Report on Modelling Tool for Production Cost of Green Ammonia in India

June, 2024

Study by:

mec+

On behalf of:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

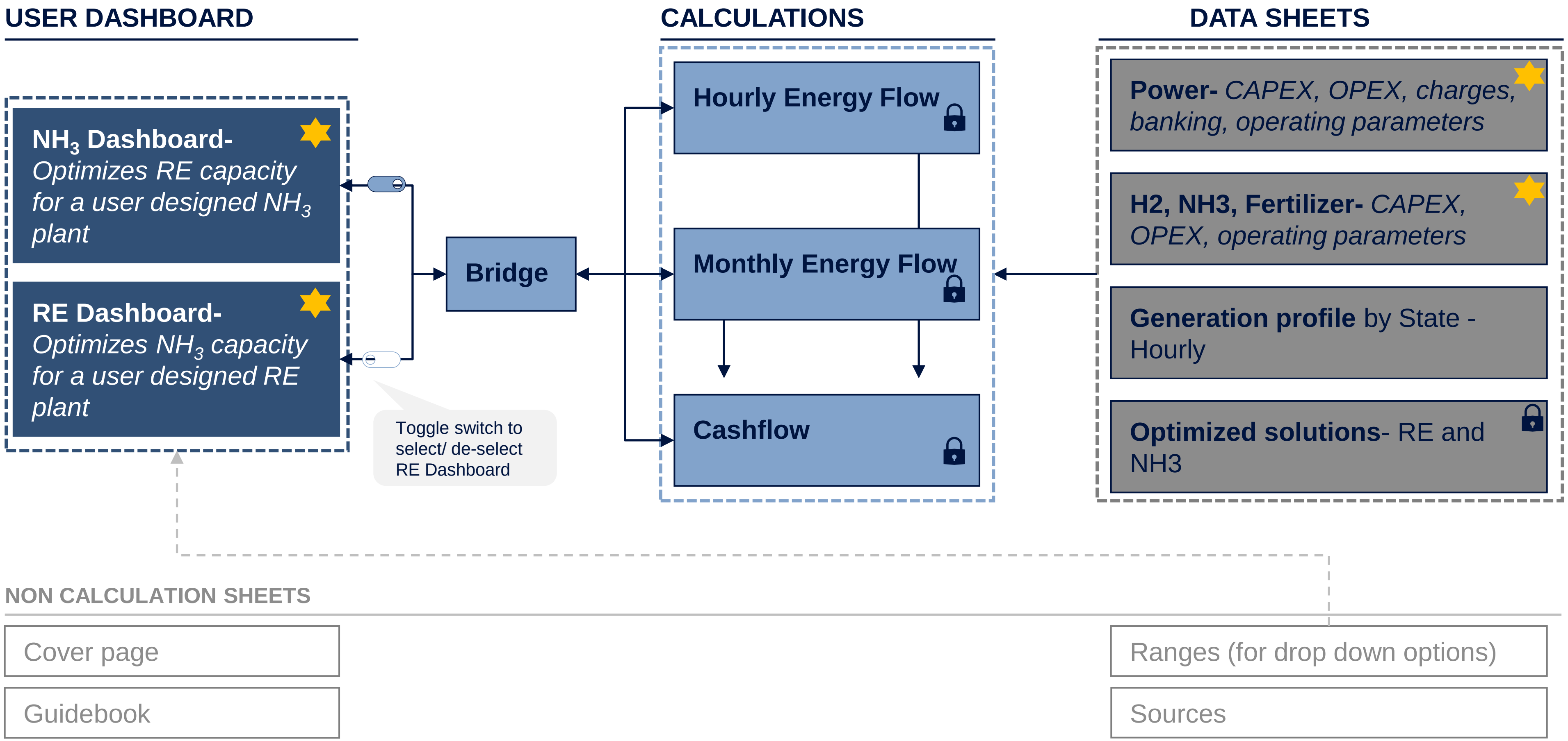
H2Uppp
International Hydrogen Ramp-up Program

igef Indo-German Energy Forum

Model Structure

User adjustable

There are two user dashboard based on the starting point of the user – a target NH3 capacity or a RE plant



Sheet overview

Function	Sheet Title	Sheet details and function
General	Cover page	Introduction to the model - scope of technology, results, model developers, acknowledgement, model limitations, copyright information and disclaimer
	Guide for the User	Provides the user with a guide on model structure, how to use the model- options and solutions
User Interface	D1.NH3 Dashboard	Dashboard where a user can input a target NH3 plant and identify the RE plant design to meet it operating requirements
	D2.RE Dashboard	Dashboard where a user can input a RE plant and NH3 plant capacity to compute the operations and cost of production
Calculations	Bridge	Sheet which acts as a switch between the two dashboards, to take user inputs for cashflow and operations sheets
	Cash Flow	Calculates the cashflow of the RE-Hydrogen-Ammonia plant and discounts them on WACC to calculate levelized cost
	Ops-Hourly	Calculates hourly production of ammonia based on plant operational profile across 24*365 (8760) Hours
	Ops-Monthly	Calculates monthly production of ammonia based on plant operational profile across the 12 months
Data	Power	Contains all the data related to the RE power plant, storage, grid charges
	H2-NH3-Fertilizer	Contains all the data related to the hydrogen production, ammonia production and fertiliser calculations
	Sites	Contains the data related to the RE project sites - solar, onshore wind and offshore wind site
	Optimised Solutions	Contains the optimized solutions (input from MEC) which feed into the dashboards
Others	Ranges	Values for all user options - drop-downs etc.
	Sources	Comprehensive list of all the sources used

Cell Format Key

XXX	Input cells for the user
XXX	Returns calculation based on a formula/criteria, for user's reference. **Do not change/overwrite this cell**
XXX	Output Cell which gives a results desired as an interim/final step. **Do not change/overwrite this cell**

Colour of Sheets

XXXXXX	Dashboard with input & output of the model
XXXXXX	Project Calculations sheets. **Do not change anything on these sheets**
XXXXXX	Data Sheets (Back -ups). User can change the assumptions/data on these sheets in the fields marked for change

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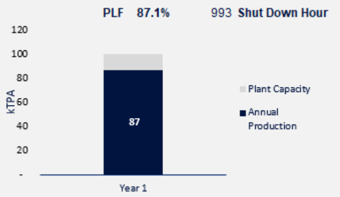
Modelling Tool for Production Cost of Green Ammonia in India

Ammonia

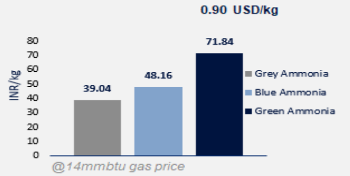
Annual Production

Annual production of NH3 (kTPA), PLF (%) and # of shutdown hours of NH3 plant



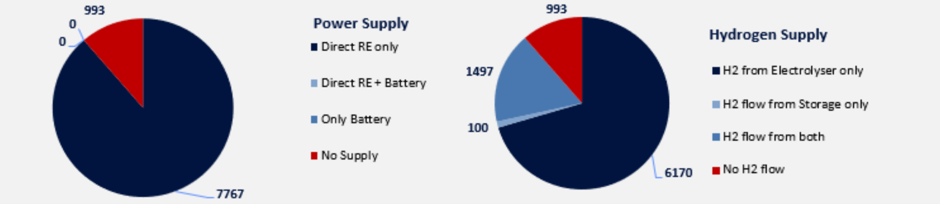
Levelized Cost

Green ammonia LCOA in INR/ USD per Kg and comparison with green and blue at user specified price of natural gas in USD/mmbtu



Operational profile

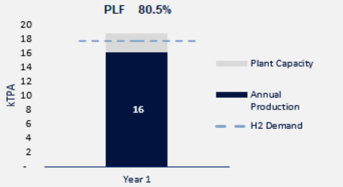
Operational profile of NH3 plant in terms of source of power (directly from RE plant vs banking vs exchange vs battery) and source of hydrogen (directly from electrolyser vs storage vs both)



Hydrogen

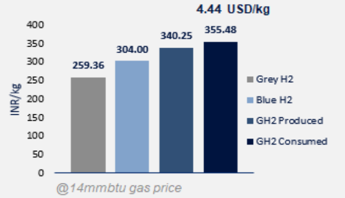
Annual Production

Annual production of H2 (kTPA), PLF (%) and # of shutdown hours of electrolyser plant



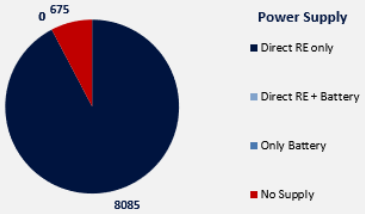
Levelized Cost

Green H2 LCOH in INR/ USD per Kg and comparison with green and blue at user specified price of natural gas in USD/mmbtu*



Operational profile

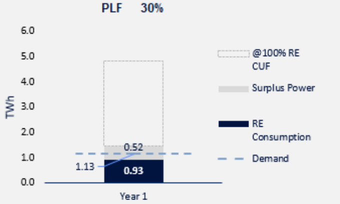
Operational profile of H2 plant in terms of source of power (directly from RE plant vs banking vs exchange vs battery)



Renewable power

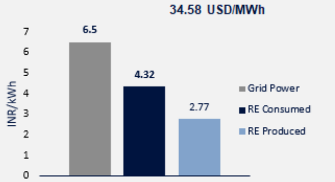
Annual Production

Annual production of RE power in TWh split by consumed vs surplus vs demand of H2-NH3 plant



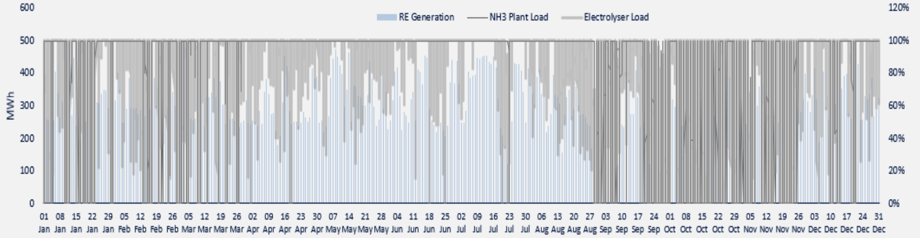
Levelized Cost

LCoE of generated vs consumed RE power vs grid power price in the state



Operational profile

Hourly operational profile (PLF) of RE, Electrolyser and NH3 plant throughout the year



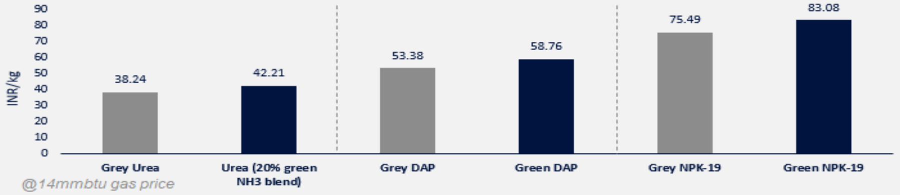
Note* Consumed LCOH/LCOE refers to levelized cost of hydrogen/power actually consumed by the NH3/H2 plant excluding the surplus

Source: MEC Intelligence analysis

Dashboard Outputs

End products

Cost comparison of grey fertilizer (Urea, DAP, NPK) vs when produced using green ammonia- 20% green ammonia blend for Urea (due to limit on CO2 availability from onsite flue gas) while 100% green ammonia for DAP and NPK



Quantity of fertilizer that can be produced using green ammonia, other end-products (O2, power, H2) and key KPI of plant

End Product from Green Ammonia produced

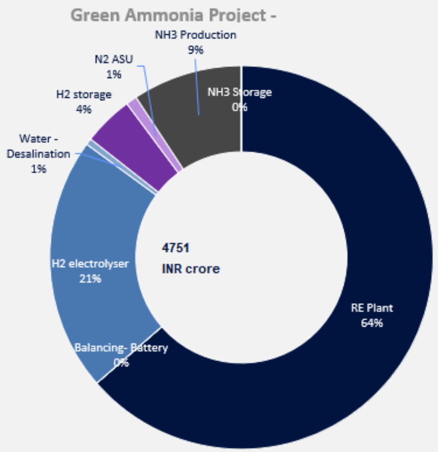
Urea	**153**	ktpa	PLF	>90%
DAP	**378**	ktpa	Shutdowr	<500 h
NPK	**376**	ktpa	Surplus	<5%

Other Products

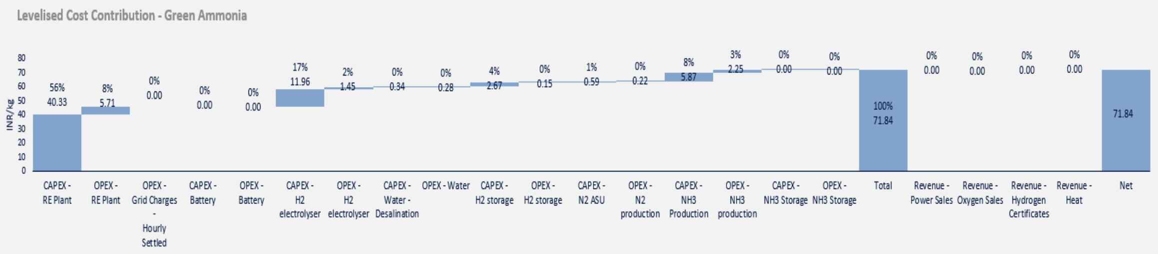
Oxygen Produced	**128.75**	ktpa
Surplus Power	**5,22,059**	MWh
Hydrogen Surplus %	**0.0%**	% of production

Break-up of Plan Capex, LCOA and LCOH

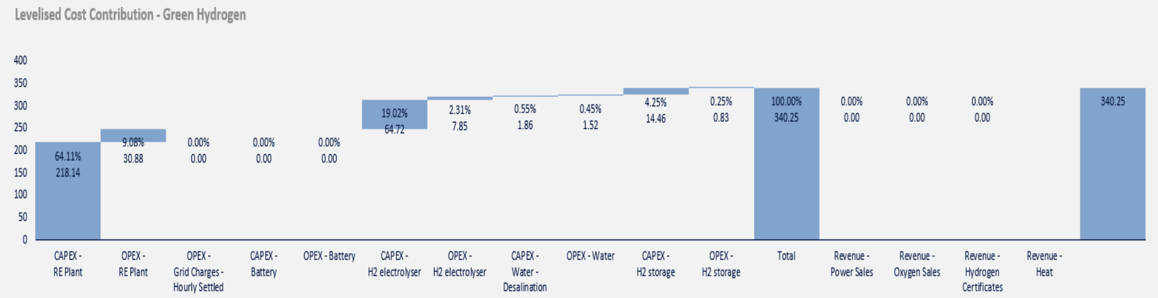
Break-up of total plant capex in INR crore



Break-up of LCOA in INR per Kg



Break-up of LCOH in INR per Kg



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Dashboard Inputs

D1.NH3 Dashboard- For Users who want to evaluate lowest cost of producing certain quantity of ammonia in different scenarios

General Plant Design Parameters			
Green Ammonia Definition (settled)	Hourly		
Target Ammonia Plant Capacity	100	kTPA	
Year of Installation	2025		
RE Generation Technology	Solar + Onshore Wind		
RE & H2-NH3 Plants Configuration	Direct connected		
Renewable Plant Location	Gujarat		
RE plant grid connection	NA - Direct Connection		
H_2 - NH_3 Plant Location	Gujarat		
H_2 -NH_3 Plant Grid Connection	NA - Direct Connection		
Balancing Mechanism	No Banking		
Electrolyser Type	Alkaline		
Curtailment in Peak Hours	1.00%	%	
Curtailment in Non-Peak Hours	0.05%	%	To Update
Financial Parameters			
Debt Interest Rate	8%	%	
Debt Share in Total Investment	40%	%	
Target IRR	12.50%	%	
WACC	10.70%	%	
Ammonia Plant Parameters			
Ammonia Plant per day capacity	273.97	TPD	
Air Sepearation Unit Capacity	225.50	TPD	
Hydrogen Volume Required	48.47	TPD	
Power Demand			
Ammonia Plant Power Demand	6.28	MW	
Air Seperation Unit Power Demand	2.16	MW	
Electrolyser Required Capacity	107.14	MW	
Power Demand & supply			
☐ Manually design the electrolyser and renewable plant			
Electrolyser Capacity Oversizing	13%	%	
Electrolyser Power Demand	121.07	MW	
Total Requirement	129.51	MW	
RE Plant Oversizing	325%	%	
Ratio Solar to Wind	55%	%	
RE Plant Capacity	550	MW	
Solar Capacity	303	MW	
Wind Capacity	248	MW	
Offshore Wind Capacity	0	MW	
Balacing Technologies			
☐ Manually input battery size			
Battery Power	0	MW	
Battery Duration	8	hours	
Battery Size	0	MWh	
Storage Infrastructure			
☐ Manually input hydrogen storage			
Hydrogen Storage	1.0	days	
Hydrogen Storage	48469	kg	
Ammonia Storage	8219	kg	
Optional Inputs			
Water Source	Desalination Plant		
CO_2 source	Onsite capture from flue gas		
Cost of CO_2	4800	INR/t	To Update
Surplus Power Price	0	INR/kWh	To Update
Share of Surplus power to sell	100%	%	
Oxygen Sales Price	0	INR/m^3	To Update
Share of Oxygen production to sell	100%	%	
Carbon (CO2) abated from Surplus H2	0	tonnes	
Carbon Credits available	0		
Share of carbon credits to sell	0%	%	
Price per carbon credit	6400	INR	To Update

Click here to manually size plant. This can be done for RE, battery, electrolyser and storage

Note: For detailed definitions, see Scope section

User to select definition of green ammonia/ hydrogen

User to configure NH3 plant capacity

User to configure RE plant

User to select technology and other plant design considerations

User to input financial assumptions to calculate WACC which is used for cash flow discounting

Calculated based on SEC assumptions

Sizing of RE, electrolyser, battery and H2 storage is done automatically for the user selected configuration to meet specific PLF and shutdown KPIs. User can adjust parameters by clicking on toggle switch

User can further adjust sources of water, CO2 (for urea), and optimize revenue through sale of by-products covering oxygen, power, carbon credit, etc.

D2.RE Dashboard- For Users who want to evaluate cost of ammonia production from a certain RE configuration in different scenarios

☐ Select for NH3 Optiimed solution

General Plant Design Parameters			
Green Ammonia Definition (settled)	Hourly		
Year of Installation	2025		
RE Generation Technology	Solar + Battery		
RE Plant Size	500	MW	
Ratio Solar to Wind	40%	%	
Battery Power	0	MW	
Plant Configuration	Grid Connected		
Renewable Plant Location	Gujarat		
RE plant grid connection	CTU		
H_2 - NH_3 Plant Location	Gujarat		
H_2 -NH_3 Plant Grid Connection	CTU		
Balancing Mechanism	No Banking		
Electrolyser Type	PEM		
Electrolyser Capacity Oversizing	25%	%	
Curtailment in Peak Hours	0.00%	%	To Update
Curtailment in Non-Peak Hours	0.00%	%	
Financial Parameters			
Debt Interest Rate	8%	%	
Debt Share in Total Investment	70%	years	
Target IRR	12.50%	%	
WACC	9.35%	%	
Ammonia Plant Parameters			
Ammonia Plant Capacity	100.00	kTPA	
Ammonia Plant per day capacity	274	TPD	
Air Sepearation Unit Capacity	226	TPD	
Hydrogen Volume Required	48	TPD	
Power Demand			
Ammonia Plant Power Demand	6	MW	
Air Seperation Unit Power Demand	2	MW	
Electrolyser Required Capacity	114	MW	
Electrolyser Power Demand	143	MW	
Total Requirement	151	MW	
Power Plant Design			
RE Plant Oversizing	331%	%	
Solar Capacity	200	MW	
Wind Capacity	0	MW	
Offshore Wind Capacity	0	MW	
Battery Duration	8		
Battery Size	0	MWh	
Storage Infrastructure			
Hydrogen Storage	1.0	days	
Hydrogen Storage	48469	kg	
Ammonia Storage	8219	kg	
Optional Inputs			
Water Source	Desalination plant		
CO_2 source	SMR Flue Gas		
Cost of CO_2	6500	INR/t	To Update
Surplus Power Price	0	INR/kWh	To Update
Share of Surplus power to sell	100%		
Oxygen Sales Price	0	INR/m^3	To Update
Share of Oxygen production to sell	100%		
Carbon (CO2) abated	0	tonnes	
Carbon Credits available	0		
Share of carbon credits to sell	100%	%	
Price per carbon credit	6400	INR	To Update

Click here to activate this Dashboard. De-select to automatically select NH3 dashboard

Input Adjustability | User can design and configure plant by selecting drop down options within 14 parameters

Green Ammonia Definition		Monthly Settlement	Hourly Settlement										
Year of commissioning		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	*10 yr time horizon*	
RE Tech.	**Monthly**	Solar	Onshore wind	Offshore wind	Solar + Onshore wind	Solar + Offshore wind							
	Hourly	Solar + Battery	Onshore wind + Battery	Offshore wind + Battery	Solar + Onshore wind	Solar + Offshore wind	Solar + ON Wind + Battery	Solar + ON Wind + Battery					
Plant Configuration		Direct connection b/w RE and H2-NH3 plant	Connectivity via Grid b/w RE and H2/NH3										
Plant Location	**Solar and H2-NH3**	TN	GJ	KA	MH	AP	TS	RJ	MP	UP	OR	S11	S12
	Onshore wind (incl. hybrid)	TN	GJ	KA	MH	AP	TS	RJ	MP				
	Offshore wind (incl. hybrid)	TN	GJ										
Balancing Technology		Banking	No Banking										
Electrolyser type		Alkaline	PEM										
Electrolyser capacity oversizing		User input											
Curtailment rate		User input for Peak hours	User input for Non-Peak hours										
Financial parameters		User input for debt:equity, debt rate and target IRR											
Source of CO2		Capture from flue gas onsite Urea plant	Externally sourced										
RE plant and Battery configuration		RE oversizing	Solar : Wind ratio	Battery capacity									
Additional revenue options		Value and % of Surplus power sales	Value and % of O2 sales										
Water Source		Desalination plant	Pipeline										

Calculation Sheet 1 | NH3 production in Hourly Settlement

- Calculates hourly production of ammonia across 8760 hours in a year (24*365) based on available RE power, battery capacity, H2 storage capacity, etc.
- See section ‘Model Flow’ for details on how Power and H2 are allocated across different consumption centers in the plant

RE Generation: Calculates Hourly RE power available for H2-NH3 plant based on Site CUF profile, RE plant capacity and curtailment

