for 2025 (Hive Energy) – Projected volume: 1Mt/y of green ammonia = ~200 kt H2</p> <p>Mining: fuel for mining trucks – 800 kt H2/y</p> <p>Further development of steel industry: 3 Mt/y of primary steel = ~200 kt/y of H2</p> <p>Other: Mobility: fuel for heavy and medium duty trucks for freight: 50 kt H2/y</p> <p>> 2,500 kt/y</p>	



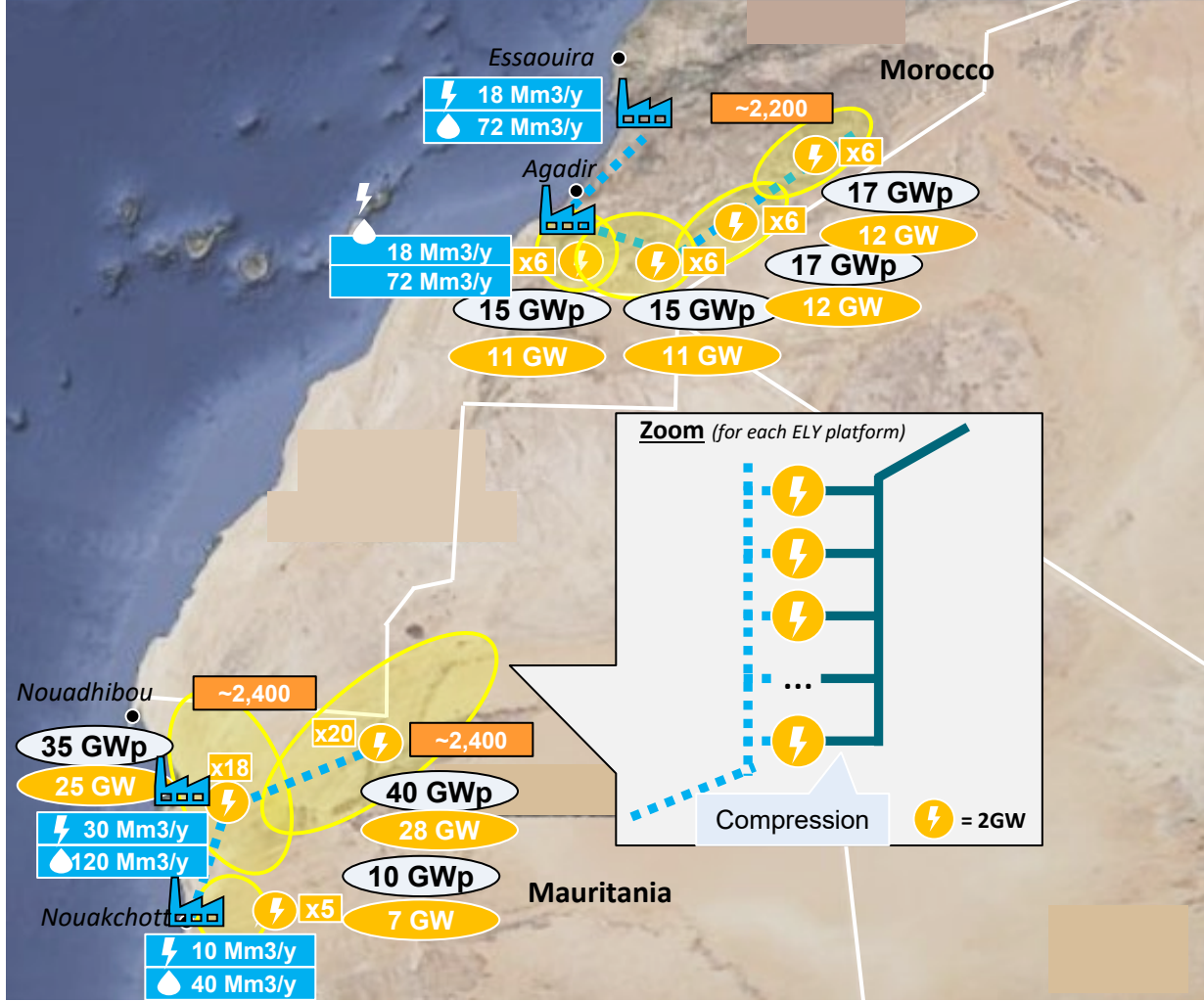
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Focus on Morocco / Mauritanian hubs – Upstream model by 2030: 150 GWp of solar capacity and 105 GWe of electrolysis capacity to be installed

Link between desalination plants and green H2 plants managed through the **development of a large fresh water supply system**, opening development potentials for a part of the countries



Key

Production

X

Solar Capacity to be installed by 2030 (GWp)

Suitable area for solar development

X

Solar yield (kWh/kWp/y)

Desalination plant

X GW

Electrolysis installed capacity

X Mm3/y

Water volumes required for electrolysis (Mm3/y)

X Mm3/y

Water volumes available for other usages (agriculture, drinking..)

X

Electrolysis platform (number of solar2H2 plants)

T&S

Potential International H2 backbones

Water pipe

Cities

Design & sizing details

Solar generation

150 GWp in 7 areas

25 MW (representing 40 GWh a year) of additional solar capacities to partially feed desalination plants for water generation dedicated to electrolysis

About 170 GWh a year of electricity used from the grid to complement the sourcing (water generation for other usage)

Water desalination

76 Mm3/y of water required from desalination for electrolysis

Up to 300 Mm3/y of fresh water available for agriculture and drinking water: 53% (160 Mm3) in Mauritania (covering ~66% of current Mauritanian needs for agriculture) and 47% (140 Mm3) in Morocco

Water transportation

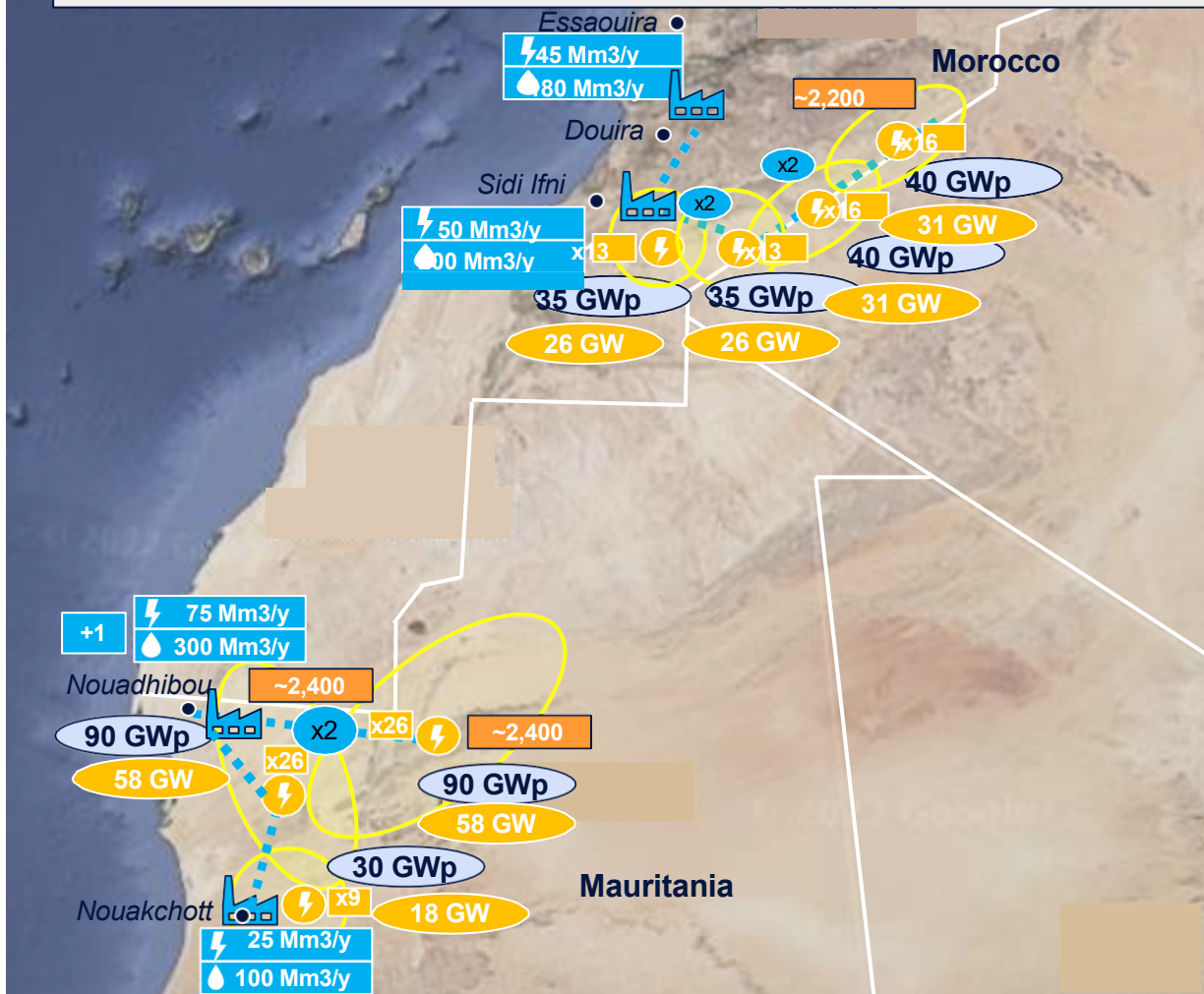
1,600 km of pipeline structures from desalination facilities to electrolysis platforms

Electrolysis

7 electrolysis domains with a total capacity of 105 GW

Focus on Morocco / Mauritanian hubs – Upstream model by 2035: 360 GWp of solar capacity and 248 GWe of electrolysis capacity to be installed

Solar and electrolysis capacities multiplied by ~2.5 vs. 2030 implying the commissioning of **63 new solar2H2 plants** and **1 new desalination plants**