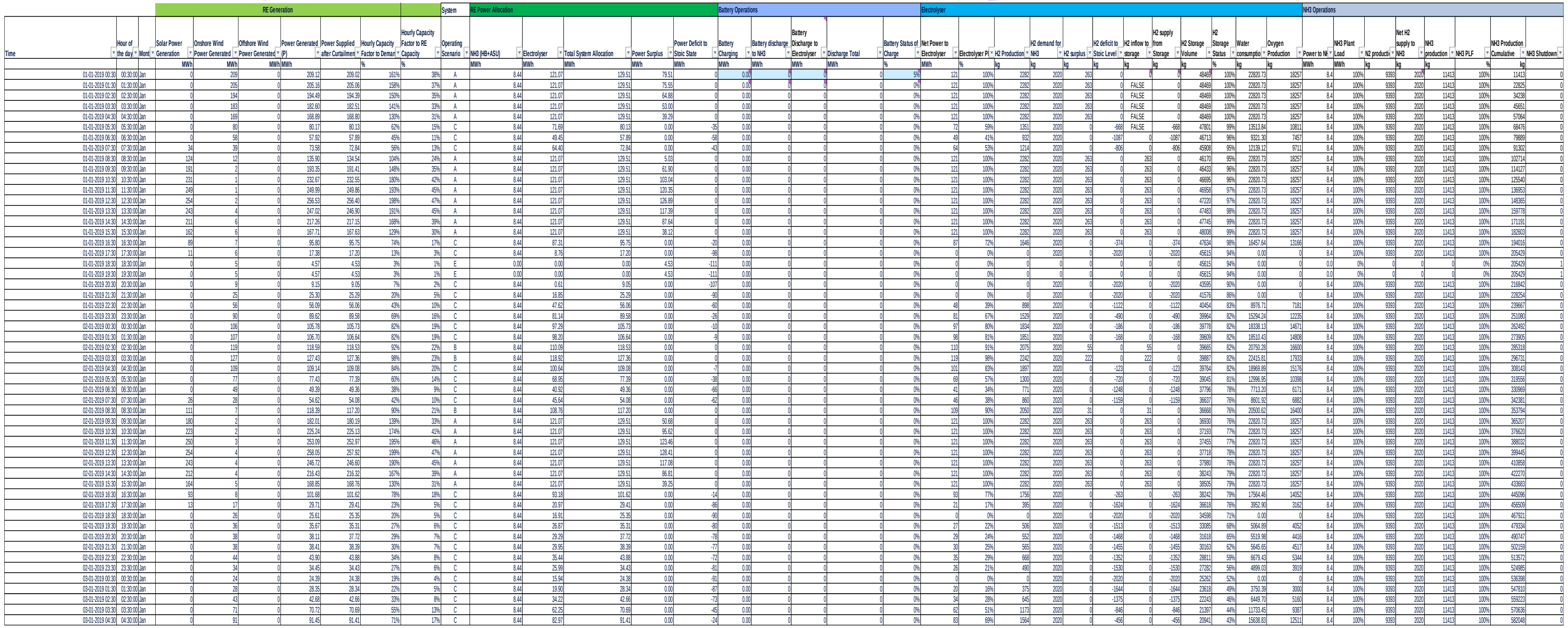
Operating scenario of Plant: for details see section ‘Model Flow’

RE power allocation: Allocates available RE power to H2, NH3 plant based on the ‘Operating Scenario’

Battery Operations: Charging-discharging operation of battery based on available RE power

Electrolyser Operations: Calculates H2 produced and stored based on RE power from plant and battery

NH3 Operations: Calculates hourly ammonia production based on RE power from plant & battery and H2 from electrolyser and storage



Operations calculated for 8760 hours per year

Calculation Sheet 2 | NH3 production in Monthly Settlement

- Calculates monthly production of ammonia based on available RE power and balancing mechanism (banking vs no banking)
- See section ‘Model Flow’ for details on how Power and H2 are allocated across different consumption centers in the plant

RE Generation: Calculates RE power available in a given month based on hourly generation profile (site CUF profile, RE plant capacity, curtailment)

Power calculations: Calculates ‘target monthly CUF’ of H2-NH3 plant based on power available

Grid banking operations: Calculates units (MWh) of power banked and accordingly the charges

No Banking Operations: Calculates units (MWh) of power sold and procured from power exchange

Electrolyser Operations: Calculates H2 production based on target monthly CUF

NH3 Operations: Calculates ammonia production based on target monthly CUF.

Operations calculated for 8760 hours per year but aggregate d at monthly level

			RE Generation							Power Calculations			Grid banking Operations			No banking Operations	
Time	Hour of the da	Mon	Solar Power Generation	Onshore Wind Power Generate	Offshore Wind Power Generate	Power Generated (P)	Power Supplied after Curtailment	Hourly Capacity Factor to Deman	Hourly Capacity Factor to RE Capacity	Demadn at Target CUF	Power Surplus	Power Deficit to Target CU	Effective Plant Load	Plant Load	Cumulative Withdrawn units	Surplus sold to exchang	Deficit purchased from Exchange
			MWh	MWh	MWh	MWh		%	%	MWh	MWh	MWh	%	MWh			
01-01-2019 00:30	00:30:00	Jan	0	209	0	209.12	209.02	161%	38%	115.6	93.44	0.00	100.0%	115.58	106847	93	0.0
01-01-2019 01:30	01:30:00	Jan	0	205	0	205.16	205.06	158%	37%	115.6	89.48	0.00	100.0%	115.58	106731	89	0.0
01-01-2019 02:30	02:30:00	Jan	0	194	0	194.49	194.39	150%	35%	115.6	78.81	0.00	100.0%	115.58	106616	79	0.0
01-01-2019 03:30	03:30:00	Jan	0	183	0	182.60	182.51	141%	33%	115.6	66.93	0.00	100.0%	115.58	106500	67	0.0
01-01-2019 04:30	04:30:00	Jan	0	169	0	168.89	168.80	130%	31%	115.6	53.22	0.00	100.0%	115.58	106385	53	0.0
01-01-2019 05:30	05:30:00	Jan	0	80	0	80.17	80.13	62%	15%	115.6	0.00	-35.45	100.0%	115.58	106269	0	-35.4
01-01-2019 06:30	06:30:00	Jan	0	58	0	57.92	57.89	45%	11%	115.6	0.00	-57.69	100.0%	115.58	106153	0	-57.7
01-01-2019 07:30	07:30:00	Jan	34	39	0	73.58	72.84	56%	13%	115.6	0.00	-42.74	100.0%	115.58	106038	0	-42.7
01-01-2019 08:30	08:30:00	Jan	124	12	0	135.90	134.54	104%	24%	115.6	18.96	0.00	100.0%	115.58	105922	19	0.0
01-01-2019 09:30	09:30:00	Jan	191	2	0	193.35	191.41	148%	35%	115.6	75.83	0.00	100.0%	115.58	105807	76	0.0
01-01-2019 10:30	10:30:00	Jan	231	1	0	232.67	232.55	180%	42%	115.6	116.97	0.00	100.0%	115.58	105691	117	0.0
01-01-2019 11:30	11:30:00	Jan	249	1	0	249.99	249.86	193%	45%	115.6	134.28	0.00	100.0%	115.58	105575	134	0.0
01-01-2019 12:30	12:30:00	Jan	254	2	0	256.53	256.40	198%	47%	115.6	140.82	0.00	100.0%	115.58	105460	141	0.0
01-01-2019 13:30	13:30:00	Jan	243	4	0	247.02	246.90	191%	45%	115.6	131.32	0.00	100.0%	115.58	105344	131	0.0
01-01-2019 14:30	14:30:00	Jan	211	6	0	217.26	217.15	168%	39%	115.6	101.57	0.00	100.0%	115.58	105229	102	0.0
01-01-2019 15:30	15:30:00	Jan	162	6	0	167.71	167.63	129%	30%	115.6	52.05	0.00	100.0%	115.58	105113	52	0.0
01-01-2019 16:30	16:30:00	Jan	89	7	0	95.80	95.75	74%	17%	115.6	0.00	-19.83	100.0%	115.58	104998	0	-19.8
01-01-2019 17:30	17:30:00	Jan	11	6	0	17.38	17.20	13%	3%	115.6	0.00	-98.38	100.0%	115.58	104882	0	-98.4
01-01-2019 18:30	18:30:00	Jan	0	5	0	4.57	4.53	3%	1%	115.6	0.00	-111.05	100.0%	115.58	104766	0	-111.1
01-01-2019 19:30	19:30:00	Jan	0	5	0	4.57	4.53	3%	1%	115.6	0.00	-111.05	100.0%	115.58	104651	0	-111.1
01-01-2019 20:30	20:30:00	Jan	0	9	0	9.15	9.05	7%	2%	115.6	0.00	-106.53	100.0%	115.58	104535	0	-106.5
01-01-2019 21:30	21:30:00	Jan	0	25	0	25.30	25.29	20%	5%	115.6	0.00	-90.29	100.0%	115.58	104420	0	-90.3
01-01-2019 22:30	22:30:00	Jan	0	56	0	56.09	56.06	43%	10%	115.6	0.00	-59.52	100.0%	115.58	104304	0	-59.5
01-01-2019 23:30	23:30:00	Jan	0	90	0	89.62	89.58	69%	16%	115.6	0.00	-26.00	100.0%	115.58	104188	0	-26.0
02-01-2019 00:30	00:30:00	Jan	0	106	0	105.78	105.73	82%	19%	115.6	0.00	-9.85	100.0%	115.58	104073	0	-9.9
02-01-2019 01:30	01:30:00	Jan	0	107	0	106.70	106.64	82%	19%	115.6	0.00	-8.94	100.0%	115.58	103957	0	-8.9
02-01-2019 02:30	02:30:00	Jan	0	119	0	118.59	118.53	92%	22%	115.6	2.94	0.00	100.0%	115.58	103842	3	0.0
02-01-2019 03:30	03:30:00	Jan	0	127	0	127.43	127.36	98%	23%	115.6	11.78	0.00	100.0%	115.58	103726	12	0.0
02-01-2019 04:30	04:30:00	Jan	0	109	0	109.14	109.08	84%	20%	115.6	0.00	-6.50	100.0%	115.58	103611	0	-6.5
02-01-2019 05:30	05:30:00	Jan	0	77	0	77.43	77.39	60%	14%	115.6	0.00	-38.19	100.0%	115.58	103495	0	-38.2
02-01-2019 06:30	06:30:00	Jan	0	49	0	49.39	49.36	38%	9%	115.6	0.00	-66.22	100.0%	115.58	103379	0	-66.2
02-01-2019 07:30	07:30:00	Jan	26	28	0	54.62	54.08	42%	10%	115.6	0.00	-61.51	100.0%	115.58	103264	0	-61.5
02-01-2019 08:30	08:30:00	Jan	111	7	0	118.39	117.20	90%	21%	115.6	1.62	0.00	100.0%	115.58	103148	2	0.0
02-01-2019 09:30	09:30:00	Jan	180	2	0	182.01	180.19	139%	33%	115.6	64.61	0.00	100.0%	115.58	103033	65	0.0
02-01-2019 10:30	10:30:00	Jan	223	2	0	225.24	225.13	174%	41%	115.6	109.55	0.00	100.0%	115.58	102917	110	0.0
02-01-2019 11:30	11:30:00	Jan	250	3	0	253.09	252.97	195%	46%	115.6	137.38	0.00	100.0%	115.58	102802	137	0.0
02-01-2019 12:30	12:30:00	Jan	254	4	0	258.05	257.92	199%	47%	115.6	142.34	0.00	100.0%	115.58	102686	142	0.0
02-01-2019 13:30	13:30:00	Jan	243	4	0	246.72	246.60	190%	45%	115.6	131.01	0.00	100.0%	115.58	102570	131	0.0
02-01-2019 14:30	14:30:00	Jan	212	4	0	216.43	216.32	167%	39%	115.6	100.74	0.00	100.0%	115.58	102455	101	0.0
02-01-2019 15:30	15:30:00	Jan	164	5	0	168.85	168.76	130%	31%	115.6	53.18	0.00	100.0%	115.58	102339	53	0.0
02-01-2019 16:30	16:30:00	Jan	93	8	0	101.68	101.62	78%	18%	115.6	0.00	-13.96	100.0%	115.58	102224	0	-14.0
02-01-2019 17:30	17:30:00	Jan	13	17	0	29.71	29.41	23%	5%	115.6	0.00	-86.17	100.0%	115.58	102108	0	-86.2
02-01-2019 18:30	18:30:00	Jan	0	26	0	25.61	25.35	20%	5%	115.6	0.00	-90.23	100.0%	115.58	101992	0	-90.2
02-01-2019 19:30	19:30:00	Jan	0	36	0	35.67	35.31	27%	6%	115.6	0.00	-80.27	100.0%	115.58	101877	0	-80.3
02-01-2019 20:30	20:30:00	Jan	0	38	0	38.11	37.72	29%	7%	115.6	0.00	-77.86	100.0%	115.58	101761	0	-77.9
02-01-2019 21:30	21:30:00	Jan	0	38	0	38.41	38.39	30%	7%	115.6	0.00	-77.19	100.0%	115.58	101646	0	-77.2

	Electrolyser								NH3 Operations							
Time	Net Power to Electrolyser	Electrolyser PL	H2 Productio	H2 demand for NH3	H2 surplus	H2 deficit to Stoic Leve	Water consumption	Oxygen Producti	Power to NH3 - ASU	NH3 Plant Load	N2 producti	Net H2 supply to NH3	NH3 production	NH3 PL	NH3 Production Cumulative	NH3 Shutdown
	MWh	%	kg	kg	kg	kg	kg	kg	MWh	MWh	kg	kg	kg	%	kg	
01-01-2019 00:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	11413	0
01-01-2019 01:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	22825	0
01-01-2019 02:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	34238	0
01-01-2019 03:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	45651	0
01-01-2019 04:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	57064	0
01-01-2019 05:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	68476	0
01-01-2019 06:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	79889	0
01-01-2019 07:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	91302	0
01-01-2019 08:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	102714	0
01-01-2019 09:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	114127	0
01-01-2019 10:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	125540	0
01-01-2019 11:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	136953	0
01-01-2019 12:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	148365	0
01-01-2019 13:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	159778	0
01-01-2019 14:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	171191	0
01-01-2019 15:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	182603	0
01-01-2019 16:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	194016	0
01-01-2019 17:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	205429	0
01-01-2019 18:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	216842	0
01-01-2019 19:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	228254	0
01-01-2019 20:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	239667	0
01-01-2019 21:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	251080	0
01-01-2019 22:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	262492	0
01-01-2019 23:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	273905	0
02-01-2019 00:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	285318	0
02-01-2019 01:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	296731	0
02-01-2019 02:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	308143	0
02-01-2019 03:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	319556	0
02-01-2019 04:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	330969	0
02-01-2019 05:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	342381	0
02-01-2019 06:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	353794	0
02-01-2019 07:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	365207	0
02-01-2019 08:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	376620	0
02-01-2019 09:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	388032	0
02-01-2019 10:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	399445	0
02-01-2019 11:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	410858	0
02-01-2019 12:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	422270	0
02-01-2019 13:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	433683	0
02-01-2019 14:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	445096	0
02-01-2019 15:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	456509	0
02-01-2019 16:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	467921	0
02-01-2019 17:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	479334	0
02-01-2019 18:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	490747	0
02-01-2019 19:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	502159	0
02-01-2019 20:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	513572	0
02-01-2019 21:30	107.14	88.5%	2020	2020	0	0	20195	16156	8.44	100%	9393	2020	11413	100%	524985	0

Calculation Sheet 3 | Cash flows of plant

- Levelized cost calculations are based on a levelized average lifetime cost approach, using the discounted cash flow (DCF)/NPV method. WACC is considered as the discount rate which is a function of cost of debt, cost of equity and debt to equity ratio.
- NPV/DCF approach has been preferred over IRR/CRF approach to simplify comparisons against geography, technologies, balancing mechanism, etc. The user can optimize the WACC/discounting factor to reflect their own cost-of-capital

Operational year 1-25

Actual and discounted annual Production of RE power, H2, NH3

Capex breakup

Depreciation of assets

Opex breakup

Additional revenue

Discounted cash flow

Levelized cost- LCOE, LCOH, LCOA

Parameter	Units/Year	Project Lifetime Sum	0	1	2	3	4	5	6	7	8	9	10	11
Operational Hours	hours		0	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760
Cummulative Operational Hours	hours		0	8760	17520	26280	35040	43800	52560	61320	70080	78840	87600	96360
Discount Rate			1.00000	0.90334	0.81603	0.73715	0.66590	0.60154	0.54339	0.49087	0.44342	0.40056	0.36185	0.32687
Power Supply														
Electricity Units produced	kWh		0	1,45,68,85,003	1,45,57,62,260	1,45,46,40,506	1,45,35,19,740	1,45,23,99,961	1,45,12,81,169	1,45,01,63,362	1,44,90,46,540	1,44,79,30,701	1,44,68,15,844	1,44,57,01,969
Surplus Power	kWh		0	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494
Electricity Consumed	kWh		-	93,48,25,509	93,37,02,766	93,25,81,012	93,14,60,246	93,03,40,468	92,92,21,675	92,81,03,868	92,69,87,046	92,58,71,207	92,47,56,350	92,36,42,475
Discounted Electricity Consumed		7,97,92,52,956	-	84,44,67,488	76,19,27,070	68,74,54,099	62,02,60,094	55,96,33,634	50,49,32,827	45,55,78,517	41,10,48,150	37,08,70,244	33,46,19,398	30,19,11,786
Production														
H2 Produced	kg	40,23,47,061	0	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882
H2 Consumed	kg	38,51,11,469	0	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459
Discounted H2 Production	kg	13,85,63,713	-	1,45,38,286	1,31,33,050	1,18,63,640	1,07,16,929	96,81,056	87,45,308	79,00,007	71,36,411	64,46,622	58,23,507	52,60,621
Discounted H2 Consumption	kg	13,26,27,972		1,39,15,500	1,25,70,461	1,13,55,430	1,02,57,841	92,66,342	83,70,680	75,61,590	68,30,704	61,70,464	55,74,042	50,35,268
O2 Produced	kg			12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059
N2 Produced	kg	1,79,12,16,133	0	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645
NH3 Produced	kg	2,17,63,27,602	0	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104
Discounted NH3 Production		74,95,02,262	-	7,86,38,757	7,10,37,721	6,41,71,383	5,79,68,729	5,23,65,609	4,73,04,073	4,27,31,773	3,86,01,421	3,48,70,299	3,14,99,819	2,84,55,121
Total Capex - Total			**₹ 45,84,90,79,275**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 1,19,46,96,587**
RE Plant	INR		₹ 30,22,59,32,304											
Balancing- Battery	INR		₹ 0											₹ 0
H2 electrolyser	INR		₹ 8,52,19,93,509											₹ 1,19,46,96,587
Water - Desalination	INR		₹ 25,75,35,485											
H2 storage	INR		₹ 2,00,31,67,369											
N2 ASU	INR		₹ 44,00,00,000											
NH3 Production	INR		₹ 4,40,00,00,000											
NH3 Storage	INR		₹ 4,50,608											
Depreciation - Total			0	₹ 44,31,72,94,364	₹ 42,83,80,31,219	₹ 41,40,94,54,004	₹ 40,02,97,92,017	₹ 38,69,73,37,353	₹ 37,41,04,42,647	₹ 36,16,75,18,903	₹ 34,96,70,33,399	₹ 33,80,75,07,669	₹ 32,68,75,15,557	₹ 31,60,56,81,347
RE Plant	INR			₹ 29,21,84,01,227	₹ 28,24,44,54,520	₹ 27,30,29,72,702	₹ 26,39,28,73,612	₹ 25,51,31,11,158	₹ 24,66,26,74,120	₹ 23,84,05,84,983	₹ 23,04,58,98,816	₹ 22,27,77,02,189	₹ 21,53,51,12,116	₹ 20,81,72,75,046
Balancing - Battery BOP	INR			₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0
Balancing - Batteries	INR			₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0
H2 electrolyser	INR			₹ 8,18,11,13,768	₹ 7,85,38,69,218	₹ 7,53,97,14,449	₹ 7,23,81,25,871	₹ 6,94,86,00,836	₹ 6,67,06,56,803	₹ 6,40,38,30,531	₹ 6,14,76,77,309	₹ 5,90,17,70,217	₹ 5,66,56,99,408	₹ 5,43,90,71,432
Water Desalination	INR			₹ 25,10,97,098	₹ 24,48,19,670	₹ 23,86,99,179	₹ 23,27,31,699	₹ 22,69,13,407	₹ 22,12,40,571	₹ 21,57,09,557	₹ 21,03,16,818	₹ 20,50,58,898	₹ 19,99,32,425	₹ 19,49,34,115
H2 storage	INR			₹ 1,92,30,40,674	₹ 1,84,61,19,047	₹ 1,77,22,74,285	₹ 1,70,13,83,314	₹ 1,63,33,27,981	₹ 1,56,79,94,862	₹ 1,50,52,75,068	₹ 1,44,50,64,065	₹ 1,38,72,61,502	₹ 1,33,17,71,042	₹ 1,27,85,00,200
N2 Production	INR			₹ 43,12,00,000	₹ 42,25,76,000	₹ 41,41,24,480	₹ 40,58,41,990	₹ 39,77,25,151	₹ 38,97,70,648	₹ 38,19,75,235	₹ 37,43,35,730	₹ 36,68,49,015	₹ 35,95,12,035	₹ 35,23,21,794
NH3 Production	INR			₹ 4,31,20,00,000	₹ 4,22,57,60,000	₹ 4,14,12,44,800	₹ 4,05,84,19,904	₹ 3,97,72,51,506	₹ 3,89,77,06,476	₹ 3,81,97,52,346	₹ 3,74,33,57,299	₹ 3,66,84,90,153	₹ 3,59,51,20,350	₹ 3,52,32,17,943
NH3 Storage	INR			₹ 4,41,596	₹ 4,32,764	₹ 4,24,109	₹ 4,15,627	₹ 4,07,314	₹ 3,99,168	₹ 3,91,185	₹ 3,83,361	₹ 3,75,694	₹ 3,68,180	₹ 3,60,816
Total Opex		₹ 10,05,25,03,506	-	₹ 89,11,77,927	₹ 90,86,28,043	₹ 92,68,52,307	₹ 94,58,86,477	₹ 96,57,68,008	₹ 98,65,36,138	₹ 1,00,82,31,972	₹ 1,03,08,98,575	₹ 1,05,45,81,065	₹ 1,07,93,26,713	₹ 1,10,51,85,046
RE Plant	INR	₹ 5,84,93,22,471		₹ 44,90,09,383	₹ 46,64,59,499	₹ 48,46,83,763	₹ 50,37,17,933	₹ 52,35,99,464	₹ 54,43,67,594	₹ 56,60,63,428	₹ 58,87,30,032	₹ 61,24,12,522	₹ 63,71,58,169	₹ 66,30,16,503
Grid Charges - Hourly Settled	INR	₹ 0		₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0
Grid Charges - Monthly Settled	INR	₹ 0		₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0
Balancing - Battery	INR	₹ 0		₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0
H2 electrolyser	INR	₹ 78,78,33,949		₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297
Water - OPEX	INR	₹ 50,70,80,798		₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548
H2 storage	INR	-₹ 22,11,43,101		₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674
N2 production	INR	₹ 28,44,75,519		₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000
NH3 production	INR	₹ 2,84,47,55,189		₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000
NH3 Storage	INR	₹ 1,78,682		₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024
Additional Revenue			0	0	0	0	0	0	0	0	0	0	0	0
Surplus Power Sales	INR	₹ 0		-	-	-	-	-	-	-	-	-	-	-
Oxygen Sales	INR	₹ 0		0	0	0	0	0	0	0	0	0	0	0
Carbon Credits Sales	INR	₹ 0		0	0	0	0	0	0	0	0	0	0	0
Net Project Expenses		₹ 57,56,15,13,475	₹ 45,84,90,79,275	₹ 89,11,77,927	₹ 90,86,28,043	₹ 92,68,52,307	₹ 94,58,86,477	₹ 96,57,68,008	₹ 98,65,36,138	₹ 1,00,82,31,972	₹ 1,03,08,98,575	₹ 1,05,45,81,065	₹ 1,07,93,26,713	₹ 2,29,98,81,634
Discounted Project Cash Flow	INR	₹ 53,84,07,73,840	₹ 45,84,90,79,275	₹ 80,50,38,778	₹ 74,14,65,408	₹ 68,32,31,172	₹ 62,98,66,532	₹ 58,09,44,588	₹ 53,60,77,122	₹ 49,49,11,014	₹ 45,71,24,999	₹ 42,24,26,720	₹ 39,05,50,067	₹ 75,17,64,226
Hydrogen Cash Flow	INR	₹ 49,59,16,53,477	₹ 41,00,86,28,667	₹ 64,91,59,903	₹ 66,66,10,019	₹ 68,48,34,283	₹ 70,38,68,452	₹ 72,37,49,983	₹ 74,45,18,113	₹ 76,62,13,948	₹ 78,88,80,551	₹ 81,25,63,041	₹ 83,73,08,688	₹ 2,05,78,63,609
Discounted Hydrogen Cash Flow	INR	₹ 47,14,66,80,648	₹ 41,00,86,28,667	₹ 58,64,13,643	₹ 54,39,72,061	₹ 50,48,27,065	₹ 46,87,06,544	₹ 43,53,61,943	₹ 40,45,66,150	₹ 37,61,11,582	₹ 34,98,08,439	₹ 32,54,83,125	₹ 30,29,76,810	₹ 67,26,55,593
Electricity Cash Outflow	INR	₹ 36,07,52,54,775	30,22,59,32,304	44,90,09,383	46,64,59,499	48,46,83,763	50,37,17,933	52,35,99,464	54,43,67,594	56,60,63,428	58,87,30,032	61,24,12,522	63,71,58,169	66,30,16,503
Discounted Electricity Cash Outflow	INR	₹ 34,50,47,36,594	30,22,59,32,304	40,56,09,199	38,06,43,747	35,72,85,679	33,54,26,159	31,49,64,124	29,58,05,700	27,78,63,660	26,10,56,928	24,53,10,125	23,05,53,143	21,67,20,757
Levelised Cost Calculations														
LCOA	INR/kg	71.8	0.90 USD/kg											
LCOH (Produced)	INR/kg	340.3	4.25 USD/kg											
LCOH (Consumed)	INR/kg	355.5	4.44 USD/kg											
LCOE (Consumed)	INR/kWh	4.32	0.05 USD/kWh											
Discounted Electricity Production	kWh	₹ 12,47,40,35,490	0	1316065946	1187941938	1072291378	967899912.8	873671410.4	788616455.4	711841957.2	642541772.7	579988241.2	523524544.2	472557807.6
LCOE (Produced)	INR/kWh	2.77	0.03 USD/kWh											

Parameter	12	13	14	15	16	17	18	19	20	21	22	23
Operational Hours	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760
Cummulative Operational Hours	105120	113880	122640	131400	140160	148920	157680	166440	175200	183960	192720	201480
Discount Rate	0.29528	0.26674	0.24095	0.21766	0.19662	0.17762	0.16045	0.14494	0.13093	0.11828	0.10684	0.09652
Power Supply												
Electricity Units produced	1,44,45,89,075	1,44,34,77,161	1,44,23,66,225	1,44,12,56,268	1,44,01,47,287	1,43,90,39,282	1,43,79,32,253	1,43,68,26,198	1,43,57,21,116	1,43,46,17,007	1,43,35,13,868	1,43,24,11,701
Surplus Power	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494	52,20,59,494
Electricity Consumed	92,25,29,581	92,14,17,667	92,03,06,731	91,91,96,774	91,80,87,793	91,69,79,789	91,58,72,759	91,47,66,704	91,36,61,622	91,25,57,513	91,14,54,375	91,03,52,207
Discounted Electricity Consumed	27,24,01,096	24,57,74,864	22,17,51,163	20,00,75,623	18,05,18,734	16,28,73,417	14,69,52,834	13,25,88,407	11,96,28,034	10,79,34,481	9,73,83,925	8,78,64,647
Production												
H2 Produced	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882	1,60,93,882
H2 Consumed	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459	1,54,04,459
Discounted H2 Production	47,52,142	42,92,811	38,77,878	35,03,051	31,64,455	28,58,586	25,82,282	23,32,685	21,07,213	19,03,535	17,19,543	15,53,336
Discounted H2 Consumption	45,48,571	41,08,917	37,11,759	33,52,989	30,28,897	27,36,131	24,71,663	22,32,758	20,16,945	18,21,992	16,45,882	14,86,795
O2 Produced	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059	12,87,51,059
N2 Produced	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645	7,16,48,645
NH3 Produced	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104	8,70,53,104
Discounted NH3 Production	2,57,04,716	2,32,20,159	2,09,75,753	1,89,48,287	1,71,16,790	1,54,62,322	1,39,67,770	1,26,17,679	1,13,98,084	1,02,96,372	93,01,149	84,02,122
Total Capex - Total	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 0**	**₹ 46,52,34,107**	**₹ 0**	**₹ 0**
RE Plant												
Balancing- Battery										₹ 0		
H2 electrolyser										₹ 46,52,34,107		
Water - Desalination												
H2 storage												
N2 ASU												
NH3 Production												
NH3 Storage												
Depreciation - Total	₹ 30,56,06,77,949	₹ 29,55,12,25,166	₹ 28,57,60,88,009	₹ 27,63,40,75,085	₹ 26,72,40,37,033	₹ 25,84,48,65,027	₹ 24,99,54,89,323	₹ 24,17,48,77,867	₹ 23,38,20,34,946	₹ 22,61,59,99,894	₹ 21,87,58,45,840	₹ 21,16,06,78,506
RE Plant	₹ 20,12,33,65,878	₹ 19,45,25,87,015	₹ 18,80,41,67,448	₹ 18,17,73,61,866	₹ 17,57,14,49,804	₹ 16,98,57,34,811	₹ 16,41,95,43,650	₹ 15,87,22,25,528	₹ 15,34,31,51,344	₹ 14,83,17,12,966	₹ 14,33,73,22,534	₹ 13,85,94,11,783
Balancing - Battery BOP	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0
Balancing - Batteries	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0
H2 electrolyser	₹ 5,22,15,08,575	₹ 5,01,26,48,232	₹ 4,81,21,42,302	₹ 4,61,96,56,610	₹ 4,43,48,70,346	₹ 4,25,74,75,532	₹ 4,08,71,76,511	₹ 3,92,36,89,450	₹ 3,76,67,41,872	₹ 3,61,60,72,197	₹ 3,47,14,29,310	₹ 3,33,25,72,137
Water Desalination	₹ 19,00,60,762	₹ 18,53,09,243	₹ 18,06,76,512	₹ 17,61,59,599	₹ 17,17,55,609	₹ 16,74,61,719	₹ 16,32,75,176	₹ 15,91,93,296	₹ 15,52,13,464	₹ 15,13,33,127	₹ 14,75,49,799	₹ 14,38,61,054
H2 storage	₹ 1,22,73,60,192	₹ 1,17,82,65,785	₹ 1,13,11,35,153	₹ 1,08,58,89,747	₹ 1,04,24,54,157	₹ 1,00,07,55,991	₹ 96,07,25,751	₹ 92,22,96,721	₹ 88,54,04,853	₹ 84,99,88,658	₹ 81,59,89,112	₹ 78,33,49,548
N2 Production	₹ 34,52,75,358	₹ 33,83,69,851	₹ 33,16,02,454	₹ 32,49,70,405	₹ 31,84,70,997	₹ 31,21,01,577	₹ 30,58,59,546	₹ 29,97,42,355	₹ 29,37,47,508	₹ 28,78,72,557	₹ 28,21,15,106	₹ 27,64,72,804
NH3 Production	₹ 3,45,27,53,584	₹ 3,38,36,98,513	₹ 3,31,60,24,542	₹ 3,24,97,04,052	₹ 3,18,47,09,971	₹ 3,12,10,15,771	₹ 3,05,85,95,456	₹ 2,99,74,23,547	₹ 2,93,74,75,076	₹ 2,87,87,25,574	₹ 2,82,11,51,063	₹ 2,76,47,28,041
NH3 Storage	₹ 3,53,600	₹ 3,46,528	₹ 3,39,597	₹ 3,32,805	₹ 3,26,149	₹ 3,19,626	₹ 3,13,234	₹ 3,06,969	₹ 3,00,830	₹ 2,94,813	₹ 2,88,917	₹ 2,83,138
Total Opex	₹ 1,13,22,07,963	₹ 1,16,04,49,842	₹ 1,18,99,67,665	₹ 1,22,08,21,146	₹ 1,25,30,72,860	₹ 1,28,67,88,385	₹ 1,32,20,36,449	₹ 1,35,88,89,083	₹ 1,39,74,21,778	₹ 1,43,77,13,662	₹ 1,47,98,47,670	₹ 1,52,39,10,734
RE Plant	₹ 69,00,39,419	₹ 71,82,81,298	₹ 74,77,99,121	₹ 77,86,52,602	₹ 81,09,04,316	₹ 84,46,19,841	₹ 87,98,67,906	₹ 91,67,20,539	₹ 95,52,53,234	₹ 99,55,45,118	₹ 1,03,76,79,126	₹ 1,08,17,42,190
Grid Charges - Hourly Settled	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0
Grid Charges - Monthly Settled	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0
Balancing - Battery	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0
H2 electrolyser	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297	₹ 15,43,65,297
Water - OPEX	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548	₹ 2,57,53,548
H2 storage	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674	₹ 2,00,31,674
N2 production	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000	₹ 2,20,00,000
NH3 production	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000	₹ 22,00,00,000
NH3 Storage	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024	₹ 18,024
Additional Revenue	0	0	0	0	0	0	0	0	0	0	0	0
Surplus Power Sales	-	-	-	-	-	-	-	-	-	-	-	-
Oxygen Sales	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Credits Sales	0	0	0	0	0	0	0	0	0	0	0	0
Net Project Expenses	₹ 1,13,22,07,963	₹ 1,16,04,49,842	₹ 1,18,99,67,665	₹ 1,22,08,21,146	₹ 1,25,30,72,860	₹ 1,28,67,88,385	₹ 1,32,20,36,449	₹ 1,35,88,89,083	₹ 1,39,74,21,778	₹ 1,90,29,47,769	₹ 1,47,98,47,670	₹ 1,52,39,10,734
Discounted Project Cash Flow	₹ 33,43,14,147	₹ 30,95,33,246	₹ 28,67,26,919	₹ 26,57,28,252	₹ 24,63,85,071	₹ 22,85,58,605	₹ 21,21,22,264	₹ 19,69,60,534	₹ 18,29,67,978	₹ 22,50,74,778	₹ 15,81,13,646	₹ 14,70,83,599
Hydrogen Cash Flow	₹ 89,01,89,939	₹ 91,84,31,818	₹ 94,79,49,641	₹ 97,88,03,121	₹ 1,01,10,54,835	₹ 1,04,47,70,361	₹ 1,08,00,18,425	₹ 1,11,68,71,058	₹ 1,15,54,03,754	₹ 1,66,09,29,745	₹ 1,23,78,29,645	₹ 1,28,18,92,710
Discounted Hydrogen Cash Flow	₹ 26,28,51,967	₹ 24,49,78,431	₹ 22,84,11,820	₹ 21,30,49,752	₹ 19,87,98,350	₹ 18,55,71,504	₹ 17,32,90,194	₹ 16,18,81,880	₹ 15,12,79,945	₹ 19,64,49,634	₹ 13,22,55,341	₹ 12,37,24,697
Electricity Cash Outflow	69,00,39,419	71,82,81,298	74,77,99,121	77,86,52,602	81,09,04,316	84,46,19,841	87,98,67,906	91,67,20,539	95,52,53,234	99,55,45,118	1,03,76,79,126	1,08,17,42,190
Discounted Electricity Cash Outflow	20,37,52,268	19,15,91,169	18,01,84,844	16,94,84,281	15,94,43,815	15,00,20,885	14,11,75,814	13,28,71,600	12,50,73,729	11,77,49,998	11,08,70,351	10,44,06,729
Levelised Cost Calculations												
LCOA												
LCOH (Produced)												
LCOH (Consumed)												
LCOE (Consumed)												
Discounted Electricity Production	426552877.1	385026698.4	347543245.2	313708940.3	283168523.7	255601321.2	230717878.3	20,82,56,920	18,79,82,608	16,96,82,063	15,31,63,132	13,82,52,368
LCOE (Produced)												

Data Sheet 1 | Power

Power data sheet includes all the assumptions related to RE power supplier to H2-NH3 plant. There are two inputs for each data point, 1. Modelled Values: The user can adjust these values to see impact of levelized cost, 2. Default Values: These are default values provided by MEC+ to guide the user. MEC+ may update these values in future version of the model.

Three sub-modules in Power data sheet

Technology capex/opex Module

Power Supply - Data

<<ToC

		Modelled values	Default values	Comments	Sources
Solar Farm Parameters	Data Year	2022			
CAPEX- 2022	INR per MW	₹ 3,61,00,000	₹ 3,61,00,000	Includes: Panel, Inverters, BOS, I&C, I	MEC+ discussions with developers and investors
Annual decline rate of CAPEX towards 2035	%	1.99%	1.99%	Calculated Annual decline till 2035	MEC+ discussions with developers and investors
OPEX- 2023	INR per MW	₹ 5,41,500	₹ 5,41,500	1.5% of Capex	WEO 2022, Lazard
Annual escalation rate of OPEX towards 2035	%	3.00%	3.00%		CERC, HERC, TNERC
Annual AEP degradation	%	0.04%	0.04%		Aurecon, 2021
Land Lease Cost	INR per MW/Year	₹ 1,13,750	₹ 1,13,750	1. 3.5 acres required per MW of solar2.	MEC+ discussions with developers and investors
Expected Useful Life	years	30	30		
Depreciation Rate	%	3.33%	3.333%		Assumption
Onshore Wind Farm Parameters	Data Year	2022			
CAPEX- 2022	INR per MW	₹ 8,43,28,000	₹ 8,43,28,000	1. Includes: Turbine Equipment Capex,	MEC+ discussions with developers and investors
Annual decline rate of CAPEX towards 2035	%	1.54%	0.0154	Calculated Annual decline based on M	MEC+ discussions with developers and investors
OPEX- 2023	INR per MW	₹ 10,11,936	₹ 10,11,936	1.2% of Capex	WEO 2022, Lazard, Industry Assessment
Annual escalation rate of OPEX towards 2035	%	5.00%	5%		CERC, HERC, TNERC
Annual AEP degradation	%	0.10%	0.10%		Aurecon, 2021
Land Lease cost	INR per MW/Year			Included in Capex	
Expected Useful Life	Years	30	30		
Depreciation Rate	%	3.3%	3.3%		Assumption
Offshore Wind Farm Parameters	Data Year	2022			
CAPEX- 2022	INR per MW	₹ 22,86,00,000	₹ 22,86,00,000	Includes: Capex turbine, BOP, Develop	FIMOI initiative
Annual decline rate of CAPEX towards 2035	%	5.40%	5.40%	2020-25: 3.1% 2025-2030-6.7%	FIMOI initiative
OPEX- 2023	INR per MW	₹ 66,29,400	₹ 66,29,400	2.9% of Capex	FIMOI initiative
Annual escalation rate of OPEX towards 2035	%	5.00%	5.00%		FIMOI initiative
Annual AEP degradation	%	0.10%	0.10%		FIMOI initiative
Land/Seabed Lease cost	INR per MW/Year				Included in development cost
Expected Useful Life	Years	30	30		
Depreciation Rate	%	3.33%	3.333%		Assumption
Battery Parameters	Data Year	2025			
CAPEX- 2025	INR per MW	₹ 9,43,00,000	₹ 9,43,00,000	Total Capex for 8 hr battery calculated	Draft National Electrcity Plan
Annual decline rate of CAPEX towards 2035	%	4.69%	4.69%	For 2024-25 to 2029-30 period	Draft National Electrcity Plan
OPEX- 2023	INR per MW	₹ 23,57,500	₹ 23,57,500	Considered as 2.5% of capex	NREL ATB
Annual escalation rate of OPEX towards 2035	%	0%	0%		-
Annual AEP degradation	%	0%	1.80%		Aurecon, 2021
Minimum state of Charge	%	5%	5%		Lazard, 2021
Maximum state of Charge	%	100%	100%	Assumption	
Round Trip Efficiency	%	85%	85%		Aurecon, 2021
Battery Replacement Cost	% of CAPEX	65%	65%		NREL ATB
Battery Lifetime	Years	10	10		BNEF, Lazard 2021
Expected Useful Life of System	Years	25	25		
Depreciation Rate	%	4.00%	4.00%		Assumption

- Covers assumptions related to capex, opex, lifetime, learning rate, degradation rate, depreciation rate, etc. for solar, onshore wind, offshore wind and Li-ion batteries

Power Banking module

Banking parameters charges

Banking period	Monthly

Banking charges	Modelled values		Default values	
State	Banking charges (% of banked kWh)	Banking Limit (% of generation that can be banked)	Banking charges (% of banked units/ kWh)	Banking Limit (% of generation that can be banked)
Gujarat	2%	100%	2%	100%
Rajasthan	2%	100%	2%	100%
Maharashtra	2%	100%	2%	100%
Karnataka	2%	100%	2%	100%
Tamil Nadu	2%	100%	2%	100%
Punjab	2%	100%	2%	100%
Uttar Pradesh	2%	100%	2%	100%
Odisha	2%	100%	2%	100%
Andhra Pradesh	2%	100%	2%	100%
Madhya Pradesh	2%	100%	2%	100%
Haryana	2%	100%	2%	100%
Chhattisgarh	2%	100%	2%	100%
Telangana	2%	100%	2%	100%
Kerala	2%	100%	2%	100%

- Covers assumptions related to banking limit and baking charges. These assumptions are policy dependent and typically have an annual refresh cycle
- States are yet to come up with banking policy for green hydrogen. For this version of model, it is assumed that states will allow 100% banking with low charges for green hydrogen to give it a policy push

Grid charges module

Grid Charges

User inputs	Values	
Plant capacity	130	MW
Generation	1456885003	kWh
Waiver	High	Default set at 'High'
Injection level (RE Plant)	NA - Direct Connection	

Injection levels

STU
CTU

<<STU means intra-state and CTU means Inter-state vi

Waivers

High	50%
Low	20%
No	0%

	INR/kWh	INR/kWh	INR/kWh	INR/kWh
State	STU Charge/Unit	STU Losses/Unit	CTU Losses/Unit	Landed Charge/Unit
Himachal Pradesh	0.01	0.00	0.00	0.01
Madhya Pradesh	0.08	0.00	0.00	0.08
Rajasthan	0.10	0.01	0.00	0.11
Uttar Pradesh	0.12	0.01	0.00	0.13
Karnataka	0.09	0.01	0.00	0.10
Kerala	0.17	0.01	0.00	0.18
Gujarat	0.07	0.01	0.00	0.07
Tamil Nadu	0.09	0.01	0.00	0.09
Andhra Pradesh	0.10	0.01	0.00	0.10
Maharashtra	0.14	0.01	0.00	0.15
Odisha	0.11	0.01	0.00	0.12
Haryana	0.21	0.01	0.00	0.22
Assam	0.23	0.02	0.00	0.24
Chhattisgarh	0.03	0.00	0.00	0.03
Telangana	0.07	0.00	0.00	0.08
Punjab	0.06	0.00	0.00	0.06

State	STU units	STU Charges/unit injected	STU loss units	STU Charges/unit withdrawn	STU loss charge/unit	CTU Units	CTU charge/unit injected	CTU loss units
	kWh	INR/kWh	kWh	INR/kWh	INR/kWh (F-D)	kWh	INR/kWh	kWh
Himachal Pradesh	1404291454	0.02	10532186	0.02	0.00	0	0.00	0
Madhya Pradesh	1404291454	0.16	36792436	0.17	0.00	0	0.00	0
Rajasthan	1404291454	0.21	53363075	0.22	0.01	0	0.00	0
Uttar Pradesh	1404291454	0.25	45920331	0.25	0.01	0	0.00	0
Karnataka	1404291454	0.19	40162736	0.19	0.01	0	0.00	0
Kerala	1404291454	0.33	47745909	0.34	0.01	0	0.00	0
Gujarat	1404291454	0.14	52239642	0.14	0.01	0	0.00	0
Tamil Nadu	1404291454	0.17	53503504	0.18	0.01	0	0.00	0
Andhra Pradesh	1404291454	0.19	42550031	0.20	0.01	0	0.00	0
Maharashtra	1404291454	0.29	44656468	0.30	0.01	0	0.00	0
Odisha	1404291454	0.23	42128744	0.23	0.01	0	0.00	0
Haryana	1404291454	0.42	25417675	0.43	0.01	0	0.00	0
Assam	1404291454	0.45	45920331	0.47	0.02	0	0.00	0
Chhattisgarh	1404291454	0.05	42128744	0.05	0.00	0	0.00	0
Telangana	1404291454	0.14	36090290	0.15	0.00	0	0.00	0
Punjab	1404291454	0.11	34264711	0.11	0.00	0	0.00	0

Data

Gird Charges Applicable in Monthly - No Banking (Buy - sell at Exchange)

IEX generator side

State	CTU charges	CTU loss	IEX margin	Total (INR/kWh)
Himachal Pradesh	0.41	0	0.02	0.43
Madhya Pradesh	0.51	0	0.02	0.53
Rajasthan	0.69	0	0.02	0.71
Uttar Pradesh	0.51	0	0.02	0.53
Karnataka	0.52	0	0.02	0.54
Kerala	0.51	0	0.02	0.53
Gujarat	0.50	0	0.02	0.52
Tamil Nadu	0.49	0	0.02	0.51
Andhra Pradesh	0.63	0	0.02	0.65
Maharashtra	0.53	0	0.02	0.55
Odisha	0.49	0	0.02	0.51
Haryana	0.55	0	0.02	0.57
Assam	0.39	0	0.02	0.41
Chhattisgarh	0.36	0	0.02	0.38
Telangana	0.48	0	0.02	0.50
Punjab	0.43	0	0.02	0.45

IEX Buyer side

					FY21			
State	CTU charges	CTU Losses	STU Charge (INR/kWh)	STU Losses	CSS	AS	IEX markgin	Total (INR/kWh)
Himachal Pradesh	0.41	0.00	0.07	0.00	0.45	0	0.02	0.95
Madhya Pradesh	0.51	0.00	1.28	0.00	1.6	1.11	0.02	4.52
Rajasthan	0.69	0.00	0.28	0.01	1.7	0.8	0.02	3.50
Uttar Pradesh	0.51	0.00	0.25	0.01	0.84	0	0.02	1.63
Karnataka	0.52	0.00	0.21	0.01	1.86	1.87	0.02	4.49
Kerala	0.51	0.00	0.47	0.01	1.2	0	0.02	2.21
Gujarat	0.50	0.00	0.36	0.01	1.48	0.69	0.02	3.05
Tamil Nadu	0.49	0.00	0.45	0.01	1.67	0.7	0.02	3.34
Andhra Pradesh	0.63	0.00	0.82	0.01	1.55	0	0.02	3.03
Maharashtra	0.53	0.00	0.41	0.01	1.67	1.33	0.02	3.97
Odisha	0.49	0.00	0.28	0.01	1.64	0	0.02	2.44
Haryana	0.55	0.00	0.36	0.01	1.02	1.15	0.02	3.11
Assam	0.39	0.00	0.43	0.02	0.5	0	0.02	1.35
Chhattisgarh	0.36	0.00	0.32	0.00	0.66	0	0.02	1.37
Telangana	0.48	0.00	0.20	0.00	1.65	0.52	0.02	2.88
Punjab	0.43	0.00	0.23	0.00	0.65	0.83	0.02	2.16

- Covers assumptions related to grid charges applicable on supply of power from RE plant to H2-NH3 plant
- There are two sub-modules- 1. Charges applicable on direct settlement of power, i.e., produced and consumed in same hour, 2. Charges applicable on settlement of power through power exchange (invites additional charges)

Data Sheet 2 | H2-NH3-Fertilizer

H2-NH3-Fertilizer data sheet includes all the assumptions related to hydrogen plant, ammonia plant and Fertilizer plant (Urea, DAP and NPK). There are two inputs for each data point, 1. Modelled Values: The user can adjust these values to see impact of levelized cost, 2. Default Values: These are default values provided by MEC+ to guide the user. MEC+ may update these values in future version of the model.