Key

Production

- Solar Capacity to be installed by 2030 (GWp)
- Suitable area for solar development
- Solar yield (kWh/kWp/y)
- Desalination plant
- Electrolysis installed capacity
- X Mm³/y Water volumes required for electrolysis (Mm³/y)
- X Mm³/y Water volumes available for other usages (agriculture, drinking..)
- Electrolysis platform (number of solar2H2 plants)

T&S

- Potential International H2 backbones
- Water pipe
- Number of parallel water pipes required
- Cities

Design & sizing details

Solar generation

- Up to 360 GWp in 7 areas, representing around 0.5 Mha
- 100 GWh/year of additional solar capacities to feed desalination plants for water generation dedicated to ELY

Water desalination

- Up to 200 Mm³/y of water required from desalination for electrolysis
- No additional desalination plants required in Morocco and 1 additional desalination plant in Mauritania
- Up to 800 Mm³/y of fresh water available for agriculture and drinking water: 53% (420 Mm³) in Mauritania (covering ~33% of current Mauritanian needs for agriculture) and 47% (380 Mm³) in Morocco covering ~2.5% of current Moroccan needs for agriculture)

Water transportation

- Around 2,700 km of water pipe infrastructures from desalination facilities to electrolysis platforms

Electrolysis

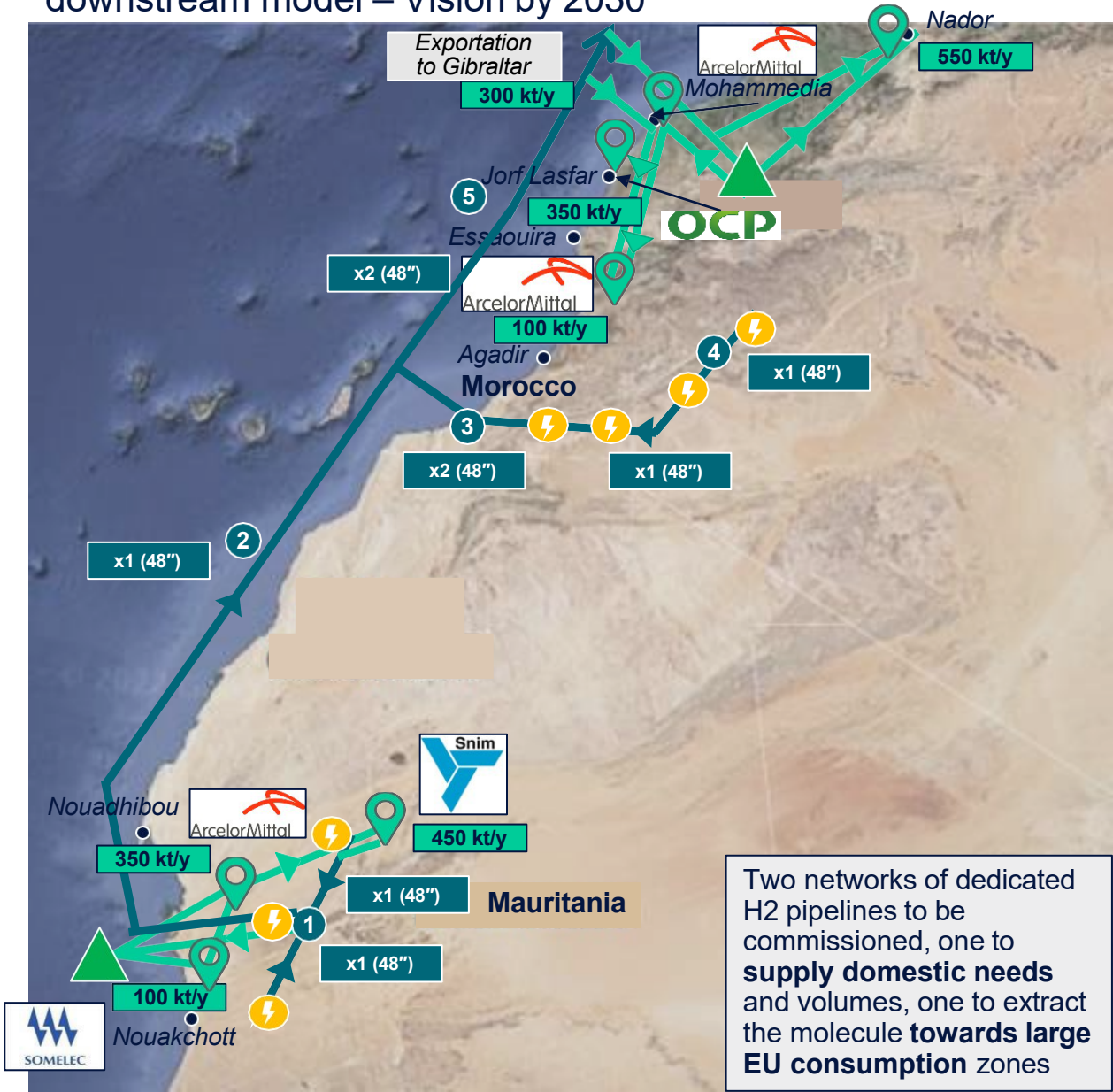
- 7 electrolysis domains with a total capacity of 250 GW

Note (1): Capacity of the largest desalination plants in the world is ~1 Mm³/day




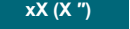





Sources: ONNE, [ArcelorMittal](#), [Moroccan government H2 roadmap](#), [Economics of hydrogen](#), MISO energy, CVA analysis




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Focus on Morocco / Mauritanian hubs – Midstream and downstream model – Vision by 2030

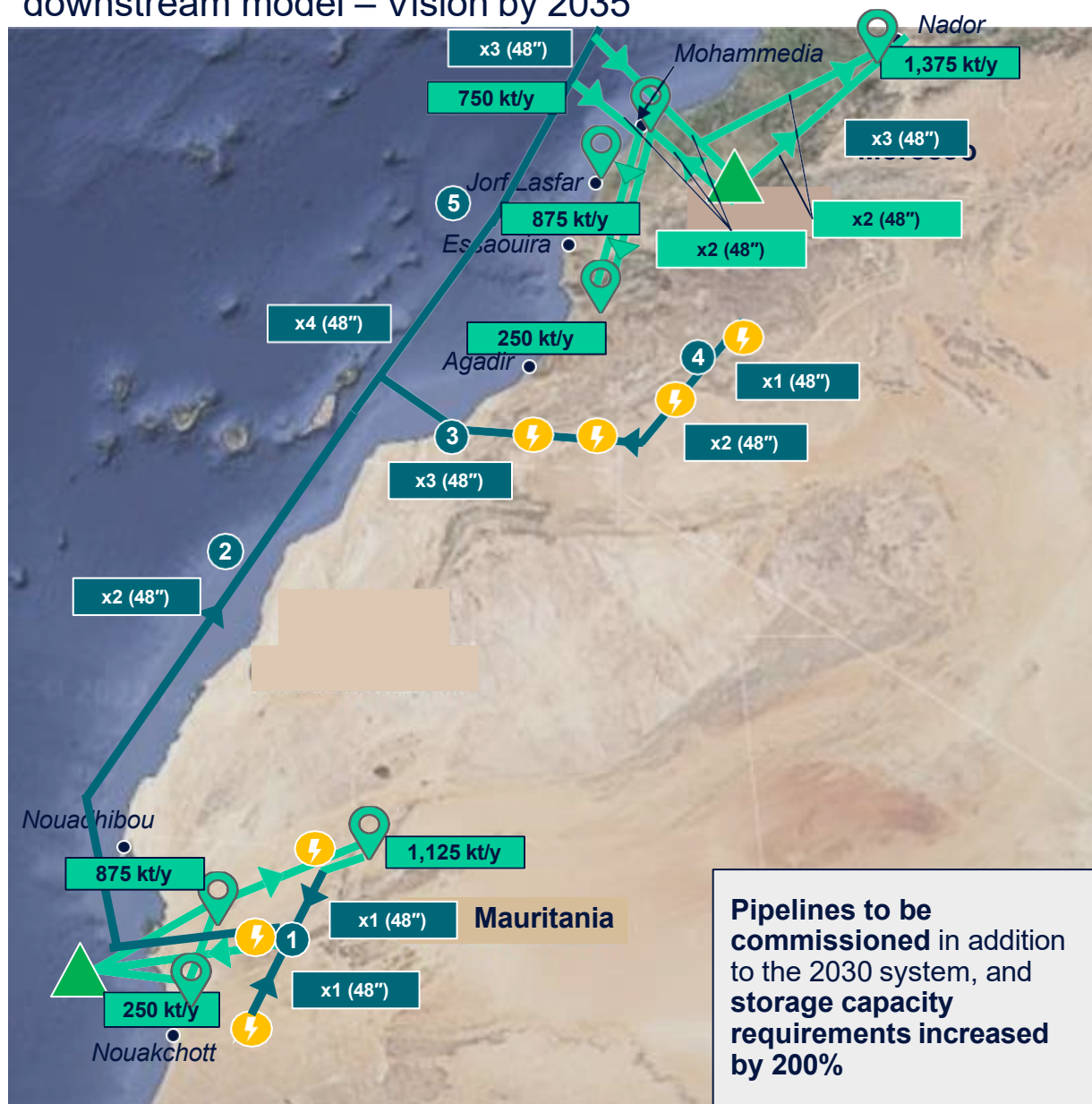


*When not detailed, the pipe is a simple 48" greenfield pipe

Key	
Production	
	Electrolysis platform
<hr/>	
T&S	
	Domestic H2 pipeline to be built
	Potential International H2 backbone
	Number of parallel pipelines (diameter of the pipe section, inches)
	International pipe length:
	1. 250 km
	2. 1,500 km
	3. 600 km
	4. 400 km
	5. 1,050 km
<hr/>	
Off-takers	
	 H2 Off-taker
	Domestic H2 volumes off-take (kt/y)
<hr/>	
Storage	
	Existing or potential salt cavern geological site

Design & sizing details	
	H2 generation
<ul style="list-style-type: none">5 Mt H2 produced in 2030 to meet:<ul style="list-style-type: none">Domestic demand in 3 main areas (~2Mt)International exportation (~3Mt)	
<hr/>	
	H2 storage
<ul style="list-style-type: none">2 national storage sites (salt caverns) to be sized for H2 dispatch management with connections to off-take sites:<ul style="list-style-type: none">23 Mm3 storage capacity in Mauritania22 Mm3 in Morocco	
<hr/>	
	H2 transportation
<ul style="list-style-type: none">1,200 km of H2 simple 48 inches greenfield pipes for domestic use in Mauritania and 1,900 km in Morocco, connected with 2 storage sites.Up to 2,800 km offshore backbone along Mauritania and Morocco west coast to Gibraltar – sections requiring up to 2 parallel 48 inches greenfield pipes	

Focus on Morocco / Mauritanian hubs – Midstream and downstream model – Vision by 2035



Key	
Production	
	Electrolysis platform
T&S	
	Domestic H2 pipeline to be built
	Number of <u>additional</u> domestic parallel pipeline and diameter of the pipe section
	Potential internat. H2 backbone
	Nb. of <u>additional</u> internat. pipelines vs. 2030 (diameter of the pipe section, inches)
	International pipe length:
	1. 250 km
	2. 1,500 km
	3. 600 km
	4. 400 km
	5. 1,050 km
Off-takers	
	H2 Off-taker
	Domestic H2 volumes off-take (kt/y)
Storage	
	Existing or potential salt cavern geological site

Design & sizing details	
	H2 generation
<ul style="list-style-type: none"> 12.5 Mt H2 produced in 2035 to meet: <ul style="list-style-type: none"> Domestic demand in 3 main areas (~5 Mt) International exportation (~7.5 Mt) 	
	H2 storage
<ul style="list-style-type: none"> 2 storage sites to be sized for H2 dispatch management (salt caverns) with connections to off-take sites <ul style="list-style-type: none"> 52 Mm3 storage capacity in Mauritania 50 Mm3 storage in Morocco Total represents ~0.1% of EU's underground Gas storage capacity 	
	H2 transportation
<ul style="list-style-type: none"> 1,200 km of H2 simple 48 inches greenfield pipes for domestic use in Mauritania and 1,900 km in Morocco, connected with 2 storage sites – sections with up to 2 parallel pipes. Up to 2,800 km offshore international backbone along Mauritania and Morocco west coast to Gibraltar – sections requiring up to 4 parallel 48 inches greenfield pipes 	







*Additional greenfield pipeline to the infrastructures built in 2030 – when not detailed, the pipe is a simple 48 inches greenfield pipe

Sources: ONNE, [ArcelorMittal](#), [Moroccan government H2 roadmap](#), [Economics of hydrogen](#), MISO energy, CVA analysis

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The H2 hub systems feature designs implying mass scale sizing while corresponding to managed capacities

The upstream and midstream sizing involves capacities falling into standards of existing industrial designs

	Capacity required	Check / benchmark	Capacity management
PV	<ul style="list-style-type: none"> 150 GWp by 2030 to 360 GWp by 2035 of solar capacity to be installed Surface power capacity density of 1.5 ha / MW 	<ul style="list-style-type: none"> Total required surface of 225,000 ha by 2030 and 540,000 ha by 2035 : 0.1% to 0.3% of the total countries area 	
Desalination	<ul style="list-style-type: none"> Desalination capacity required : 376 Mm3 by 2030 and 1,000 Mm3 by 2035 4 to 5 desalination facilities with a capacity of 250 Mm3/y 	<ul style="list-style-type: none"> Desalination plants designed with a capacity of ~250 Mm3/y, i.e. ~70% of the current largest desalination plants in the world (e.g. in RAK, Saudi Arabia or in Taweelah, UAE) 	
Water pipe	<ul style="list-style-type: none"> 1,600 to 2,700 km of water transportation pipe infrastructures, including double pipe sections by 2035 Water pipe designed with a maximum of 60 inches 	<ul style="list-style-type: none"> Total length acceptable, i.e. 90% of Manmade pipeline Water pipe designed with diameter of 60 inches, i.e. ~75% of the largest water pipeline diameters in the world (e.g. Oguz-Gabala-Baku Water Pipeline) 	
Electrolysis	<ul style="list-style-type: none"> Units of 2GWp captive solar plants, injecting in electrolysis platforms with a total electrolysis capacity of 105 GWe by 2030 and 248 GWe by 2035 	<ul style="list-style-type: none"> ~300 MWe global electrolysis installed capacity in 2020 	 <div data-bbox="2186 868 2339 982">~1000x current global electrolysis capacity</div>
H2 pipe	<ul style="list-style-type: none"> Total length of greenfield pipes infrastructures is 3,700 H2 pipes designed with 48 inches diameter 	<ul style="list-style-type: none"> ~1% of total global brownfield transport infrastructure length in 2020 and around 4x Nord Stream gas pipe length 	
Storage	<ul style="list-style-type: none"> 45 Mm3 by 2030 and 102 Mm3 by 2035 of metric storage volume required 2 potential salt dome geological storage sites 	<ul style="list-style-type: none"> ~0.1% of total EU underground storage capacities Typical salt cavern volume capacity is 0.5 to 1 Mm3 	



Focus on Egypt hub – Upstream model by 2030: 240 GWp of solar capacity and 185 GWe of electrolysis capacity to be installed



Key

Production

X

Solar Capacity to be installed by 2030 (GWp)

Suitable area for solar development

X

Solar yield (kWh/kWp/y)

Desalination plant

X GW

Electrolysis installed capacity

X Mm3/y

Water volumes required for electrolysis (Mm3/y)

X Mm3/y

Water volumes available for other usages (agriculture, drinking..)

X

Electrolysis platform (number of solar2H2 plants)

T&S

Water pipe

Cities

Design & sizing details

Solar generation

• 240 GWp in 5 areas

• 53 MW (representing 84 GWh a year) of additional solar capacities to partially feed desalination plants for water generation dedicated to electrolysis

• About 335 GWh a year of electricity used from the grid to complement the sourcing (water generation for other usage)

Water desalination

• 150 Mm3/y of water required from desalination for electrolysis

• Up to 600 Mm3/y of fresh water available representing 1% of current agricultural water needs

Water transportation

• 720 km of water pipe infrastructures from desalination facilities to electrolysis platforms

Electrolysis

• 5 electrolysis domains with a total capacity of 185 GW

Sources: Oxford Institute, Economics of hydrogen, NREL, CVA analysis

Focus on Egypt hub – Upstream model by 2035: 451 GWp of solar capacity and 351 GWe of electrolysis capacity to be installed



Note (1): Capacity of the largest desalination plants in the world is ~1 Mm3/day
 Sources: Oxford Institute, [Economics of hydrogen](#), NREL, CVA analysis





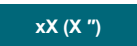








Key	Design & sizing details
Production <ul style="list-style-type: none"> Solar Capacity to be installed by 2030 (GWp) Suitable area for solar development Solar yield (kWh/kWp/y) Desalination plant Electrolysis installed capacity X Mm3/y Water volumes required for electrolysis (Mm3/y) X Mm3/y Water volumes available for other usages (agriculture, drinking..) Electrolysis platform (number of solar2H2 plants) 	<ul style="list-style-type: none"> Solar generation <ul style="list-style-type: none"> 451 GWp in 5 areas 107 MW (representing 168 GWh a year) of additional solar capacities to partially feed desalination plants for water generation dedicated to electrolysis About 672 GWh a year of electricity used from the grid to complement the sourcing (water generation for other usage) which represent >0.5% of the national electricity consumption in 2019
T&S <ul style="list-style-type: none"> Potential International H2 backbones Water pipe Number of parallel water pipes required Cities 	<ul style="list-style-type: none"> Water desalination <ul style="list-style-type: none"> 300 Mm3/y of water required from desalination for electrolysis Up to 1,200 Mm3/y of fresh water available representing 3% of current agricultural water needs Water transportation <ul style="list-style-type: none"> 1,030 km of water pipe infrastructures from desalination facilities to electrolysis platforms Electrolysis <ul style="list-style-type: none"> 5 electrolysis domains with a total capacity of 351 GW

Focus on Egypt hub – Midstream and downstream model – Vision by 2030



*When not detailed, the pipe is a simple 48" greenfield pipe

Sources: Oxford Institute, [Economics of hydrogen](#), NREL, CVA analysis

Key	Design & sizing details
<h3>Production</h3> <p> Electrolysis platform</p> <hr/> <h3>T&S</h3> <p> Domestic H2 pipeline to be built</p> <p> Existing gas pipeline</p> <p> Potential International H2 backbone</p> <p> Number of parallel pipelines (diameter of the pipe section, inches)</p> <p> International pipe length:</p> <ol style="list-style-type: none"> 110 km 230 km 220 km 150 km 190 km <hr/> <h3>Off-takers</h3> <p>  H2 Off-taker</p> <p> Domestic H2 volumes off-take (kt/y)</p> <hr/> <h3>Storage</h3> <p> Existing or potential salt cavern geological site</p>	<div>  <h3>H2 generation</h3> <ul style="list-style-type: none"> 10 Mt H2 produced in 2030 to meet: <ul style="list-style-type: none"> Domestic demand in 4 main areas (~3Mt) International exportation (~7Mt) </div> <hr/> <div>  <h3>H2 storage</h3> <ul style="list-style-type: none"> 1 national storage site (salt caverns) to be sized for H2 dispatch management with connections to off-take sites: <ul style="list-style-type: none"> 56 Mm3 storage capacity </div> <hr/> <div>  <h3>H2 transportation</h3> <ul style="list-style-type: none"> 2,310 km of H2 48 inches greenfield pipes for domestic use in Egypt, connected with 1 storage site. Sections requiring up to 3 parallel 48 inches greenfield pipes ... </div>