Three sub-modules in H2-NH3-Fertilizer data sheet

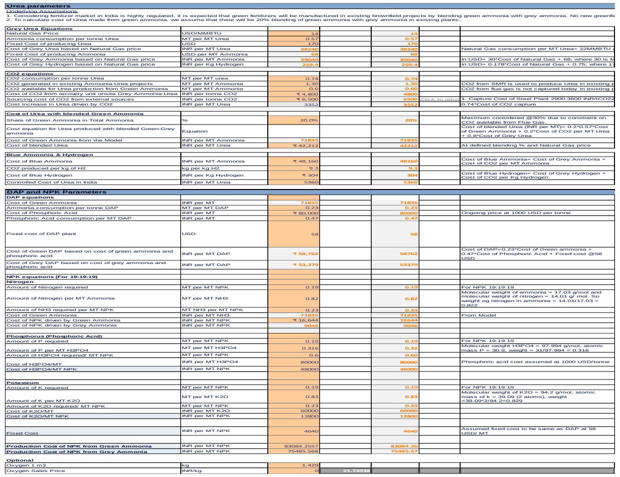
Hydrogen module

- Covers electrolyser assumptions related to capex, opex, lifetime, learning rate, degradation rate, depreciation rate, minimum turndown load, etc
- Covers desalination plant assumptions related to capex, opex, brine management, etc.
- Covers hydrogen storage assumptions related to capex, opex, minimum turndown level, lifetime, etc.

Ammonia module

- Covers assumptions on Haber Bosch related to capex, opex, lifetime, learning rate, degradation rate, depreciation rate, minimum turndown load, etc
- Covers assumptions on Cryogenic ASU related to capex, opex, lifetime, learning rate, depreciation rate
- Covers assumptions on ammonia storage related to capex, opex and duration

Fertilizer module



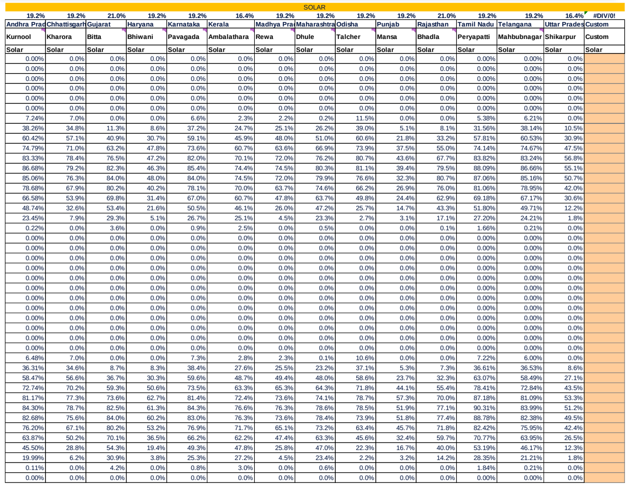
- Covers assumptions on Urea plant related to cash cost calculation equation for green and grey urea, cost of CO2, blending %, etc.
- Covers assumptions on DAP and NPK plant related to cash cost calculation equation for green and grey DAP/NPK cost, cost of phosphoric acid, potassium, etc.

Data Sheet 3 | Site profile

- Site profile data sheet includes hourly generation profile of solar, onshore wind and offshore wind sites across different states considered for the modelling
- Model also allows user to upload a custom site profile to evaluate results

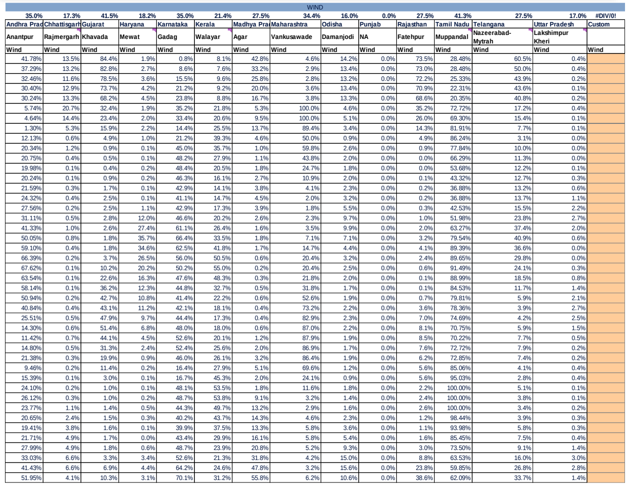
Three sub-modules in Site profile data sheet

Solar module



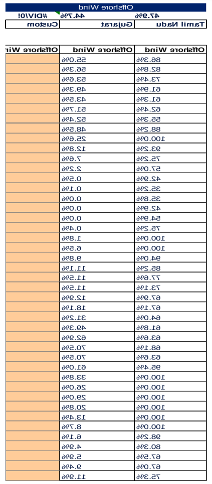
- Covers hourly generation profile for solar across 14 different states for the year 2019
- The data has been sourced from Renewables Ninja website and is based on weather data from global reanalysis models and satellite observations
- User has option to add profile of their own site

Onshore wind module



- Covers hourly generation profile for onshore wind across different states for the year 2019
- The data has been sourced from Renewables Ninja website and is based on weather data from global reanalysis models and satellite observations
- User has option to add profile of their own site

Offshore wind module



- Covers hourly generation profile for offshore wind in Tamil Nadu for the year 2019
- The data has been sourced from Renewables Ninja website for a coastal site in Tamil Nadu for which CUF has been bumped in line with CUF reported by NIWE and other outlets
- User has option to add profile of their own site

giz

Data Sheet 4 | Optimized solutions

- Optimized Solutions sheet includes RE and Electrolyser plant configuration which give lowest cost of ammonia while meeting pre-defined KPI for NH3 plant, i.e., PLF >85%, shut down time of <1000 hour and H2 surplus of <5% (of total generation)
- The purpose of optimized solutions is to provide User of NH3 dashboard with a baseline plant configuration and cost levels, so that user is not limited by the knowledge of RE, H2 and Ammonia plant.

Two sub-modules in Optimized Solutions data sheet

Monthly Settlement

Monthly Settlement

RE Generation Technology	Solar	Solar	Solar	Solar	Solar	Solar	Solar	Solar	Solar	Solar
Class	Class I	Class I	Class I	Class I	Class II	Class II	Class II	Class II	Class III	Class III
Battery Storage	No	No	No	No	No	No	No	No	No	No
Balancing Technology	Grid Banking	Grid Banking	No Banking	No Banking	Grid Banking	Grid Banking	No Banking	No Banking	Grid Banking	Grid Banking
Electrolyser Type	PEM	Alkaline	PEM	Alkaline	PEM	Alkaline	PEM	Alkaline	PEM	Alkaline
MatchCode	SolarClass INoGrid BankingPEM	SolarClass INoGrid BankingAlkaline	SolarClass INoNo BankingPEM	SolarClass INoNo BankingAlkaline	SolarClass IINoGrid BankingPEM	SolarClass IINoGrid BankingAlkaline	SolarClass IINoNo BankingPEM	SolarClass IINoNo BankingAlkaline	SolarClass IIINoGrid BankingPEM	SolarClass IIINoGrid BankingAlkaline
Electrolyser Capacity Oversizing	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
RE Oversizing	370%	370%	340%	340%	405%	405%	395%	395%	475%	475%
Solar to Wind	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Battery size 8hr	0	0	0	0	0	0	0	0	0	0
Total Demand in MW	0	0	0	0	0	0	0	0	0	0
NH3 plant size in kTPA	0	0	0	0	0	0	0	0	0	0
Hydrogen Storage	0	0	0	0	0	0	0	0	0	0

Hourly Settlement

Hourly

RE Generation Technology	Solar	Solar	Solar	Solar	Solar	Solar	Onshore Wind	Onshore Wind	Onshore Wind	Onshore Wind	Onshore Wind
Class	Class I	Class I	Class II	Class II	Class III	Class III	Class I	Class I	Class I- Tamilnadu	Class I- Tamilnadu	Class II
Battery Storage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Balancing Technology	No Banking	No Banking	No Banking	No Banking	No Banking	No Banking	No Banking	No Banking	No Banking	No Banking	No Banking
Electrolyser Type	PEM	Alkaline	PEM	Alkaline	PEM	Alkaline	PEM	Alkaline	PEM	Alkaline	PEM
MatchCode	SolarClass IYesNo BankingPEM	SolarClass IYesNo BankingAlkaline	SolarClass IIYesNo BankingPEM	SolarClass IIYesNo BankingAlkaline	SolarClass IIIYesNo BankingPEM	SolarClass IIIYesNo BankingAlkaline	Onshore WindClass IYesNo BankingPEM	Onshore WindClass IYesNo BankingAlkaline	Onshore WindClass I-TamilnaduYesNo BankingPEM	Onshore WindClass I-TamilnaduYesNo BankingAlkaline	Onshore WindClass IIYesNo BankingPEM
Electrolyser Capacity Oversizing	9%	9%	9%	9%	9%	9%	28%	28%	23%	23%	28%
RE Oversizing	350%	330%	430%	410%	560%	545%	315%	320%	532%	560%	490%
Solar to Wind	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%	0%
Battery size 8hr	197	192	205	200	185	175	52	52	50	50	50
Total Demand in MW	0	0	0	0	0	0	0	0	0	0	0
NH3 plant size in kTPA	0	0	0	0	0	0	0	0	0	0	0
Hydrogen Storage	1	1	1	1	1	1	1.1	1.1	1.1	1.1	1.8

- The optimal configuration varies by the type of settlement chosen- monthly vs hourly since the fundamental plant design are different in the two cases
- The optimal configuration is on five dimensions- 1. RE oversizing, 2. Solar to wind ratio, 3. Electrolyser oversizing, 4. Battery size and 5. H2 storage size, and is influenced by five design parameters- 1. RE tech, 2. RE resource class, 3. Battery selection, 4. Balancing mechanism, 5. Electrolyser tech.

ToC

Framework | Cost of green ammonia is determined by four factors

Boundary condition:
Definition of Green Ammonia
- Monthly Settlement
- Hourly Settlement

A

Plant Utilization
- RE generation profile
- RE resource quality at location
- Balancing tech. (battery, H2 storage)
- Operational characteristics of plant

2

Policy
- Definitions
- Subsidies and Incentives
- Charges and taxes

1

Production of Green Ammonia and Fertilizers

3

Capex and Opex
- System design
- Technology choices
- Feedstock
- Learning rates towards 2034

4

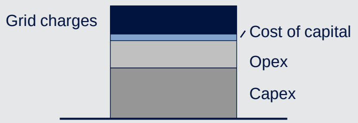
Cost of Capital (WACC)
- Cost of debt
- Cost of equity
- Debt : Equity ratio
- Depreciation
- Cash flow duration

Note* Wind and solar grid constraints taken into account
Source: MEC Intelligence analysis

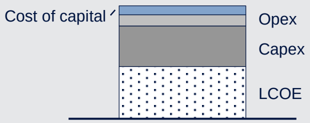
Framework | Within the four factors, 25+ parameters impact the cost of green ammonia, out of which model allows flexibility on ~14 parameters

User adjusted
Default inputs

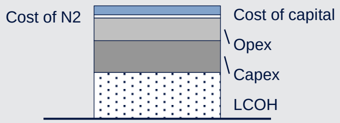
LCOE



LCOH



LCOA



Key parameters	LCOE	LCOH	LCOA
Plant utilization (CUF)	Generation profile as per RE Site Location Balancing tech.- Battery storage Curtailment rate	Plant availability based on RE generation Plant availability based on location and connectivity Electrolyser tech. and operating characteristic	Plant availability based on RE generation Plant availability based on H2 generation Plant availability based H2 storage (balancing tech.)
Policy definition and charges	Grid charges as per CTU/STU connectivity of RE-NH3 plants Waive-offs and incentives on grid charges	Type of Settlement: Monthly vs Hourly Power Banking vs No Banking	Type of Settlement: Monthly vs Hourly Power Banking vs No Banking
Capex and Opex	RE Tech.- Solar, ON wind, OF wind, Storage and learning rate Year of commissioning of plant: 2025-2034 System size in MW	Electrolyser tech: Alkaline, PEM and learning rate Water source: Desalination vs Pipeline System size in Tonne per Day/ MW	NH3 tech: Haber Bosch and learning rate ASU tech: Cryogenic System size in Tonne per Day/ MW
Cost of capital	Cost of debt and equity Debt: Equity ratio Depreciation rate and cashflow duration	Cost of debt and equity Debt: Equity ratio Depreciation rate and cashflow duration	Cost of debt and equity Debt: Equity ratio Depreciation rate and cashflow duration

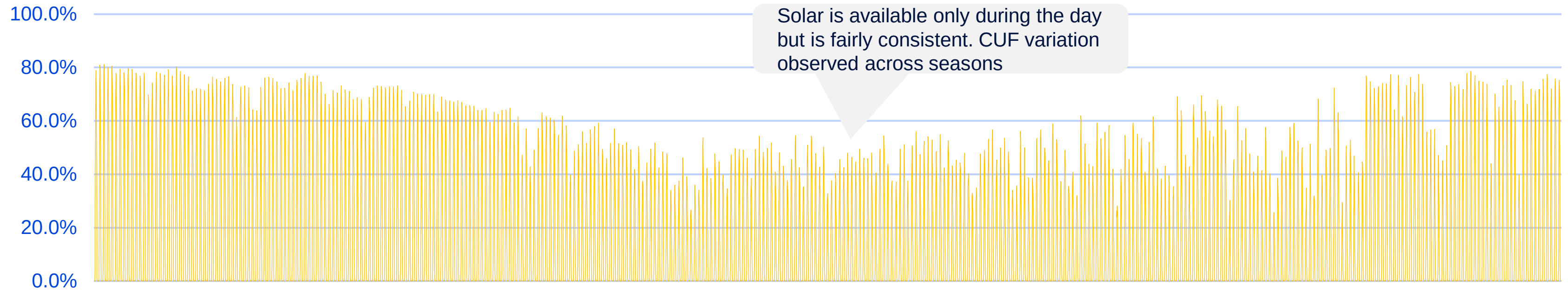
Definition | Green Hydrogen/Ammonia definition considered in Europe and India

	India	Europe
Definition	• Green Hydrogen/Ammonia is defined as Hydrogen/Ammonia produced by way of electrolysis of water using Renewable Energy • Includes Renewable Energy which has been banked and Hydrogen/Ammonia produced from Biomass	• Green Hydrogen/Ammonia comes under 'Renewable liquid and gaseous transport fuels of non-biological origin' which are defined as those produced from Renewable Electricity
Rules- Temporal and Geographical Correlation	• No specific rules around temporal correlation of RE power production and consumption have been defined yet, however, policy provides monthly power banking facility which indicates a ***Monthly settlement*** mechanism, i.e., it is green hydrogen/ammonia if RE power consumed is generated in the same calendar month • No specific rules around geographical correlation. In their absence we assume that RE power plant and H2-NH3 plant can be located anywhere across India	• Until 31 December 2029, the temporal correlation condition shall be considered complied with if the renewable liquid and gaseous transport fuel of non-biological origin is produced during ***the same calendar month*** as the renewable electricity produced • From 1 January 2030, the temporal correlation condition shall be considered complied with if the renewable liquid and gaseous transport fuel of non-biological origin is produced during the same ***one-hour period*** as the renewable electricity produced

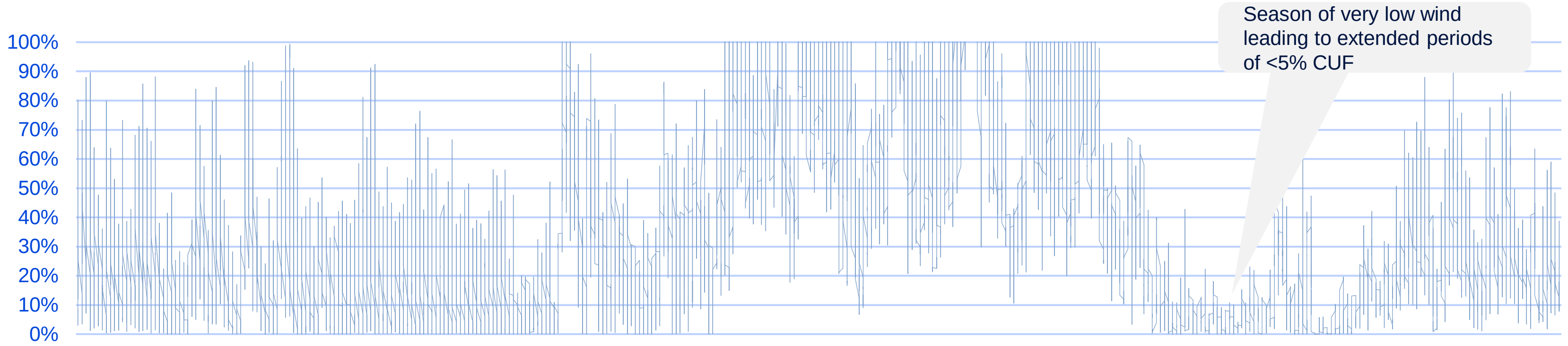
Design challenge | RE power is intermittent and varies by location, time of day and season; hourly settlement requires balancing mechanisms for steady operation of H2-NH3 plant

Hourly CUF in Tamil Nadu throughout the year 2019 for the three technologies

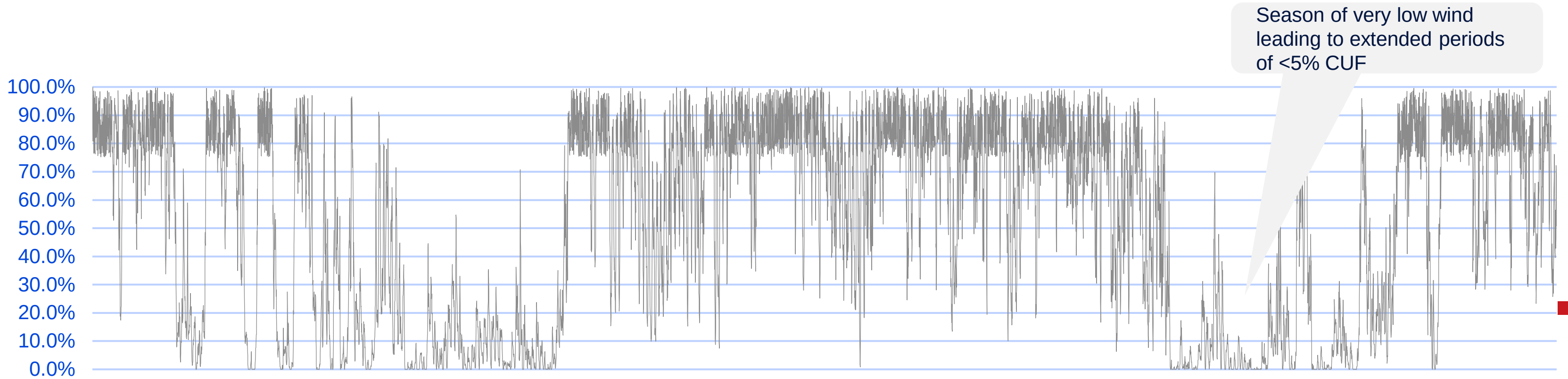
Solar



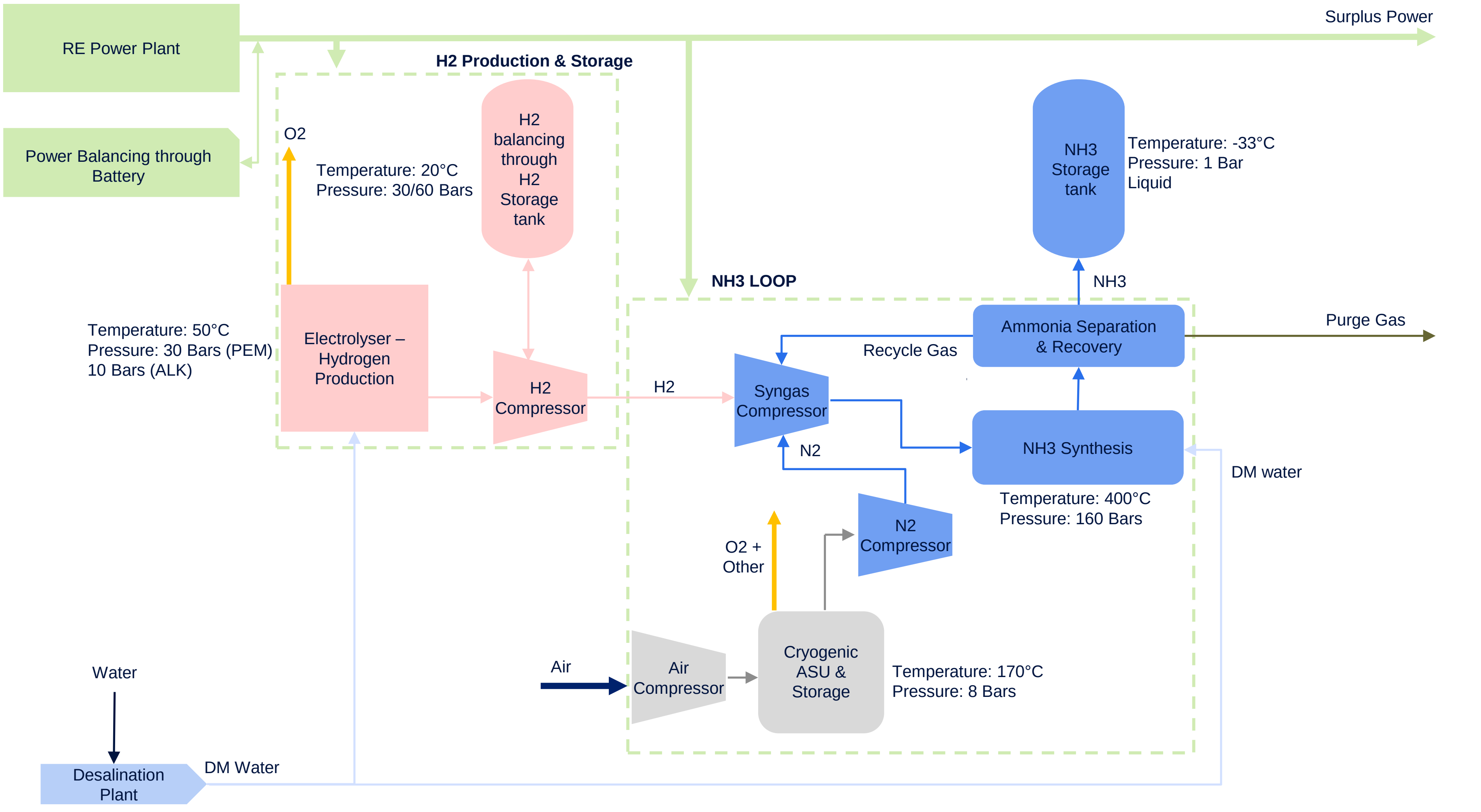
Onshore wind



Offshore wind



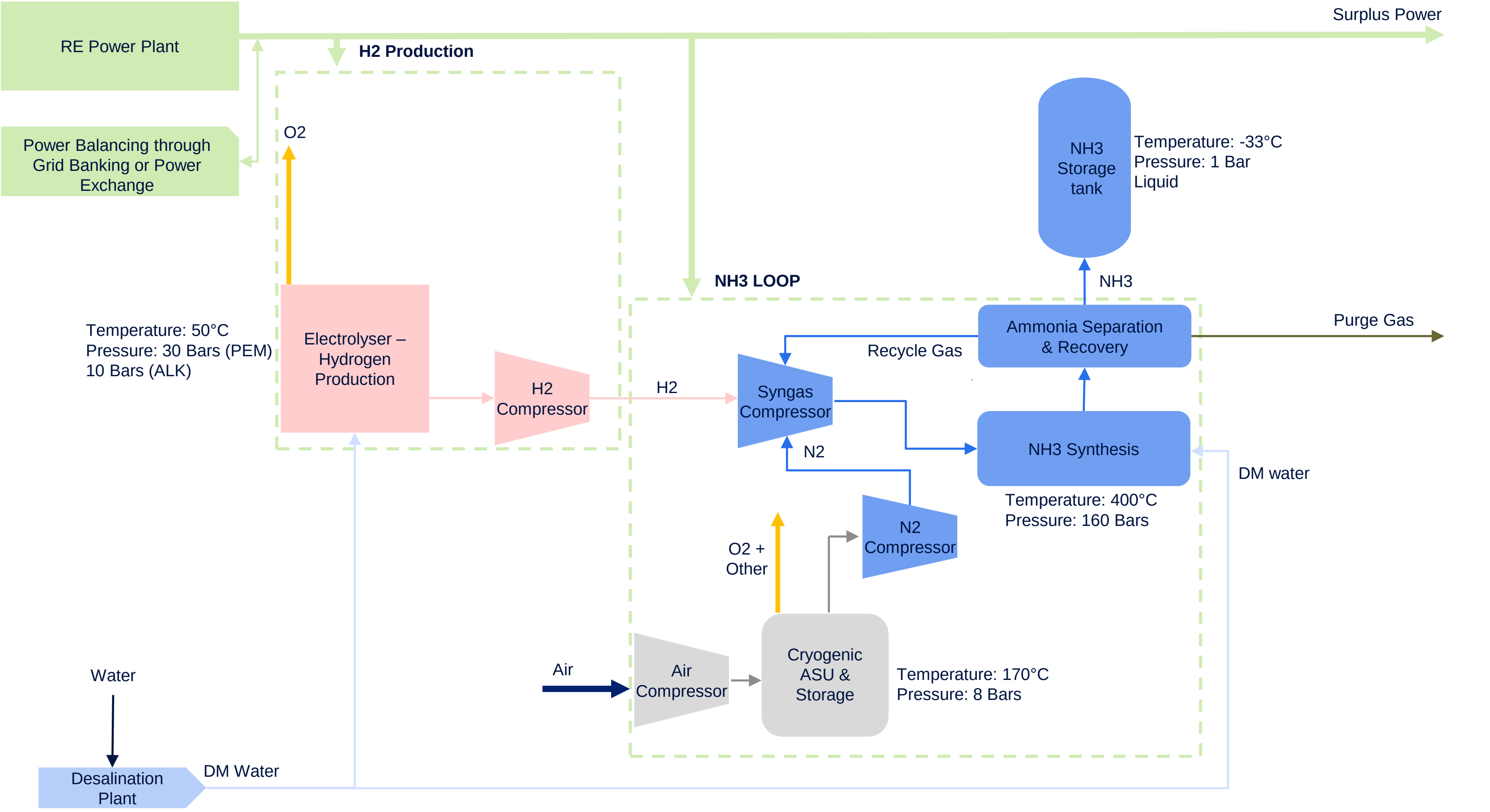
Plant design for Hourly Settlement | Battery and H2 storage act as the balancing mechanisms for intermittent RE



Note:
Source: MEC+ Analysis

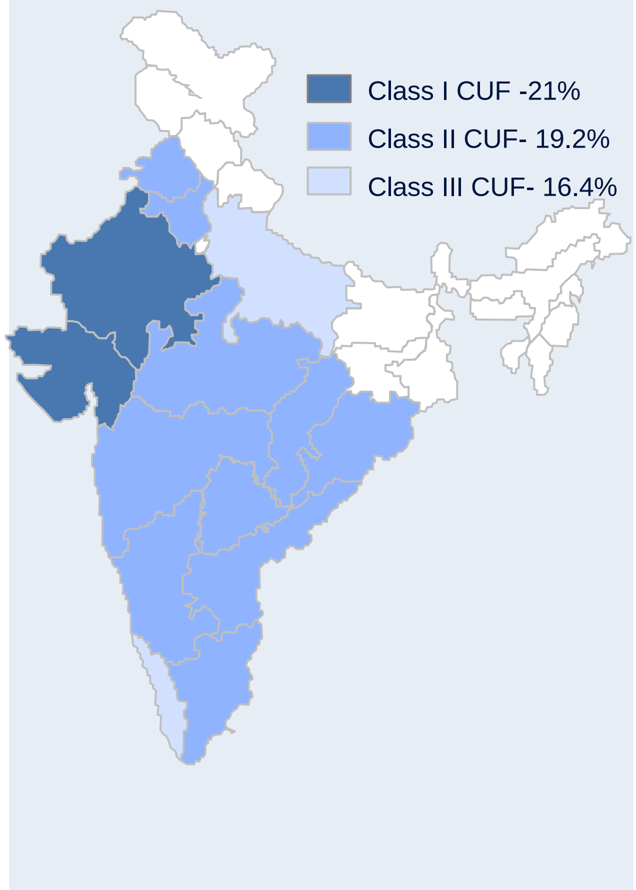
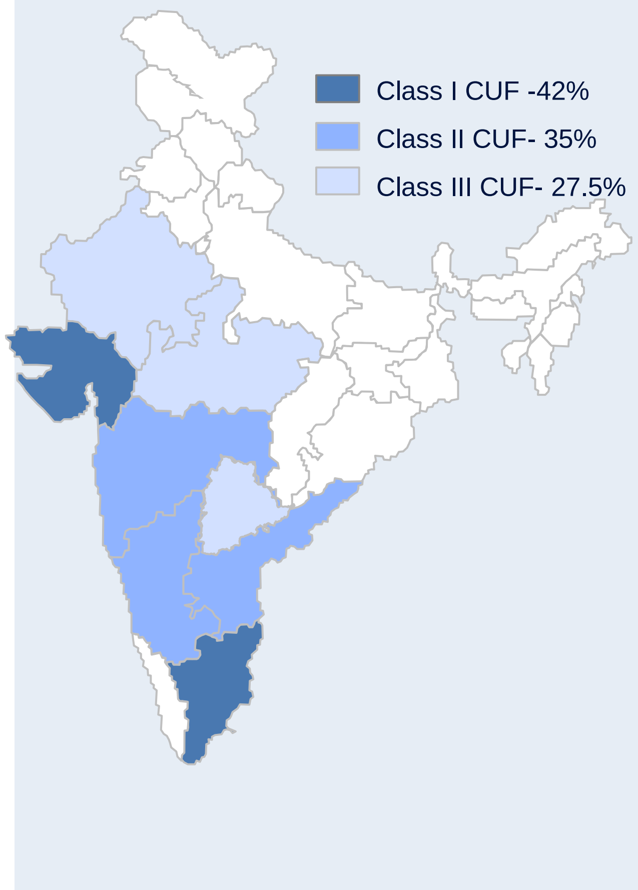
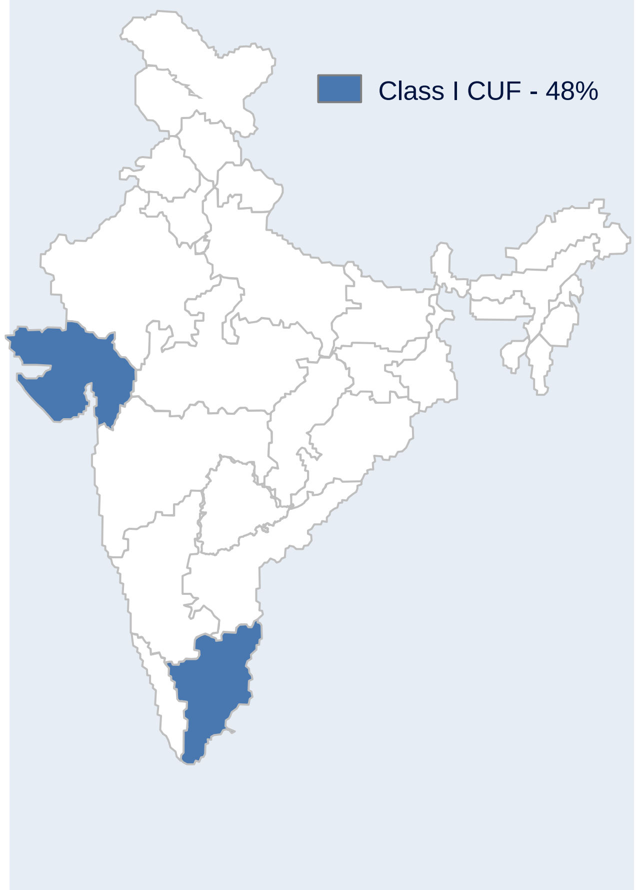
giz

Plant design for Monthly Settlement | Grid Banking and Power Exchange act as the balancing mechanism for consistent power supply



Note:
Source: MEC+ Analysis

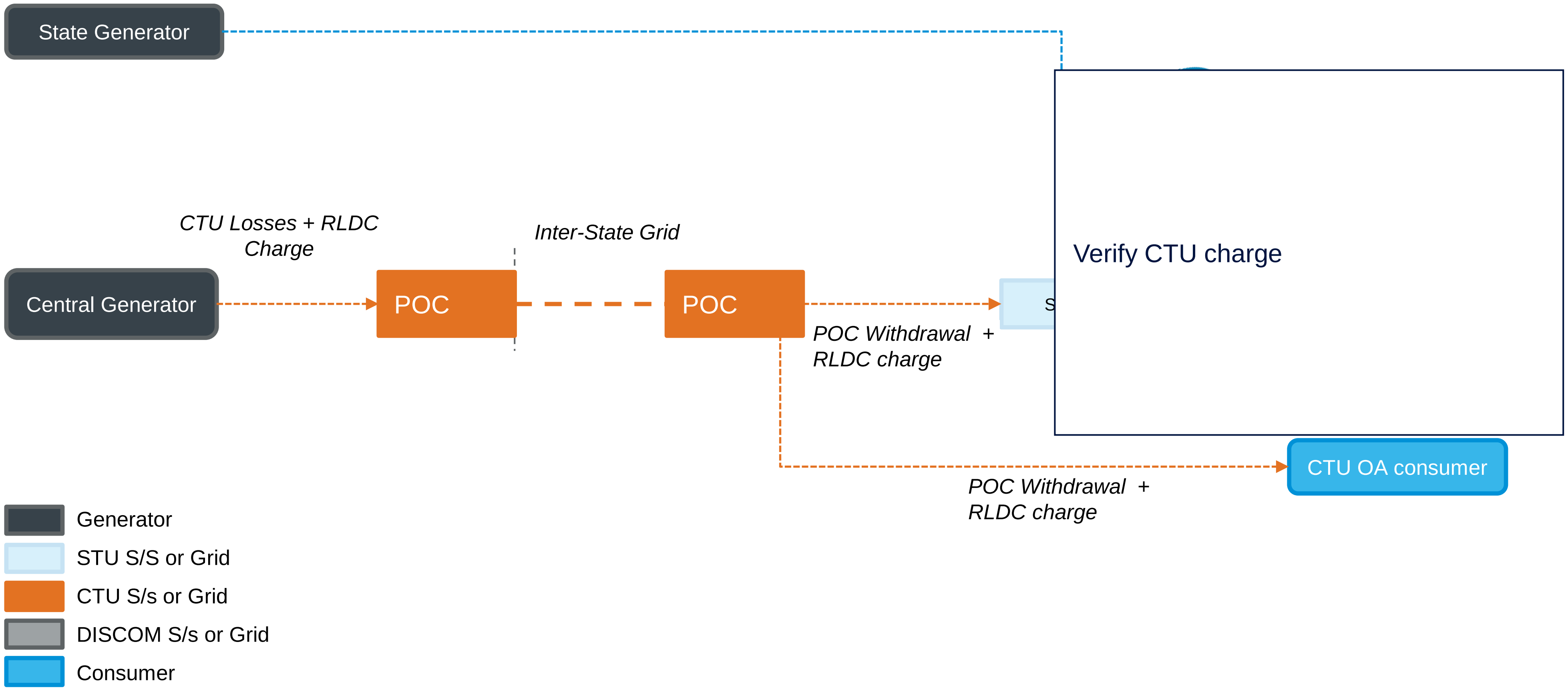
Geography | Sites considered by RE technology and their CUF; variability and curtailment assumptions

Solar states/zones with CUF	Onshore wind states/zones with CUF	Offshore wind states/zones with CUF
		

Note: CUF- Capacity Utilisation factor
Source: MEC+ analysis

Power flow framework | For power settled in same hourly window

Framework of charges for power settled in same hourly/15-min window for inter-state and intra-state flow

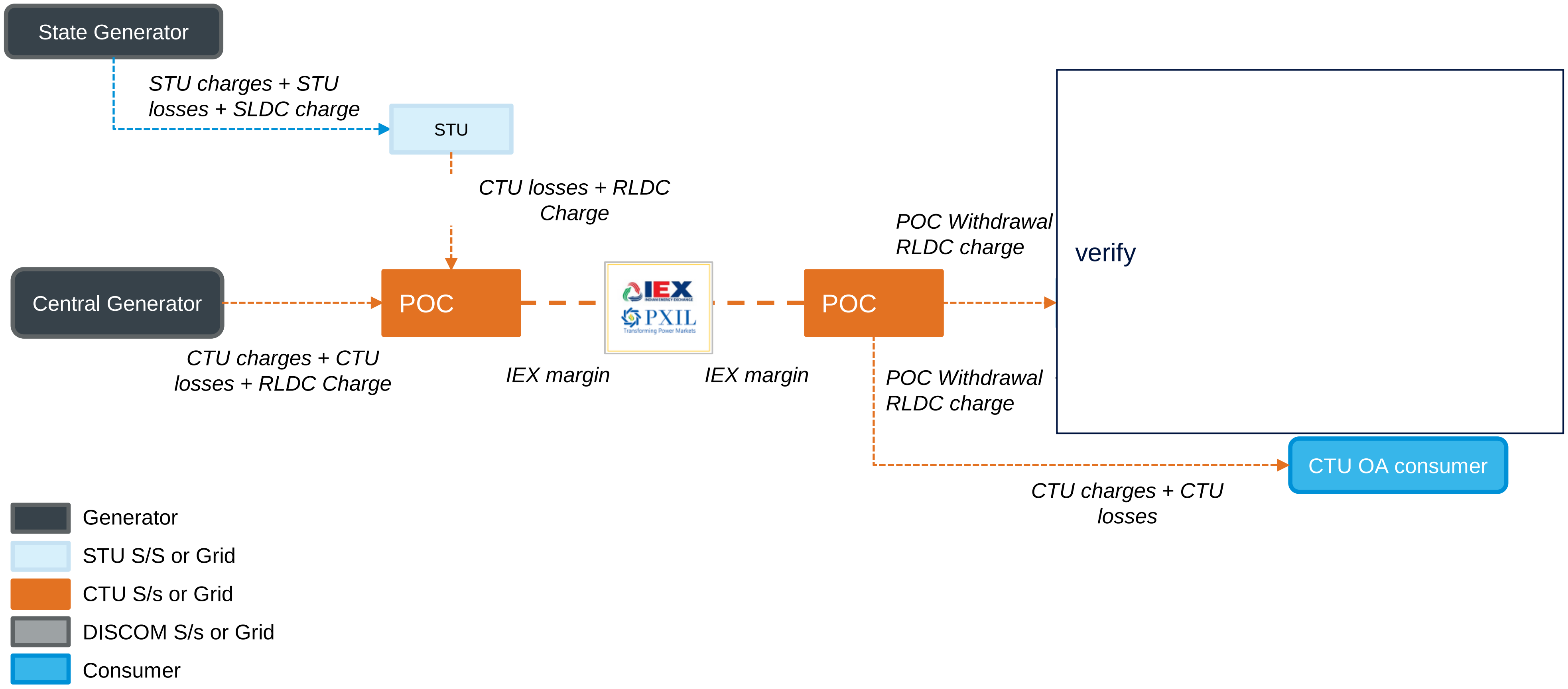


Note: CTU: Central Transmission Utility; STU: State Transmission Utility; SLDC: State Load Dispatch Center; RLDC: Regional Load Dispatch Center; OA: Open Access; POC: Point Of Connection; Tx: Transmission

Source: PGCIL; OA Policy; RLDC/SLDC; mec+ analysis

Power flow framework | For power sold and procured from power exchange

Framework of charges for power sold and procured from exchange and modelled in the Tool



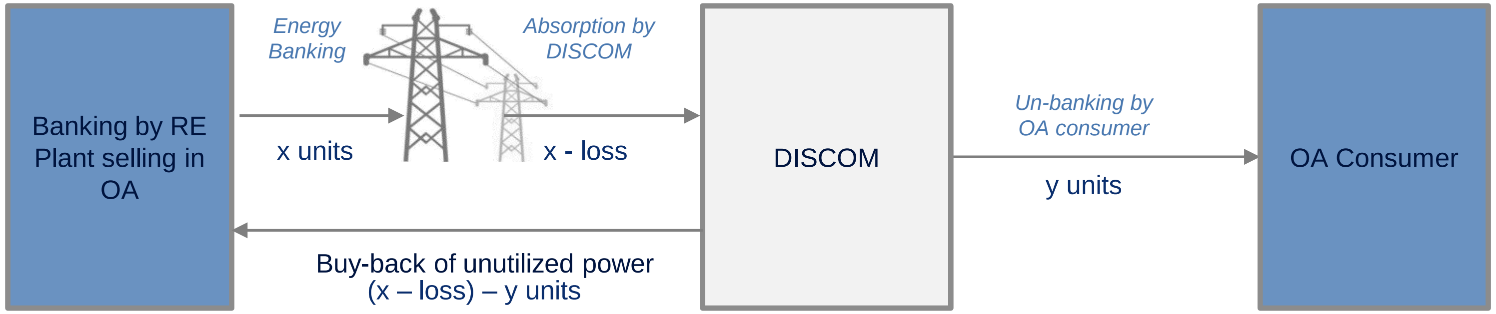
Note: CTU: Central Transmission Utility; STU: State Transmission Utility; SLDC: State Load Dispatch Center; RLDC: Regional Load Dispatch Center; OA: Open Access; POC: Point Of Connection; Tx: Transmission

Source: PGCIL; OA Policy; RLDC/SLDC; mec+ analysis

Power Banking Framework in India

Management of excess power through banking mechanism at intra-state level

RE plant selling to OA consumer: Unconsumed electricity by OA consumer



- A RE plant selling power under open access can bank unconsumed power by consumer with the DISCOM for a given banking period by paying banking charges in kind
- The banked power can be unbanked by the OA consumer within the banking period; unconsumed units are compensated by DISCOM at reduced tariff to plant