Focus on Egypt hub – Midstream and downstream model – Vision by 2035



*Additional greenfield pipeline to the infrastructures built in 2030 – when not detailed, the pipe is a simple 48 inches greenfield pipe







Sources: Oxford Institute, [Economics of hydrogen](#), NREL, CVA analysis

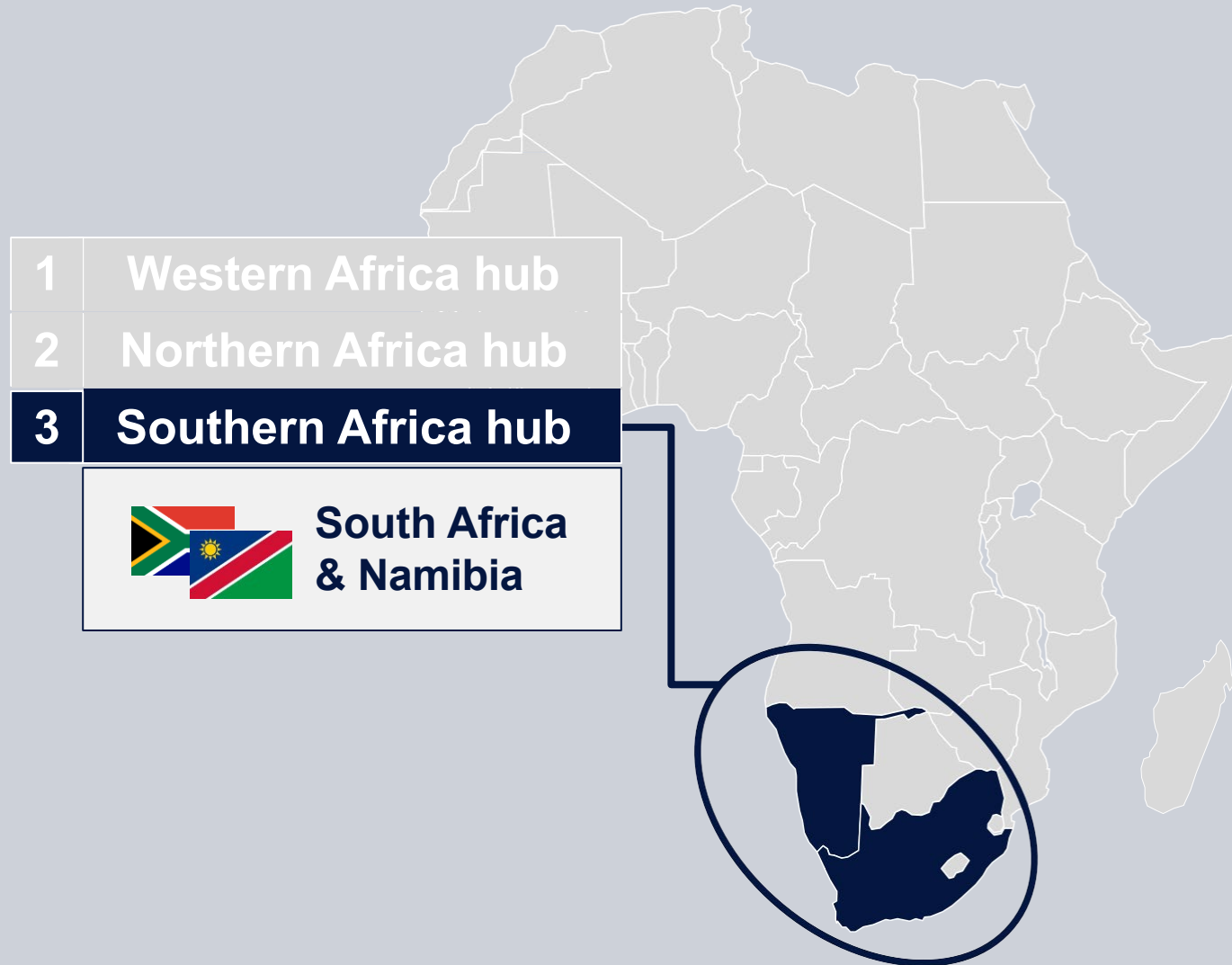
Key	Design & sizing details
Production <ul style="list-style-type: none"> ⚡ Electrolysis platform 	H₂ generation <ul style="list-style-type: none"> 20 Mt H₂ produced in 2035 to meet: <ul style="list-style-type: none"> Domestic demand in 4 main areas (~7.5Mt) International exportation (~12.5Mt)
T&S <ul style="list-style-type: none"> — Domestic H2 pipeline to be built — Existing gas pipeline — Potential International H2 backbone xX (X ") Number of parallel pipelines (diameter of the pipe section, inches) 1 International pipe length: <ol style="list-style-type: none"> 110 km 230 km 220 km 150 km 190 km 	H₂ storage <ul style="list-style-type: none"> 1 national storage site (salt caverns) to be sized for H₂ dispatch management with connections to off-take sites: <ul style="list-style-type: none"> 105 Mm3 storage capacity Total is <0.1% of Europe's Underground Gas Storage capacity but restricted to one area only
Off-takers <ul style="list-style-type: none"> 📍 H₂ Off-taker X kt/y Domestic H₂ volumes off-take (kt/y) 	H₂ transportation <ul style="list-style-type: none"> 2,310 km of H₂ 48 inches greenfield pipes for domestic use in Egypt, connected with 1 storage site. Sections requiring up to 5 parallel 48 inches greenfield pipes ...
Storage <ul style="list-style-type: none"> ▲ Existing or potential salt cavern geological site 	

Salt caverns potential capacity to be assessed

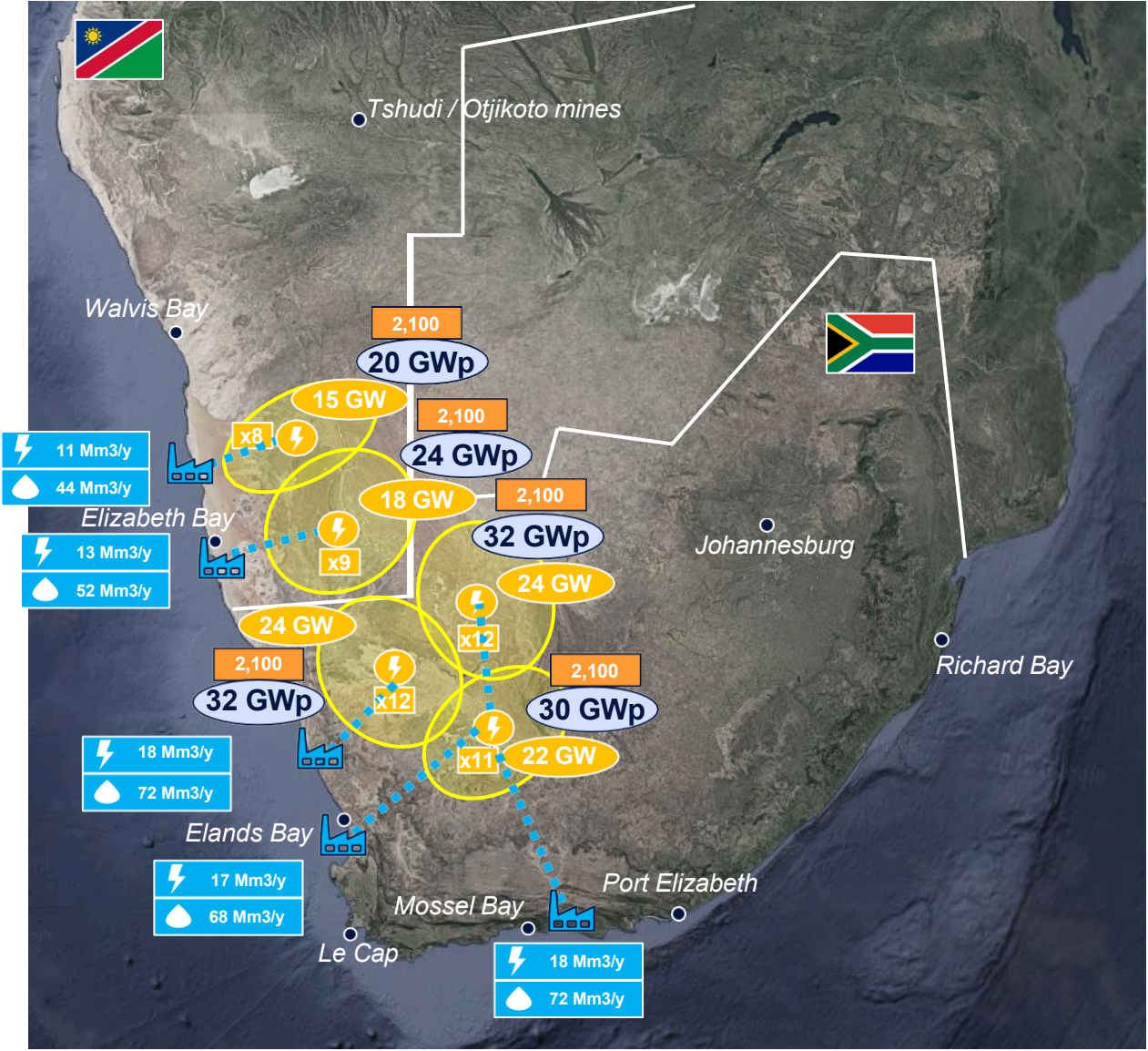
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The upstream and midstream sizing involves capacities falling into standards of existing industrial designs

	Capacity required	Check / benchmark	Capacity management
PV	<ul style="list-style-type: none"> 240 GWp by 2030 to 451 GWp by 2035 of solar capacity to be installed Surface power capacity density of 1.5 ha / MW 	<ul style="list-style-type: none"> Total required surface of 360,000 ha by 2030 and 677,000 ha by 2035 < 0.7% of the total countries area 	
Desalination	<ul style="list-style-type: none"> Desalination capacity required : 750 Mm3 by 2030 and 1,500 Mm3 by 2035 6 desalination facilities with a capacity of 250 Mm3/y 	<ul style="list-style-type: none"> Desalination plants designed with a capacity of ~250 Mm3/y, i.e. ~70% of the current largest desalination plants in the world (e.g. in RAK, Saudi Arabia or in Taweelah, UAE) 	
Water pipe	<ul style="list-style-type: none"> 720 to 1,030 km of water transportation pipe infrastructures, including one double pipe section by 2035 Water pipe designed with a maximum of 60 inches 	<ul style="list-style-type: none"> Realistic length, ~30% of Manmade pipeline Water pipe designed with diameter of 60 inches, i.e. ~75% of the largest water pipeline diameters in the world (e.g. Oguz-Gabala-Baku Water Pipeline) 	
Electrolysis	<ul style="list-style-type: none"> Units of 2GWp captive solar plants, injecting in electrolysis platforms with a total electrolysis capacity of 185 GWe by 2030 and 351 GWe by 2035 	<ul style="list-style-type: none"> ~300 MWe global electrolysis installed capacity in 2020 	<div>~1000x current global electrolysis capacity</div> 
H2 pipe	<ul style="list-style-type: none"> Total cumulated length of greenfield pipes infrastructures is 2,310 km by 2030 and 4,000 by 2035 H2 pipes designed with 48 inches diameter Sections with up to 3 parallels pipes 	<ul style="list-style-type: none"> <1% of total global brownfield transport infrastructures length in 2020 and around 2 to 4 times Nord Stream gas pipe length 	
Storage	<ul style="list-style-type: none"> 56 Mm3 by 2030 and 105 Mm3 by 2035 of metric storage volume required <u>Only 1 potential salt dome geological storage site</u> 	<ul style="list-style-type: none"> ~0.1% of total EU underground storage capacities Typical salt cavern volume capacity is 0.5 to 1 Mm3 	<div>Limited geological potential</div> 



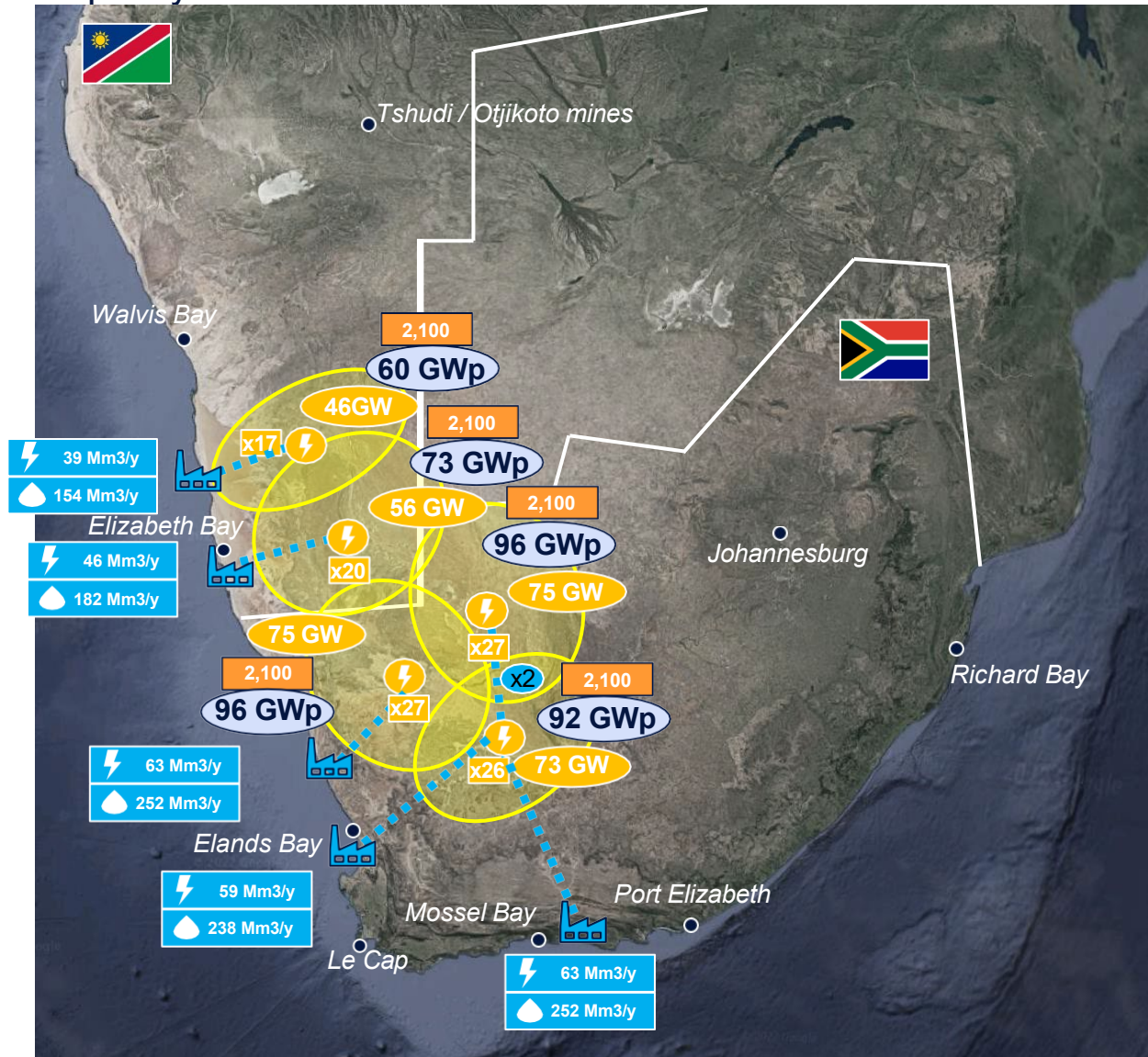
Focus on South-African hub – Upstream model by 2030:
138 GWp of solar capacity and 104 GWe of electrolysis capacity to be installed



Key	Design & sizing details
Production	Solar generation <ul style="list-style-type: none">138 GWp in 5 areas9 MW (representing 14 GWh a year) in Namibia and 19 MW (representing 30 GWh) in SA of additional solar capacity to partially feed desalination plants for water generation dedicated to electrolysisAbout 170 GWh a year of electricity used from the grid to complement the sourcing (water generation for other usage) which represent <1% of SA electricity generation
Solar Capacity to be installed by 2030 (GWp)	Water desalination <ul style="list-style-type: none">77 Mm3/y of water required from desalination for electrolysisUp to 308 Mm3/y of fresh water available: 31% (96 Mm3) in Namibia (covering mostly the overall current Namibian water consumption for agriculture) and 69% (212 Mm3) in South-Africa (covering around 2% of current SA agricultural water consumption)
Suitable area for solar development	Water transportation <ul style="list-style-type: none">570 km in Namibia and 1,000 km in SA of water pipe infrastructures from desalination facilities to electrolysis platforms
Solar yield (kWh/kWp/y)	Electrolysis <ul style="list-style-type: none">5 electrolysis domains with a total capacity of 104 GW
Desalination plant	
Electrolysis installed capacity	
X Mm3/y Water volumes required for electrolysis (Mm3/y)	
X Mm3/y Water volumes available for other usages (agriculture, drinking..)	
Electrolysis platform (number of solar2H2 plants)	
T&S	
Water pipe	
Cities	

Sources: [FAO Aquastat](#), CSIS, Department of Science and Innovation of South-Africa, CVA analysis

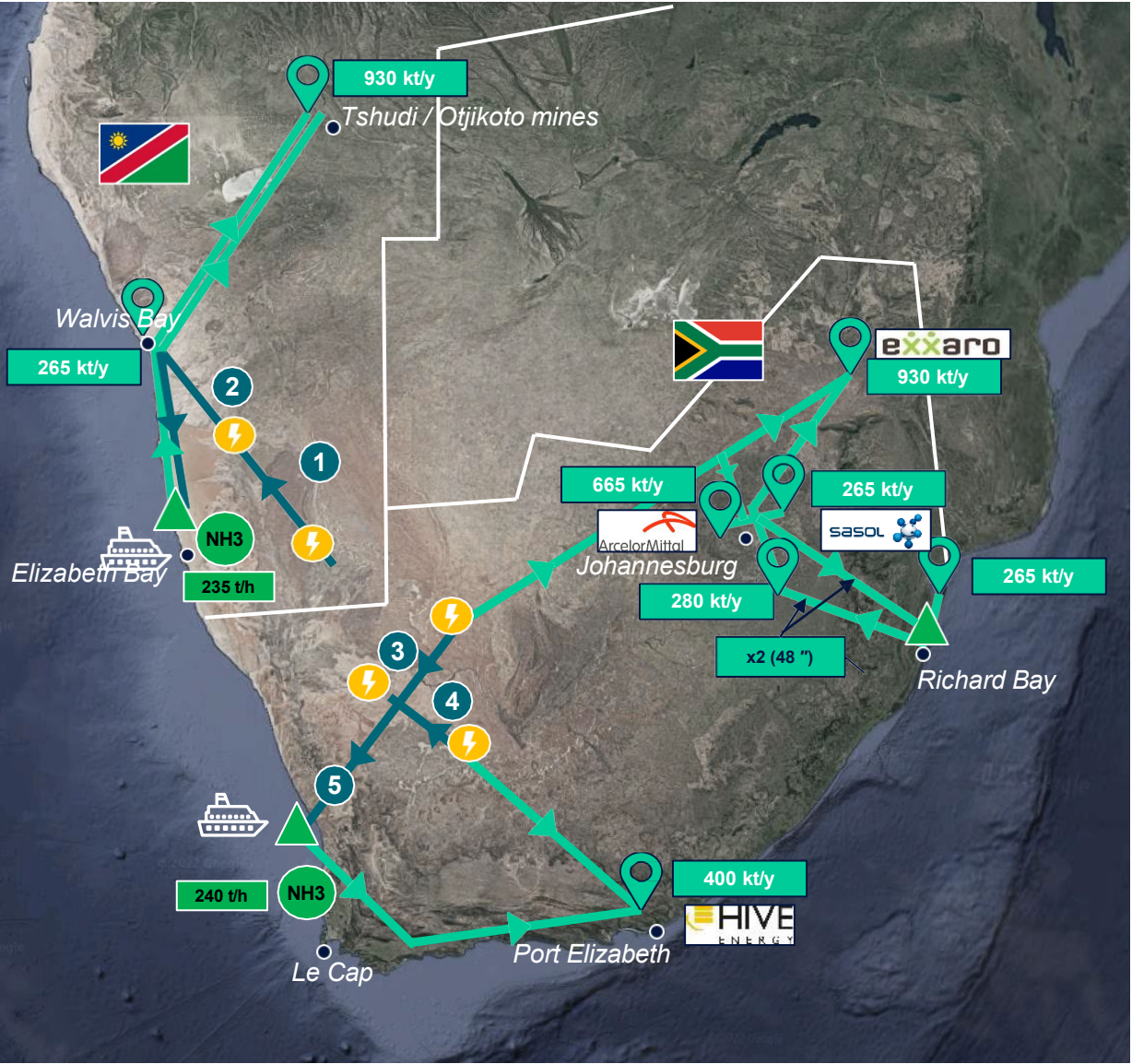
Focus on South-African hub – Upstream model by 2035: 420 GWp of solar capacity and 325 GWe of electrolysis capacity to be installed