Charges levied in kind
Charges = C% of Banked power

Or absolute banking charges

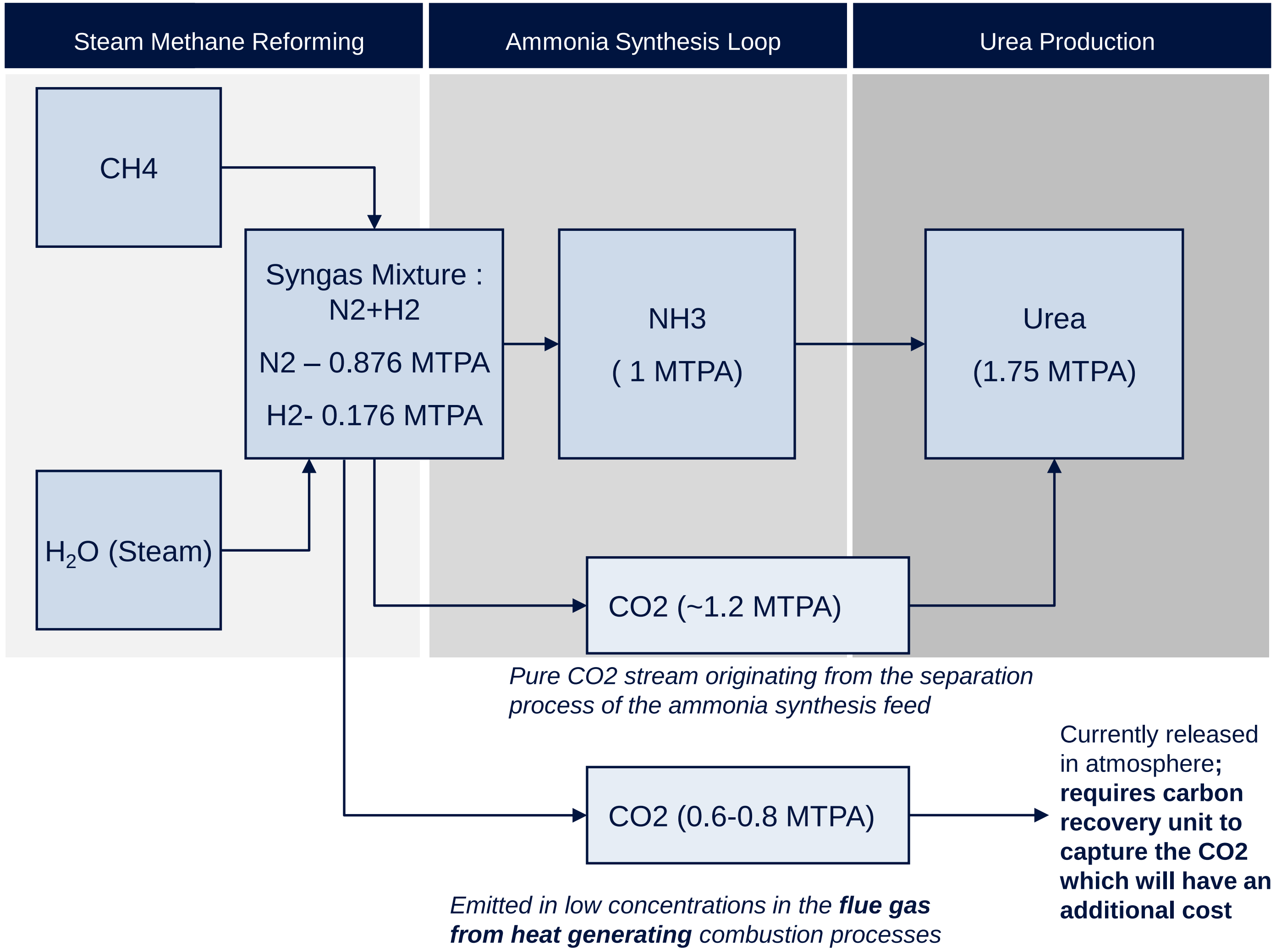
Banked energy to be bought back at a certain percentage of PPA tariff or APPC

Buy-back rate = P% * PPA Tariff or P% * APPC

Note: C%- Banking charges (2%-12%); P%- Percentage of tariff applicable (60%-75%)
* Wheeling losses charged once at the time of injection of power
Source: MEC+ analysis

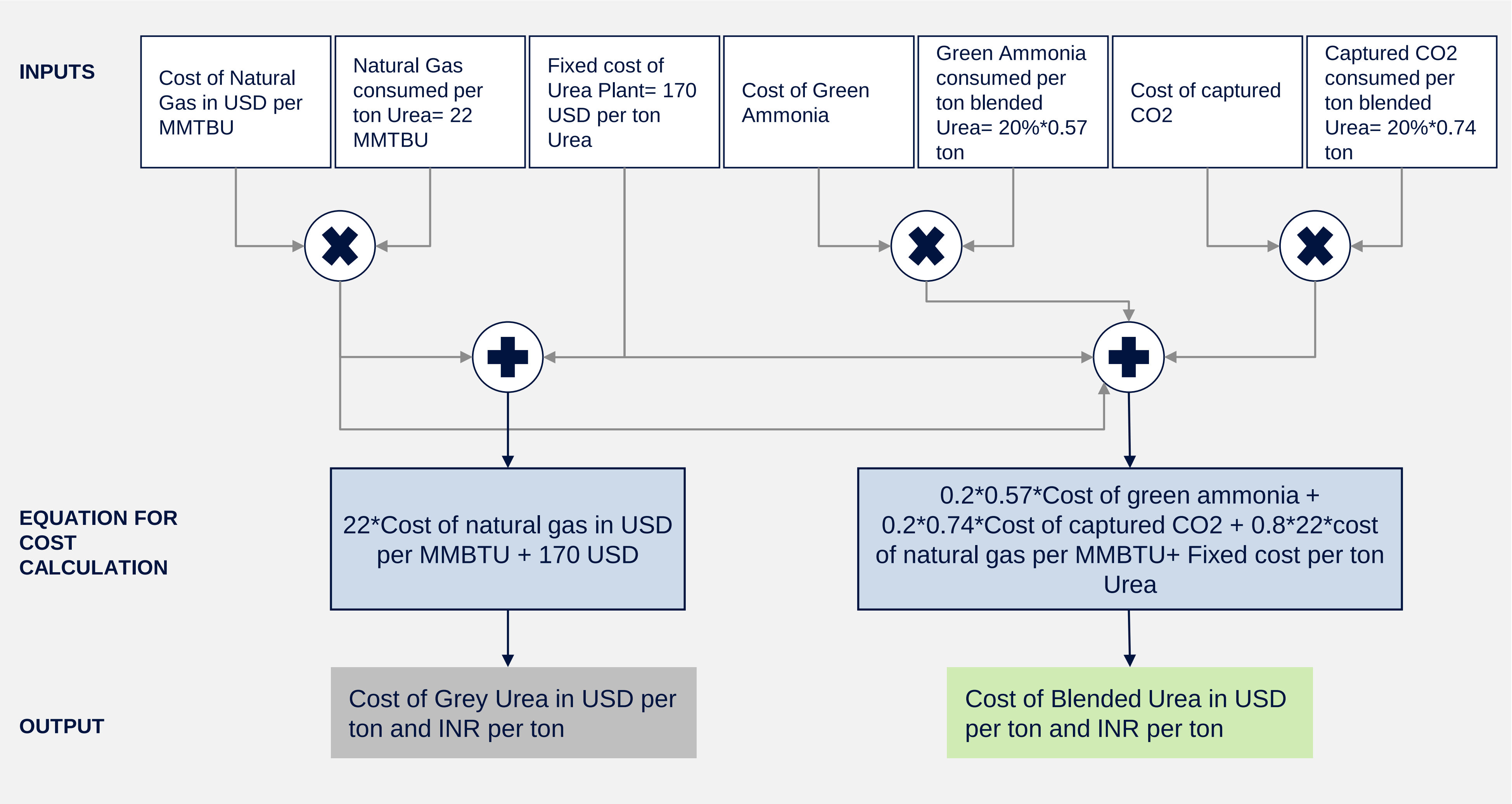
Urea | Brownfield plant with blending of green ammonia

- Considering fertilizer market in India is highly regulated, it is expected that green fertilizers will be manufactured in existing brownfield projects by introducing green ammonia in the fertliser plant. The green ammonia produced will be an integrated hydrogen and ammonia loop
- CO_2 is a major feedstock in Urea production (0.74 ton CO_2 per ton Urea).
- 100% replacement of grey ammonia with green ammonia is not possible without an external source of CO_2.
- However, blending of green ammonia with grey ammonia is possible. This is because ~0.6-0.8 ton CO_2 is produced in form of flue gas from heat generating combustion process in existing natural gas-based plants, as a pure stream originating from the separation process of the ammonia synthesis feed
- In the model, we have considered 20% blending of green ammonia with grey ammonia



 Source: mec + analysis, Technical reports

Urea | Equation for cost calculation of Urea



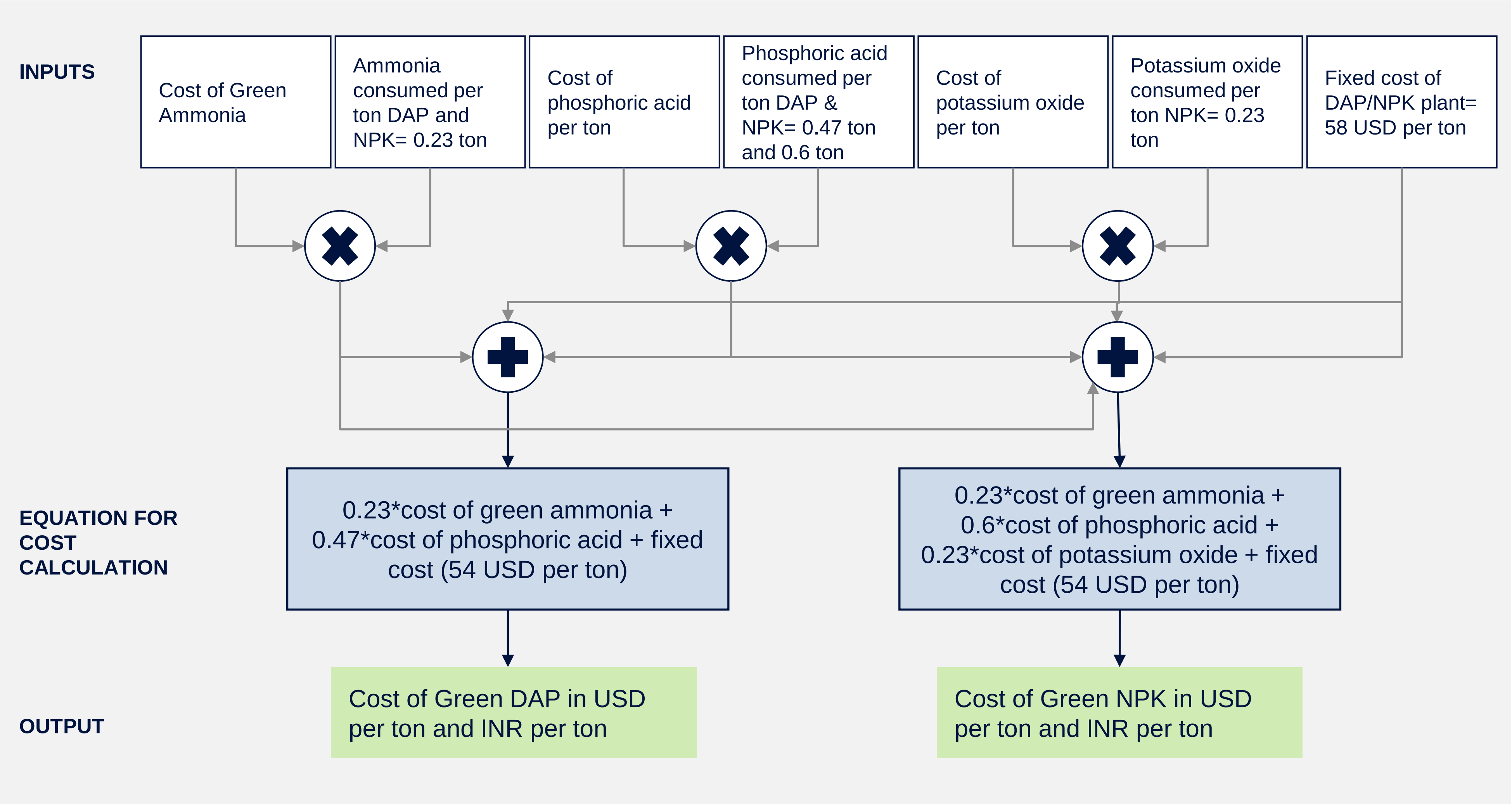
 Source: mec + analysis, Technical reports

DAP and NPK | Brownfield project where we replace imported ammonia with green ammonia

- Considering fertilizer market in India is highly regulated, it is expected that green fertilizers will be manufactured in existing brownfield projects by either replacing grey ammonia with green ammonia or blending green ammonia with grey ammonia
- Several DAP and NPK plants in India are using imported ammonia to produce the complex fertilizers. These plants are typically located at ports (see graphic)
- Considering the ease of storage and transport of ammonia, we believe 100% replacement of grey ammonia with green ammonia is possible in existing DAP and NPK plants
- In the model, we have considered full replacement of grey ammonia with green ammonia for DAP and NPK production in a brownfield project

DAP plants located portside and consuming imported ammonia

DAP and NPK | Equation for cost calculation of Green DAP and NPK

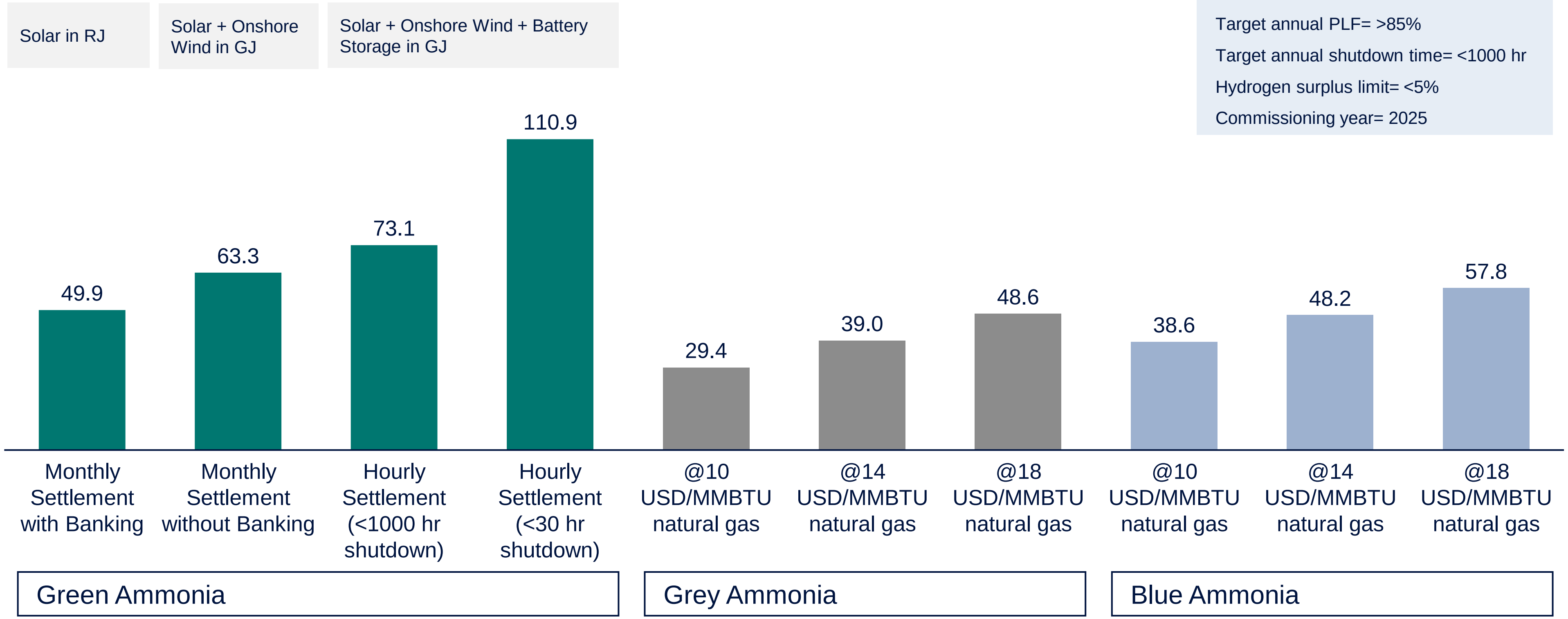


 Source: mec + analysis, Technical reports

ToC

Lowest cost of Green Ammonia will be in monthly settlement with power banking, alkaline technology, solar in Rajasthan, which is competitive with blue ammonia at current price level of natural gas

Comparison of cost of Green Ammonia in various scenarios against grey/blue in 2025
INR/Kg



Green Ammonia 'Model' Plant Spec

Size= 100 kTPA

Target annual PLF= >85%

Target annual shutdown time= <1000 hr

Hydrogen surplus limit= <5%

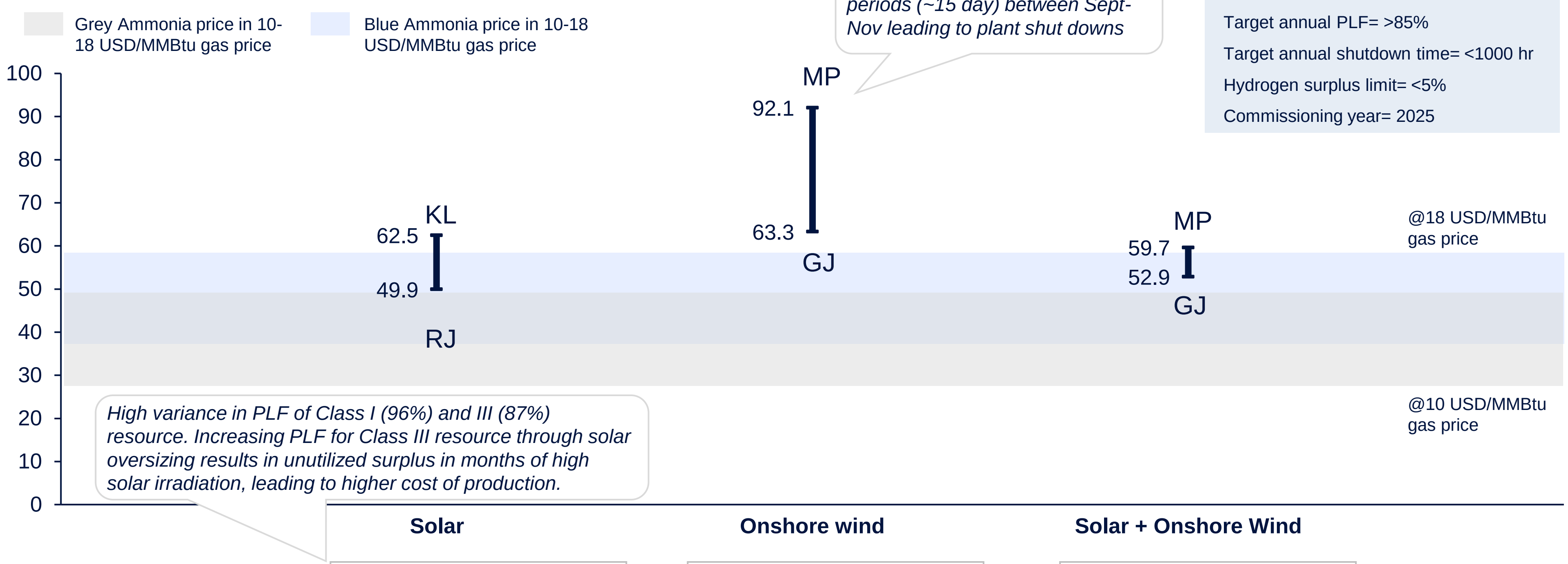
Commissioning year= 2025

- The best case for Green Ammonia in 2025 will be competitive with blue ammonia produced at current gas price of 14 USD/MMBtu
- Ammonia produced in monthly settlement without banking is relevant for exports while ammonia produced with hourly settlement will be relevant for export to countries who adopt hourly settlement of RE used

Note: RJ – Rajasthan; GJ – Gujarat;
Source: MEC+ Analysis

Monthly- Banking | Cost of Green Ammonia varies by RE Technology with banking across India with higher ranges expected due to onshore wind alone

Comparison of cost of Green Ammonia by RE Technology in India in 2025
INR/Kg



Green Ammonia 'Model' Plant Spec

Size= 100 kTPA

Target annual PLF= >85%

Target annual shutdown time= <1000 hr

Hydrogen surplus limit= <5%

Commissioning year= 2025

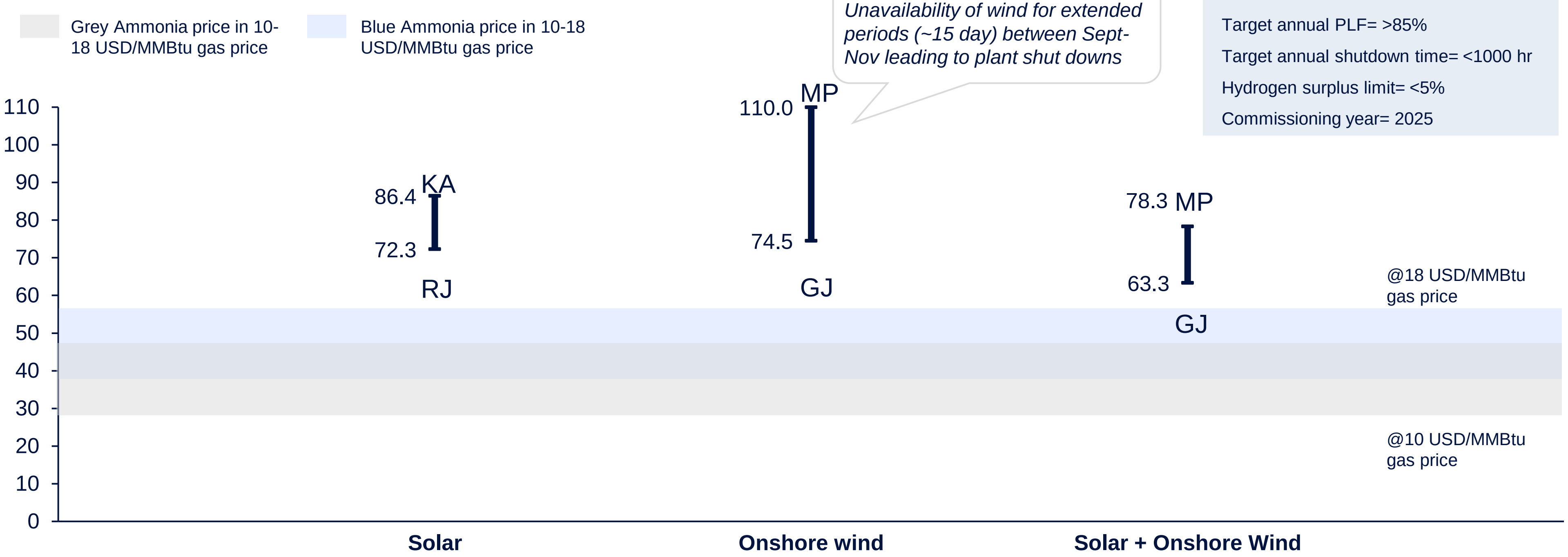
Solar	Onshore wind	Solar + Onshore Wind
NH3 Plant PLF: 87– 96%	NH3 Plant PLF: 85 – 87%	NH3 Plant PLF: 88 – 90%
Shutdown time: 0 hr	Shutdown time: 702 – 995 hr	Shutdown time: 0 hr

- Standalone Solar is the lowest cost technology option in monthly settlement with banking, followed by Solar- Onshore Wind hybrid and Standalone Onshore Wind
- Green Ammonia produced with RE from RJ (Solar) and GJ (Solar + Onshore Wind) can compete with blue ammonia and grey ammonia (with govt. support) at current price levels (@14 - 18 USD/MMBtu gas price)

Note: RJ – Rajasthan; KL – Kerala; GJ – Gujarat; MP – Madhya Pradesh; TN – Tamil Nadu
Source: MEC+ Analysis

Monthly- No Banking | Without power banking facility, surplus power is sold on exchange while deficit is bought from exchange, leading to >10 INR per Kg increase in cost of ammonia across all the RE Technology

Comparison of cost of Green Ammonia by RE Technology with monthly settlement via exchange set up in 2025
INR/Kg



Solar	Onshore wind	Solar + Onshore Wind
NH3 Plant PLF: 88– 92%	NH3 Plant PLF: 85 – 87%	NH3 Plant PLF: 90%
Shutdown time: 0 hr	Shutdown time: 695 – 995 hr	Shutdown time: 0 hr

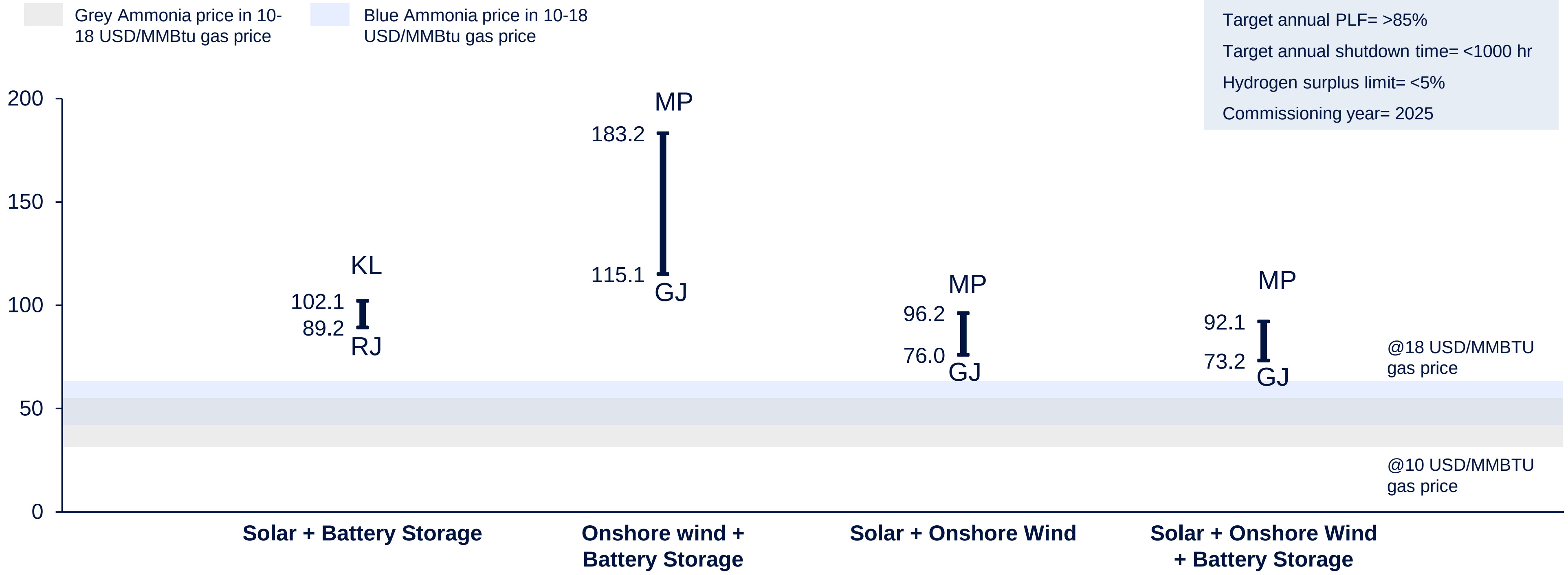
Green Ammonia 'Model' Plant Spec
- Size= 100 kTPA
- Target annual PLF= >85%
- Target annual shutdown time= <1000 hr
- Hydrogen surplus limit= <5%
- Commissioning year= 2025

- Solar-Onshore Wind hybrid is the lowest cost technology option in monthly settlement with no banking, followed by standalone Solar and Onshore Wind
- Green Ammonia produced with RE from GJ (Solar + Onshore Wind) can compete with blue ammonia (with govt. support) at current price levels (@14 - 18 USD/MMBtu gas price) with no banking

Note: Power purchase/sale from exchange assumed at same price. Increase in LCOA (compared to banking) due to grid charges. Battery storage is not considered as exchange is used; RJ – Rajasthan; KA – Karnataka; GJ – Gujarat; MP – Madhya Pradesh
Source: MEC+ Analysis

Hourly- High flexibility | Cost of ammonia increases further by >10 INR per Kg in case of hourly settlement wherein NH3 plant is running proportional to RE power available in that hour

Comparison of cost of Green Ammonia by RE Technology for hourly settlement of a plant setup in 2025
INR/Kg



Green Ammonia 'Model' Plant Spec

Size= 100 kTPA

Target annual PLF= >85%

Target annual shutdown time= <1000 hr

Hydrogen surplus limit= <5%

Commissioning year= 2025

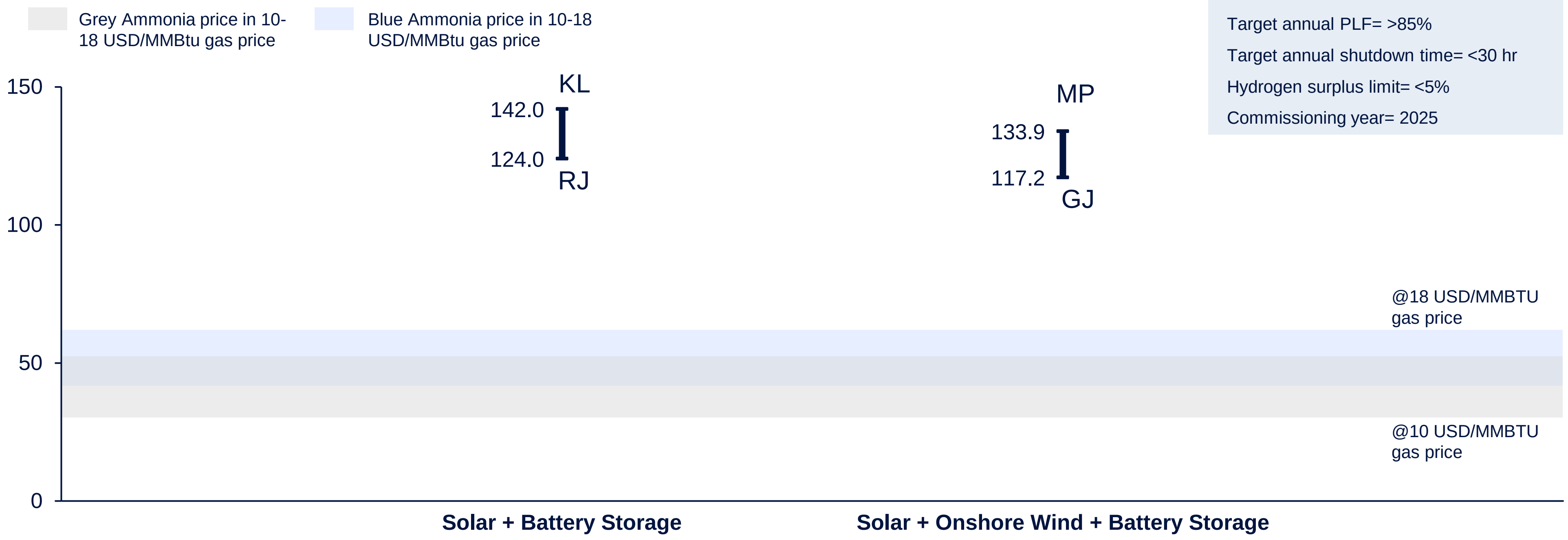
	Solar + Battery Storage	Onshore wind + Battery Storage	Solar + Onshore Wind	Solar + Onshore Wind + Battery Storage
NH3 Plant PLF	86 – 87%	87%	86 – 87%	87%
Shutdown time	963 - 997 hr	994 - 998 hr	993 - 997 hr	977 - 991 hr

- Solar-Wind and battery storage hybrid is the lowest cost technology option in hourly settlement no banking, followed by Solar-Wind hybrid, Solar and battery storage & Onshore Wind and battery storage
- Green Ammonia with hourly settlement will require strong financial and regulatory support to compete with grey and blue ammonia

Note: RJ – Rajasthan; KL – Kerala; GJ – Gujarat; MP – Madhya Pradesh
Source: MEC+ Analysis

Hourly- Limited flexibility | Significant increase in cost of ammonia (>40 INR per Kg) on running an 'always on' NH3 plant

Comparison of cost of Green Ammonia by RE Technology for hourly settlement with <30 hrs Shutdown
INR/Kg



NH3 Plant PLF: 99%
Shutdown time: 29 hr

NH3 Plant PLF: 99%
Shutdown time: 30 hr

<u>Green Ammonia 'Model' Plant Spec</u>

Size= 100 kTPA

Target annual PLF= >85%

Target annual shutdown time= <30 hr

Hydrogen surplus limit= <5%

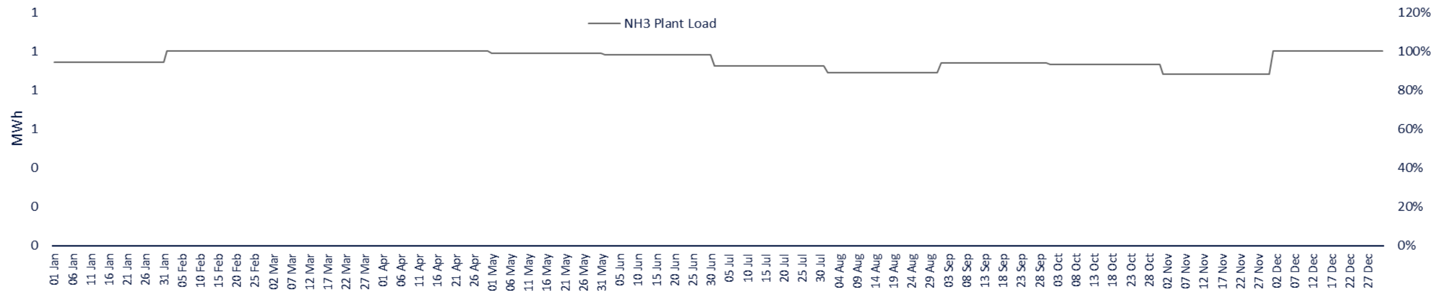
Commissioning year= 2025

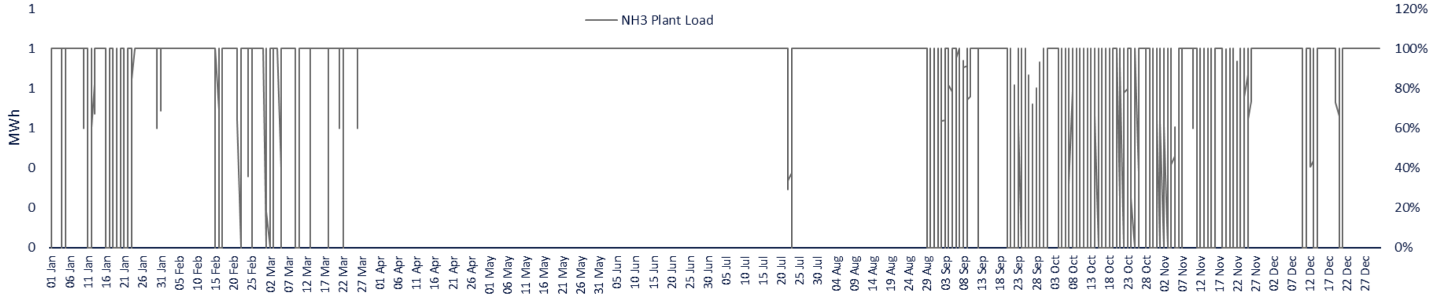
- With shutdown hours limited to ~30 hours, solar + onshore wind + battery is the cheapest option with LCOA at INR 113.5
- Reduction in shutdown hours is achieved by operating at higher PLFs (increased RE and storage capacity) leading to higher LCOA

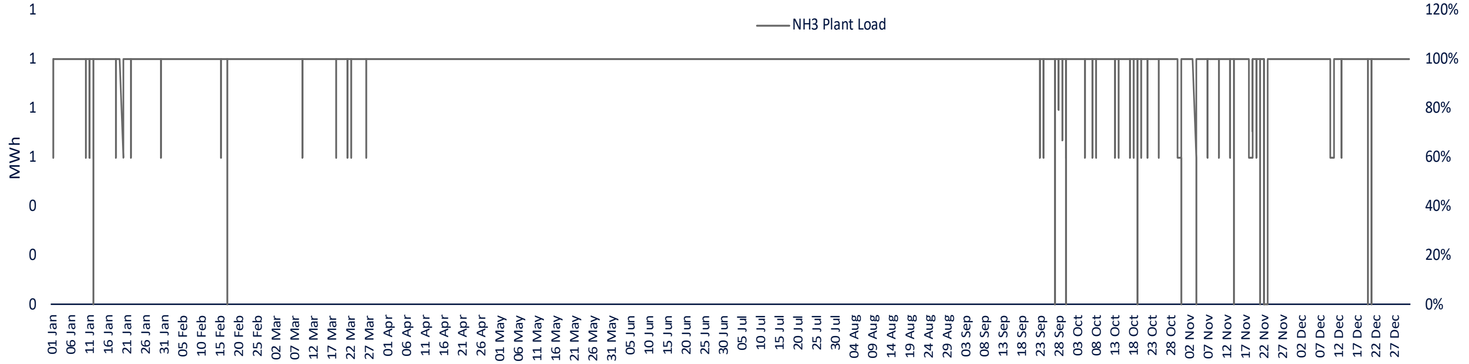
Note: RJ – Rajasthan; KL – Kerala; GJ – Gujarat; MP – Madhya Pradesh
Source: MEC+ Analysis

OPERATIONAL PROFILE | H2-NH3 plant can be run without shutdowns in monthly settlement, but for hourly settlement, plant shutdowns are observed due to intermittency of RE, especially for the months of October and November

Operational profile of RE vs H2-NH3 plant for Solar + Onshore wind hybrid (banking in Monthly and Battery in Hourly) for 100 kTPA plant







Monthly- No Shutdowns

- Grid banking/power from exchange enables excess energy to be banked/sold and used/bought at times when RE is not available (LCOA of INR 49.91/kg)

Hourly- For shutdown time <1000 hrs

- Multiple shut-downs/turn-ons of plant throughout the year
- Requires high degree of flexibility in ammonia process (Haber-Bosch)

Hourly- For shutdown time <30 hrs

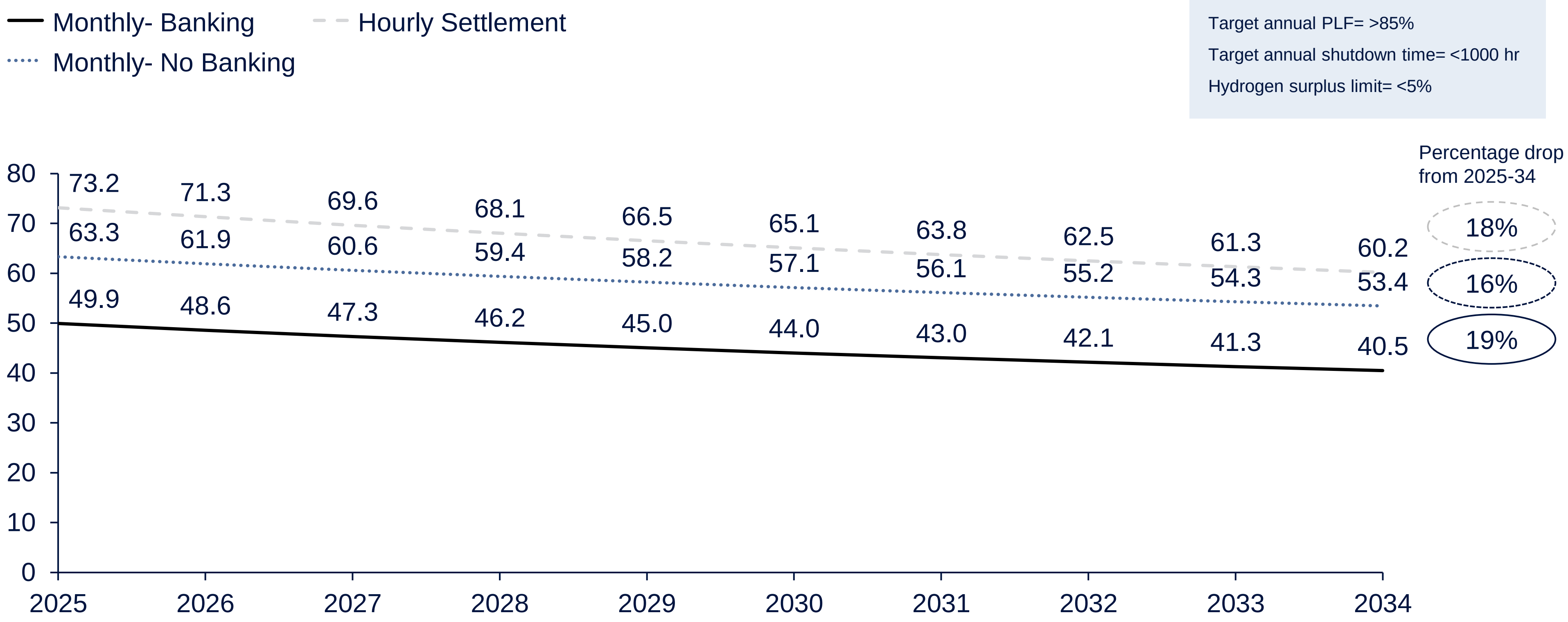
- Significant RE oversizing and battery storage can reduce the shutdown hours to resemble the operational profile traditional ammonia plant

Note: LCOA – Levelized Cost of Ammonia
Source: MEC+ Analysis

giz

BY TIMELINE | Trend in Cost of Ammonia towards 2034 for the archetype plant in monthly-banking, No-Banking and Hourly Settlements

Comparison of lowest cost of Green Ammonia by year of commissioning
INR/Kg



Green Ammonia 'Model' Plant Spec

Size= 100 kTPA

Target annual PLF= >85%

Target annual shutdown time= <1000 hr

Hydrogen surplus limit= <5%

- Green Ammonia in monthly settlement with banking (domestic case for consumption and import substitution) will be competitive with grey ammonia (@14 USD/MMBtu) with support by 2034
- Green Ammonia in monthly settlement without banking (export case to countries without hourly settlement requirement) to fall close INR 55/kg by 2032

Note: Monthly- Banking | Solar in Rajasthan; Monthly – No Banking | Solar + Onshore Wind in Gujarat; Hourly Settlement | Solar + Onshore Wind + Battery Storage in Gujarat

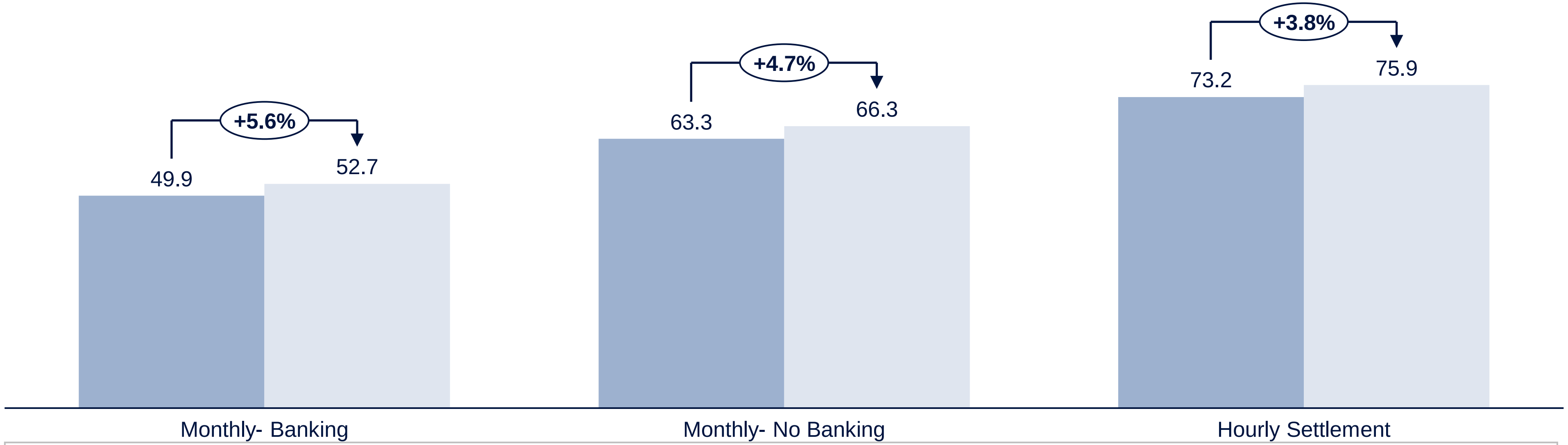
Source: MEC+ Analysis

BY ELECTROLYSER TECH | Cost of Ammonia by Electrolyser technology in Monthly & Hourly

Comparison of lowest cost of Green Ammonia by Electrolyser technology in India in 2025
INR/Kg

<u>Green Ammonia ‘Model’ Plant Spec</u>
Size= 100 kTPA
Target annual PLF= >85%
Target annual shutdown time= <1000 hr
Hydrogen surplus limit= <5%
Commissioning year= 2025