Note (1): Capacity of the largest desalination plants in the world is ~1 Mm3/day
Sources: [FAO Aquastat](#), CSIS, Department of Science and Innovation of South-Africa, CVA analysis

Key	Design & sizing details
Production <ul style="list-style-type: none"> Solar Capacity to be installed by 2030 (GWp) Suitable area for solar development Solar yield (kWh/kWp/y) Desalination plant Electrolysis installed capacity Water volumes required for electrolysis (Mm3/y) Water volumes available for other usages (agriculture, drinking..) Electrolysis platform (number of solar2H2 plants) 	<ul style="list-style-type: none"> Solar generation <ul style="list-style-type: none"> 300 GWp in 5 areas 29 MW (representing 46 GWh a year) in Namibia and 66 MW (representing 104 GWh) in SA of additional solar capacity to partially feed desalination plants for water generation dedicated to electrolysis About 467 GWh a year of electricity used from the grid to complement the sourcing (water generation for other usage) which represent <2% of SA electricity generation Water desalination <ul style="list-style-type: none"> 270 Mm3/y of water required from desalination for electrolysis Up to 1,080 Mm3/y of fresh water available: 31% (335 Mm3) in Namibia (covering more that 2 times the overall current Namibian water consumption for agriculture, industry and municipalities) and 69% (745 Mm3) in South-Africa (covering 7% of current SA agricultural water consumption) Water transportation <ul style="list-style-type: none"> 570 km in Namibia and 1,240 km in SA of water pipe infrastructures from desalination facilities to electrolysis platforms Electrolysis <ul style="list-style-type: none"> 5 electrolysis domains with a total capacity of 325 GW
T&S <ul style="list-style-type: none"> Water pipe Number of parallel water pipes required Cities 	

Focus on South-African hub – Midstream and downstream model – Vision by 2030

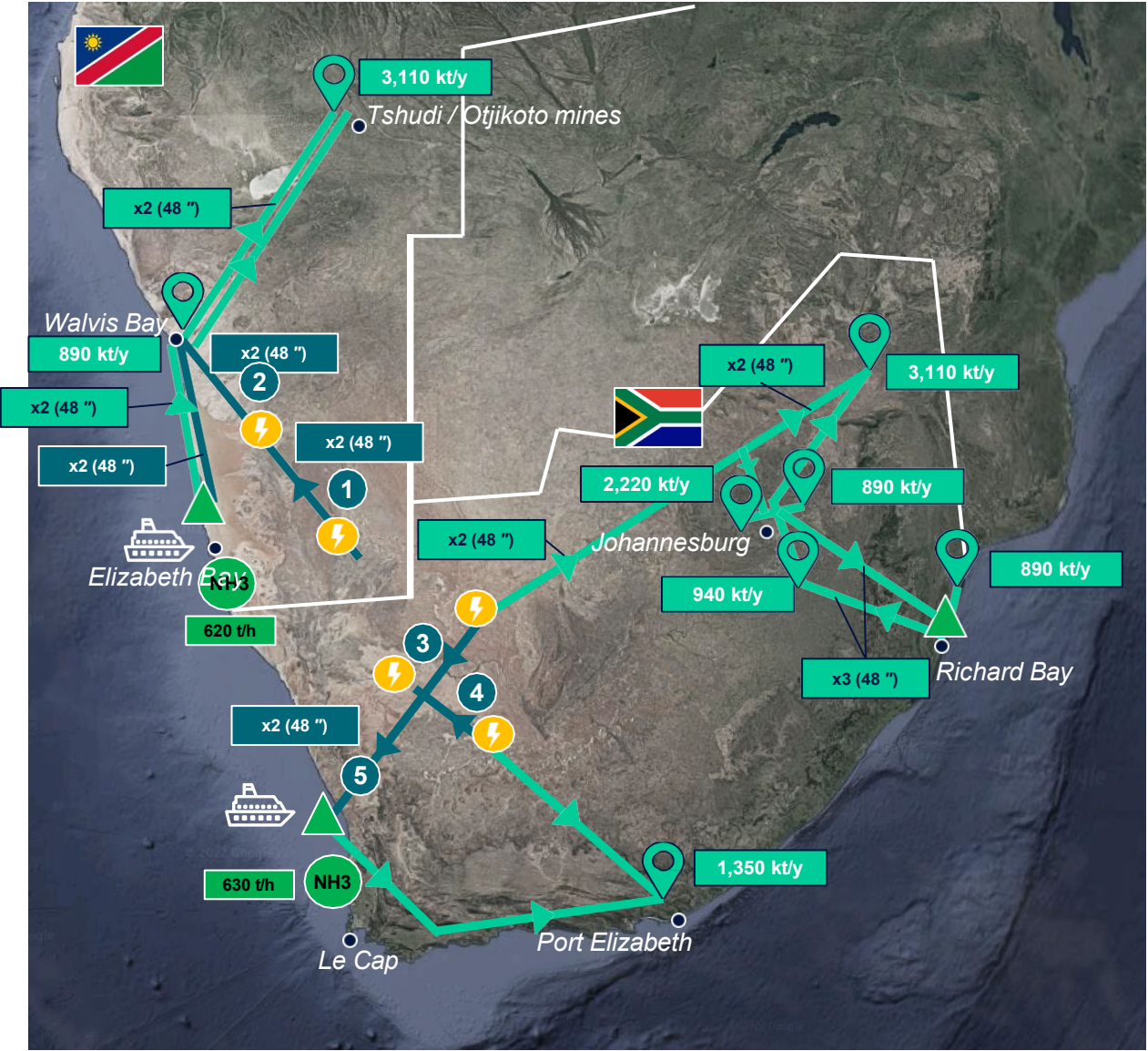


*When not detailed, the pipe is a simple 48" greenfield pipe

Sources: [FAO Aquastat](#), CSIS, Department of Science and Innovation of South-Africa, CVA analysis

Key	Design & sizing details
Production Electrolysis platform	H2 generation <ul style="list-style-type: none">5 Mt H2 produced in 2030 to meet:<ul style="list-style-type: none">Domestic demand in 6 main areas (~4Mt)International exportation (~1Mt)
T&S Domestic H2 pipeline to be built Existing gas pipeline Potential International H2 backbone Number of parallel pipelines (diameter of the pipe section, inches) International pipe length: <ol style="list-style-type: none">240 km170 km140 km100 km240 km	H2 storage <ul style="list-style-type: none">2 storage sites in SA and 1 in Namibia to be sized for H2 dispatch management with connections to off-take sites:<ul style="list-style-type: none">10 and 20 Mm3 storage capacity in SA10 Mm3 storage capacity in Namibia
Off-takers H2 Off-taker Domestic H2 volumes off-take (kt/y) Port infrastructure for H2 exportation as NH3	H2 transportation <ul style="list-style-type: none">5,500 km of H2 transportation pipes : 48 inches greenfield connected with 2 storage sites in South-Africa and one in NamibiaUp to 2 parallels pipes
Storage Existing or potential salt cavern geological site Ammonia facility for exportation of H2 as NH3 Ammonia max. capacity required	NH3 exportation <ul style="list-style-type: none">1 Mt of H2 to be exported by boat as ammoniaStorage capacity available for line pack process: 3Mt H2 in SA and 1Mt in Namibia235 t/h ammonia production capacity facility in Namibia and 240 t/h in SA

Focus on South-African hub – Midstream and downstream model – Vision by 2035










*When not detailed, the pipe is a simple 48" greenfield pipe

Sources: [FAO Aquastat](#), CSIS, Department of Science and Innovation of South-Africa, CVA analysis

Key	Design & sizing details
Production Electrolysis platform	H₂ generation <ul style="list-style-type: none">17.5 Mt H₂ produced in 2035 to meet:<ul style="list-style-type: none">Domestic demand in 6 main areas (~13.5 Mt), incl. H₂ for export of finished products (steel & fertilizers)International export. (~4 Mt)
T&S Domestic H2 pipeline to be built Existing gas pipeline Potential International H2 backbone Number of parallel pipelines (diameter of the pipe section, inches) International pipe length: 1. 240 km 2. 170 km 3. 140 km 4. 100 km 5. 240 km	H₂ storage <ul style="list-style-type: none">2 storage sites in SA & 1 in Namibia to be sized for H₂ dispatch mgmt. with connections to off-take sites:<ul style="list-style-type: none">~70 Mm³ storage capacity in SA~30 Mm³ storage capacity in NamibiaTotal <0.1% of Europe's Underground Gas Storage capacity
Off-takers H ₂ Off-taker Domestic H ₂ volumes off-take (kt/y) Port infrastructure for H ₂ exportation as NH ₃	H₂ transportation <ul style="list-style-type: none">5,500 km of H₂ transportation pipes: 48 inches greenfield connected with 2 storage sites in South-Africa and one in NamibiaUp to 3 parallels pipes
Storage Existing or potential salt cavern geological site Ammonia facility for exportation of H ₂ as NH ₃ Ammonia max. capacity required	NH₃ exportation <ul style="list-style-type: none">4 Mt to be exported by boat as ammoniaStorage capacity available for line pack process: 4.5 MtH₂ in SA and 2.1 Mt in Namibia620 t/h ammonia prod. capacity facility in Namibia and 630 t/h in SA

The H2 hub systems feature designs implying mass scale sizing while corresponding to managed capacities

The upstream and midstream sizing involves capacities falling into standards of existing industrial designs

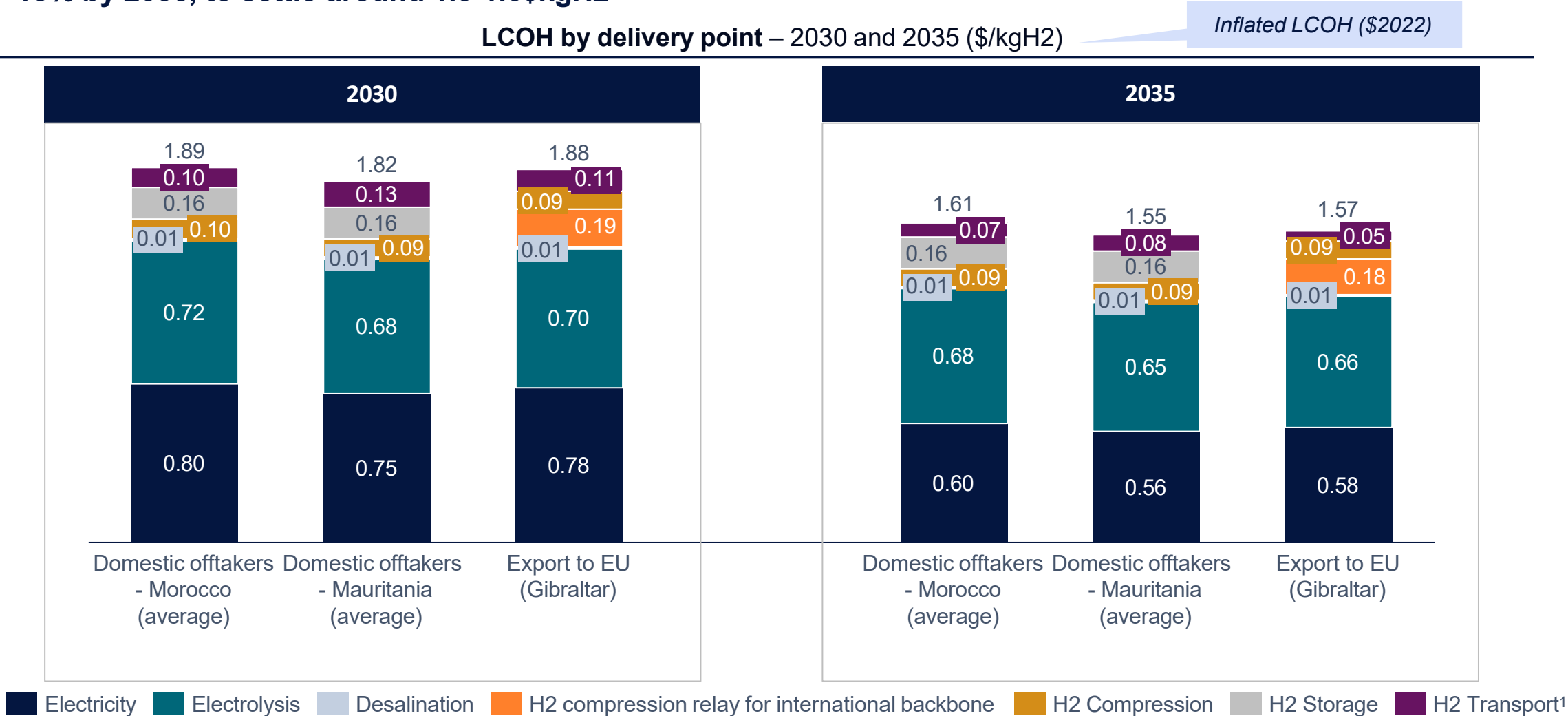
	Capacity required	Check / benchmark	Capacity management
PV	<ul style="list-style-type: none"> 138 GWp by 2030 to 420 GWp by 2035 of solar capacity to be installed Surface power capacity density of 1.5 ha / MW 	<ul style="list-style-type: none"> Total required surface of 207,000 ha by 2030 and 630,000 ha by 2035 < 0.1% of the total countries area 	
Desalination	<ul style="list-style-type: none"> Desalination capacity required : 385 Mm3 by 2030 and 1,350 Mm3 by 2035 5 desalination facilities with a capacity of 250 Mm3/y 	<ul style="list-style-type: none"> Desalination plants designed with a capacity of ~250 Mm3/y, i.e. ~70% of the current largest desalination plants in the world (e.g. in RAK, Saudi Arabia or in Taweelah, UAE) 	
Water pipe	<ul style="list-style-type: none"> 1,570 to 1,810 km of water transportation pipe infrastructures, including one double pipe section by 2035 Water pipe designed with a maximum of 60 inches 	<ul style="list-style-type: none"> Total length acceptable, i.e. ~60% of Manmade pipeline Water pipe designed with diameter of 60", i.e. ~75% of the largest water pipeline diameters in the world (e.g. Oguz-Gabala-Baku) 	
Electrolysis	<ul style="list-style-type: none"> Units of 2GWp captive solar plants, injecting in electrolysis platforms with a total electrolysis capacity of 104 GWe by 2030 and 325 GWe by 2035 	<ul style="list-style-type: none"> ~300 MWe global electrolysis installed capacity in 2020 	 <p>~500 to 1,000x current global electrolysis capacity</p>
H2 pipe	<ul style="list-style-type: none"> Total cumulated length of greenfield pipes infra. is 5,500 km by 2030 and 10,000 by 2035 / H2 pipes designed with 48 inches diameter, sections with up to 3 parallels pipes 	<ul style="list-style-type: none"> <1% of total global brownfield transport infrastructures length in 2020 and around 5 to 10 times Nord Stream gas pipe length 	
Storage	<ul style="list-style-type: none"> 40 Mm3 by 2030 and ~100 Mm3 by 2035 of metric storage volume required 3 potential salt dome geological storage site 	<ul style="list-style-type: none"> ~0,1% of total EU underground storage capacities Typical salt cavern volume capacity is 0.5 to 1 Mm3 	
Final product exportation	<ul style="list-style-type: none"> 98 Mt of steel production to be exported by 2035 and 42 Mt of fertilizers 	<ul style="list-style-type: none"> 5% of global steel production and 7% of global demand for fertilizers 	

Agenda

1. African H2 hubs system design – Demand equation to address – 2030 and 2035
2. African H2 hubs system design – Design and sizing of the 3 hubs
- 3. African H2 hubs system design – Resulting costs for the 3 hubs**
4. Value creation impact

Mauritanian / Morocco systems costing – LCOH per delivery zone

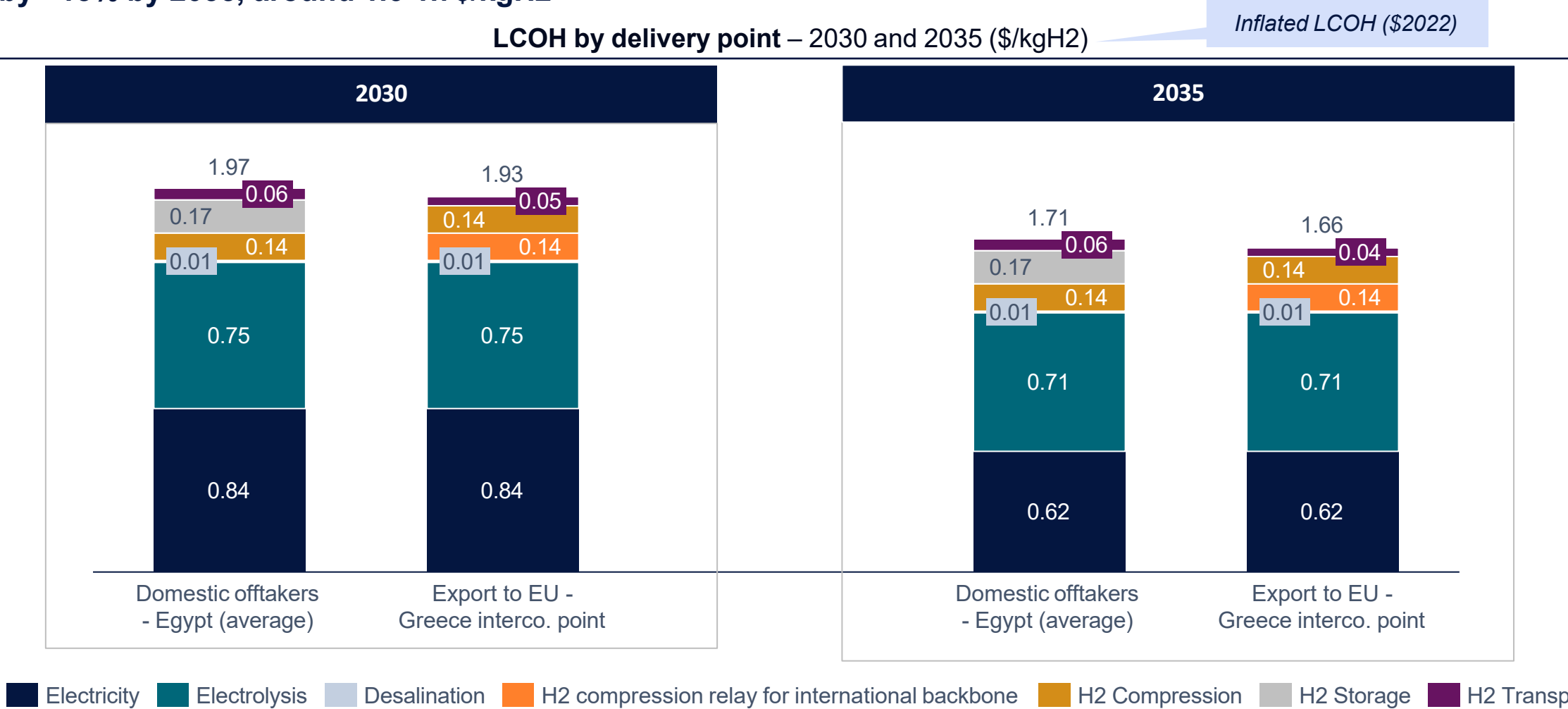
LCOHs around 1.8-1.9\$/kgH2 in 2030 both for domestic offtake and EU exports, expected to decrease by ~15% by 2035, to settle around 1.5-1.6\$/kgH2



Note (1): Corresponds to transportation through greenfield pipes – domestic costs for transportation include domestic greenfield and international backbone proportionally to the share of total production / EU costs for transportation include only international backbone costs

Egypt system costing – LCOH per delivery zone

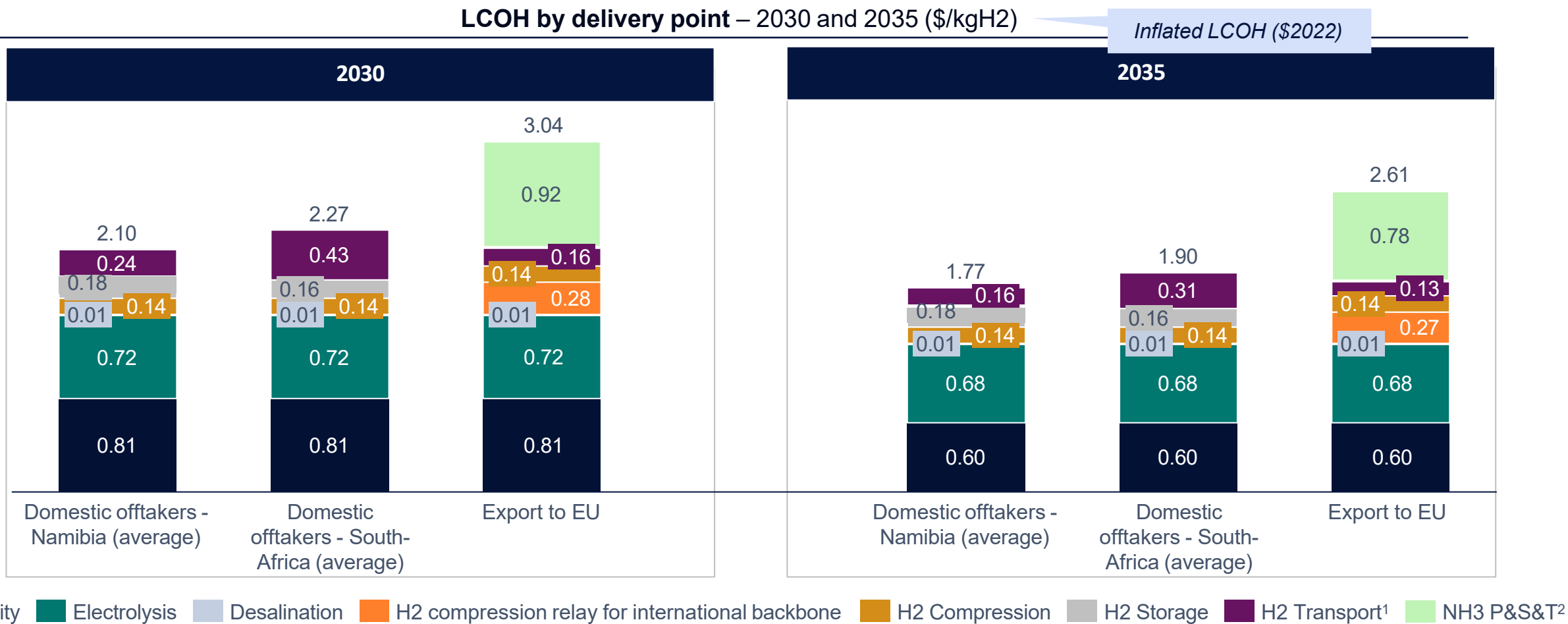
LCOHs around 1.9-2.0/kgH2 for both domestic offtake and European exports in 2030, expected to decrease by ~15% by 2035, around 1.6-1.7\$/kgH2



Note (1): Corresponds to transportation through greenfield pipes – domestic costs for transportation include domestic greenfield and international backbone / EU costs for transportation include only international backbone costs

Southern Africa systems costing – LCOH per delivery zone

LCOHs around 2-2.3\$/kgH2 for domestic offtake and 3\$/kgH2 for European exports in 2030, expected to decrease by ~15% by 2035 – NH3 exportation costs represent around 30% of total EU H2 costs



Note (1): Corresponds to transportation through greenfield pipes – domestic costs for transportation include domestic greenfield and international backbone proportionally to the share of total production / EU costs for transportation include only international backbone costs

Note (2): Includes conversion, NH3 storage, loading cost and shipping costs

Sources: BloombergNEF, IEA, NSE, CVA analysis

Systems costing – Key hypotheses for 2030 and 2035

Total investments required around 500 Bn\$ in 2030 and additional 900 Bn\$ in 2035, with solar PV and electrolysis accounting together for >60% of the total CAPEX by 2035

	Item	Unit	Western Africa hub				Egypt hub		Southern Africa hub			
			2030		2035		2030	2035	2030		2035	
			Mor.	Maur.	Mor.	Maur.			S. Afr.	Nam.	S. Afr.	Nam.
Upstream	CAPEX PV	M\$/MWp	0.39		0.30		0.39	0.30	0.39		0.30	
	OPEX PV	% CAPEX	2%		2%		2%	2%	2%		2%	
	PV degradation ¹	%/year	0.35%		0.35%		0.35%	0.35%	0.35%		0.35%	
	Yield	kWh/kWp	2,200	2,400	2,200	2,400	1,990	1,990	2,100	2,100	2,100	2,100
	WACC	%	6.5%		6.5%		6.5%	6.5%	6.5%		6.5%	
	CAPEX Electrolyser	\$/Wp	0.42		0.35		0.42	0.35	0.42		0.35	
	O&M Electrolyser	% CAPEX	2%		2%		2%	2%	2%		2%	
	Water desalination CAPEX	M\$	142	158	376	396	594	828	210	95	524	237
	Water pipe CAPEX	M\$	578	603	1,206	1,207	579	1,187	804	458	997	458
	WACC	%	8%		8%		8%	8%	8%		8%	
	Storage CAPEX	M\$	3,060	2,650	6,770	6,040	10,750	20,885	3,900	2,420	16,620	5,720
	CAPEX Pipeline (Green Field)	M\$	6,630	7,388	13,144	14,460	18,600	35,908	31,470	9,500	63,560	18,200
	OPEX Pipeline (Green Field)	% CAPEX	1%		1%		1%	1%	1%		1%	
	WACC	%	6.5%		6.5%		6.5%	6.5%	6.5%		6.5%	
Total CAPEX (PV, ELY, desalination, elec. transmission and storage, greenfield)		Bn\$	~67	~58	+59	+55	~219	+145	~108	~46	+108	+42

Note (1): Yields are averages of the different developed areas, and technological improvements of the panels are assumed, explaining yield improvements

Agenda

1. African H2 hubs system design – Demand equation to address – 2030 and 2035
2. African H2 hubs system design – Design and sizing of the 3 hubs
3. African H2 hubs system design – Resulting costs for the 3 hubs
4. **Value creation impact**

Multiple value creation impacts both for local production countries and green H2 import countries – Vision at 50 Mt H2 production / year



Cost competitiveness and differentiation

1.55-1.90 € / kg H2 at delivery points
(equivalent to 79-96€ per Brent oil barrel,
comparable to historical prices plus CO2)



Growth for local economies

An average of 40 Bn€ of direct GDP
created / year all along the project lifetime
corresponding to ~5% of the current
considered countries' GDPs



Strong impact for the communities

Development of an at scale freshwater
system: ~3,500 Mm3 production capacity
available on the 5 different countries, i.e.
more than 5% of the current volumes
consumed locally



Direct employment creation

Massive creation of permanent
quality jobs along the value
chain



Global energy transition

Supply of ~25Mt H2 (equiv. ~70
Mtoe) to overseas countries.
~15% of the current EU gas
demand, as an illustration



Dedicated captive energy system

Dedicated production and
transmission capacities, to
avoid disturbing the existing
energy system used for current
usages



Contribution to decarbonization

~500 Mt CO2 / y avoided in
2035, either by direct usage of
H2 or the supply of green
commodities (~40% of African
CO2 emissions in 2020)