Alkaline
PEM



	Alkaline	PEM	Alkaline	PEM	Alkaline	PEM
PLF:	95.6 %	95.6 %	89.5 %	89.5 %	87.2 %	86.8 %
Shutdown:	0 hr	0 hr	0 hr	0 hr	977 hr	950 hr

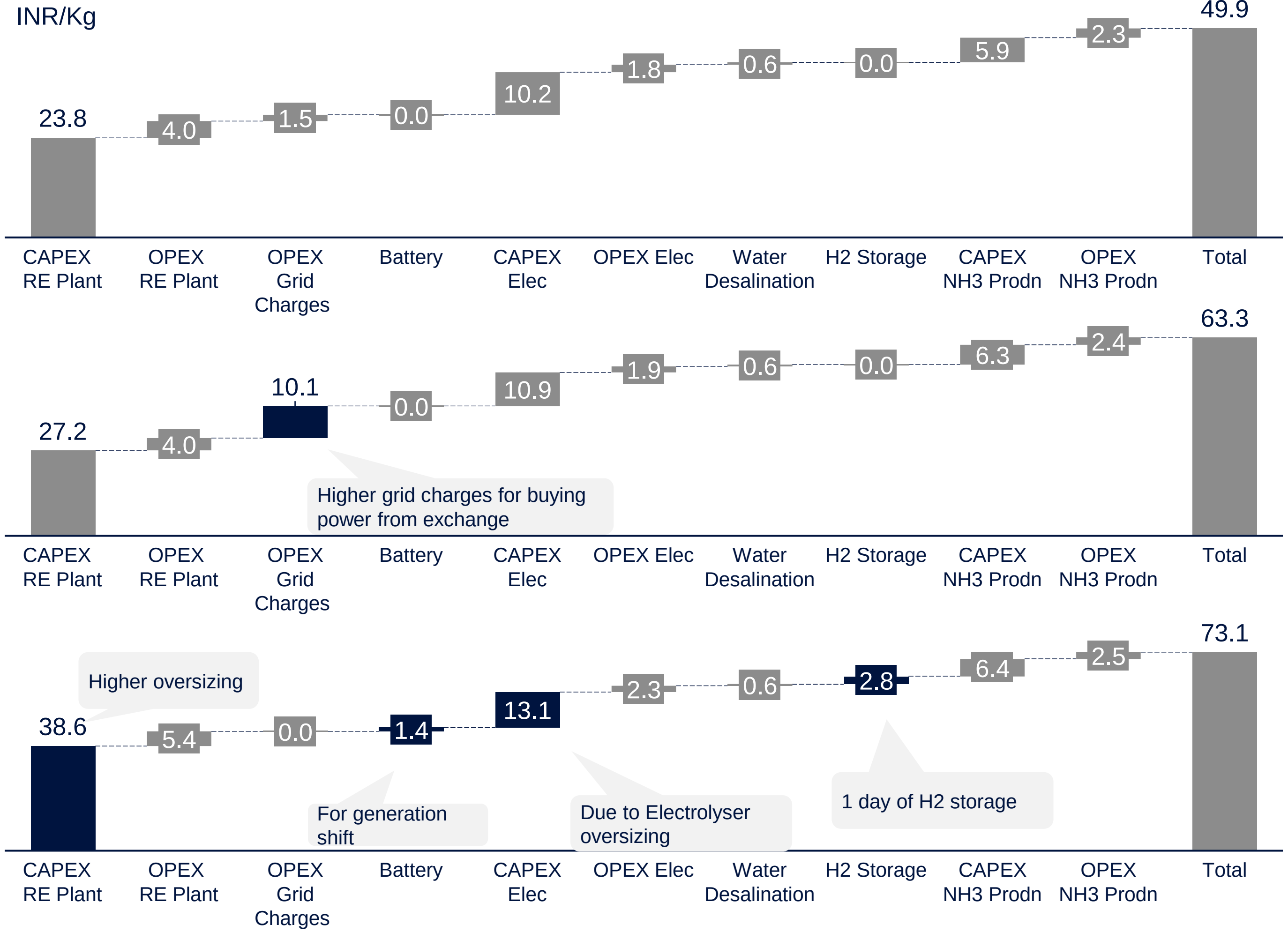
With the same plant location and specifications, Alkaline gives INR 2-3 cheaper green ammonia than PEM technology across monthly-banking, monthly- no banking and hourly settlement scenarios

Note: Monthly- Banking | Solar in Rajasthan; Monthly – No Banking | Solar + Onshore Wind in Gujarat; Hourly Settlement | Solar + Onshore Wind + Battery Storage in Gujarat
Source: MEC+ Analysis

LCOA | RE Plant, Electrolyser and NH3 unit are the key cost drivers with Electrolyser oversizing, hydrogen storage and battery adding costs in hourly settlement

Waterfall of LCOA and key cost drivers incl. capex and opex

INR/Kg



Monthly Banking

- RE plant (56%), electrolyser (23%) and NH3 Unit (17%) are the major LCOA drivers

Monthly No Banking

- Buying power from the exchange to meet monthly demand (when RE is unavailable) leads to increase in grid charges

Hourly Settlement

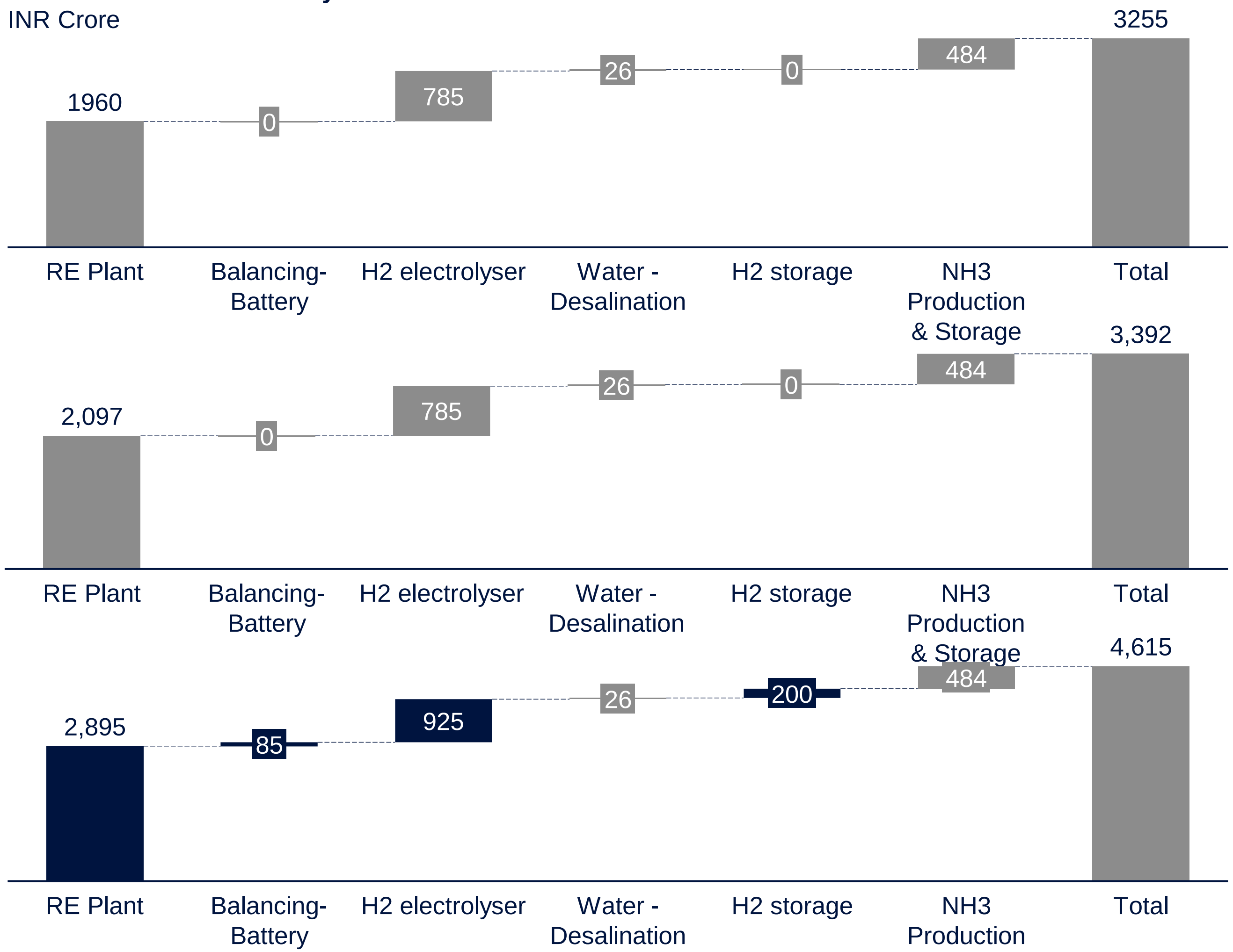
- Increased cost of RE, electrolyser oversizing, hydrogen storage and battery leads to increased LCOA

Note: Elec – Electrolyser; Prodn – Production; Archetype plant specifications (considered in the above slides) used for monthly and hourly scenarios; LCOA – Levelized cost of Ammonia

Source: MEC+ Analysis

CAPEX | RE Plant, Electrolyser and NH3 unit are the key cost drivers with Electrolyser oversizing, hydrogen storage and battery increasing CAPEX in hourly settlement

Waterfall of CAPEX and key cost drivers
INR Crore



Monthly Banking

- RE plant (59%), electrolyser (24%) and NH3 Unit (15%) are the major CAPEX drivers

Monthly No Banking

- Capex similar to monthly banking

Hourly Settlement

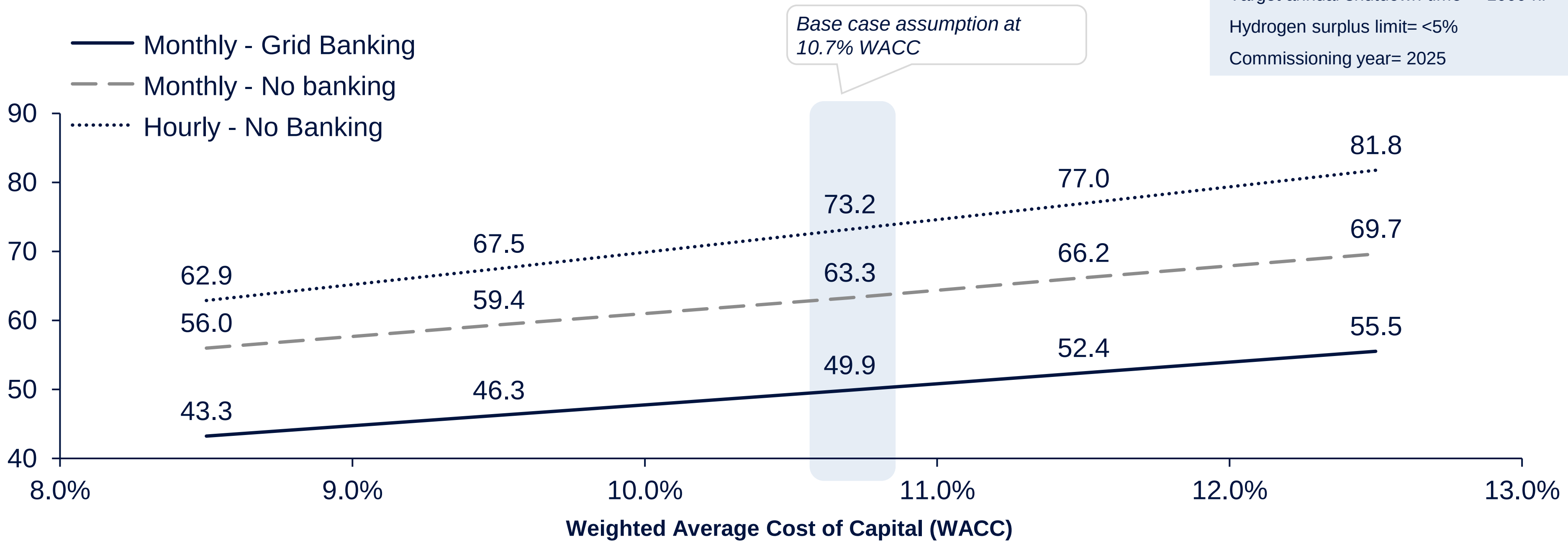
- Increase in CAPEX is led by RE plant, electrolyser oversizing, added hydrogen storage and battery

Note: Archetype plant specifications (considered in the above slides) used for monthly and hourly scenarios
Source: MEC+ Analysis

giz

SENSITIVITY | Cost of capital

Comparison of cost of Green Ammonia at different levels of WACC in 2025
INR/Kg



Green Ammonia 'Model' Plant Spec

Size= 100 kTPA

Target annual PLF= >85%

Target annual shutdown time= <1000 hr

Hydrogen surplus limit= <5%

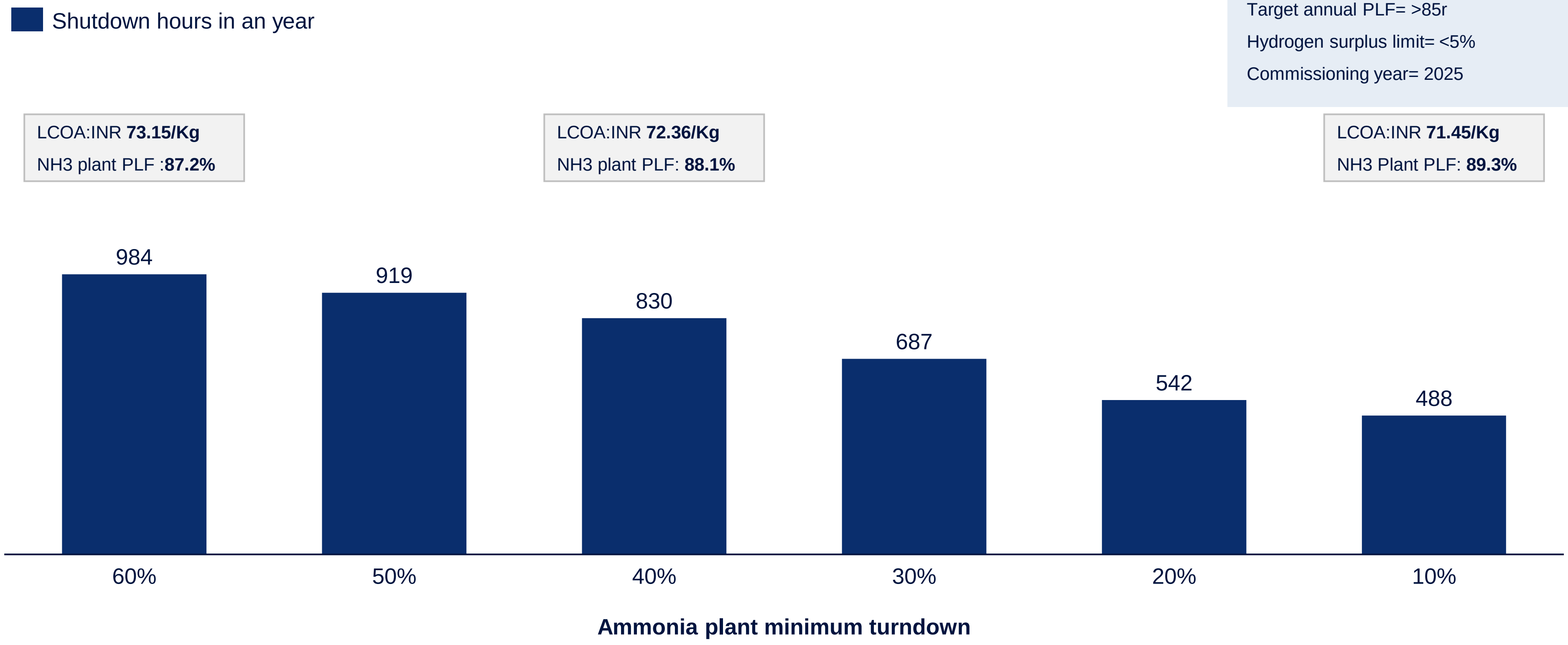
Commissioning year= 2025

- As the WACC increase as does the cost of green ammonia with difference of almost 12-15 INR/kg

Note:
Source: MEC+ Analysis

SENSITIVITY | Ammonia plant operational flexibility

Comparison of NH3 plant shutdown time at different minimum turndown load of ammonia plant
# of hours



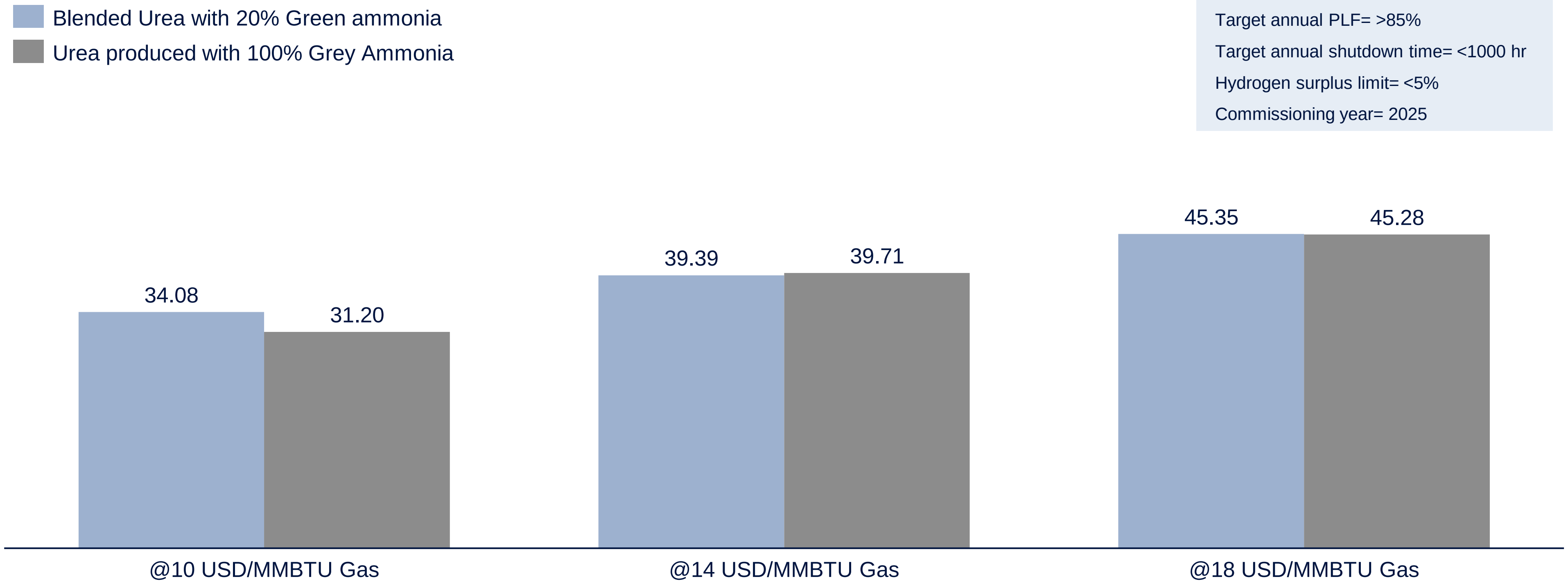
Green Ammonia 'Model' Plant Spec
Size= 100 kTPA
Target annual PLF= >85r
Hydrogen surplus limit= <5%
Commissioning year= 2025

- Flexible technology for ammonia production can significantly reduce the shutdown time and operational profile of NH3 plant resulting in lower cost of ammonia

Note: LCOA- Levelized Cost of Ammonia in INR/Kg, PLF: Plant load factor
Source: MEC+ Analysis

Urea plant | Cost of urea produced by blending 20% green ammonia vs grey ammonia at different gas prices in a brownfield plant

Comparison of cost of producing Urea when blended with 20% green ammonia vs grey ammonia (2025)
INR/Kg



Green Ammonia 'Model' Plant Spec

Size= 100 kTPA

Target annual PLF= >85%

Target annual shutdown time= <1000 hr

Hydrogen surplus limit= <5%

Commissioning year= 2025

- Blended urea (with 20% green and 80% grey ammonia) gets more competitive with increase in gas prices
- Blended urea with 20% green Ammonia in 2025 can compete with grey urea at price levels of gas between 14 – 18 USD/MMBtu and is INR 3 more expensive than urea with 100% grey ammonia at 10 USD/MMBtu

Note: Monthly Banking | Solar in Rajasthan
Source: MEC+ Analysis

DAP | Cost of DAP produced by replacing 100% grey ammonia (imported) with 100% green ammonia at different gas prices in a brownfield plant

Comparison of cost of producing DAP with green ammonia vs grey ammonia (2025)
INR/Kg

- DAP produced with 100% green ammonia
- DAP produced with 100% grey ammonia

<u>Green Ammonia ‘Model’ Plant Spec</u>

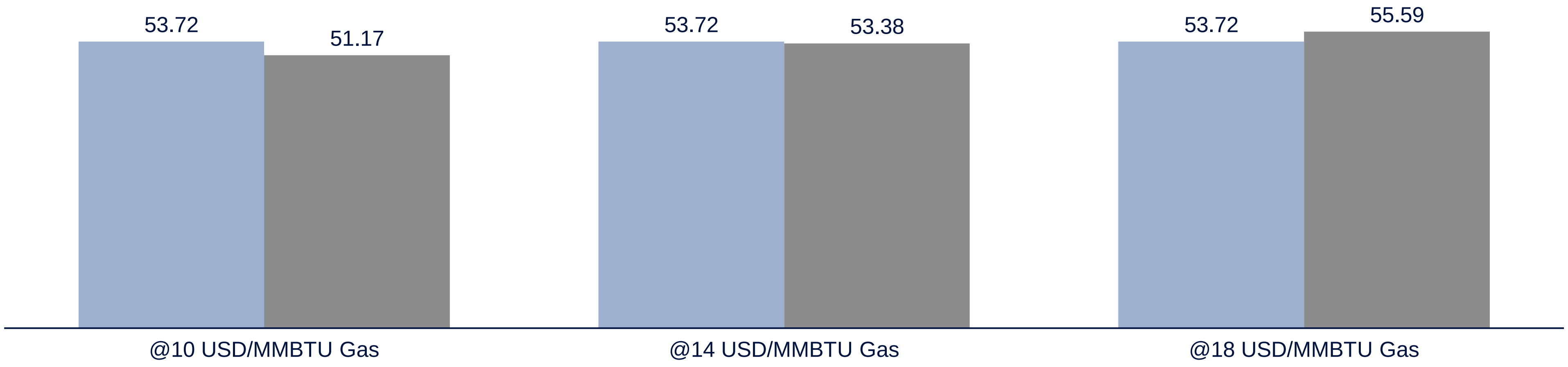
Size= 100 kTPA

Target annual PLF= >85%

Target annual shutdown time= <1000 hr

Hydrogen surplus limit= <5%

Commissioning year= 2025



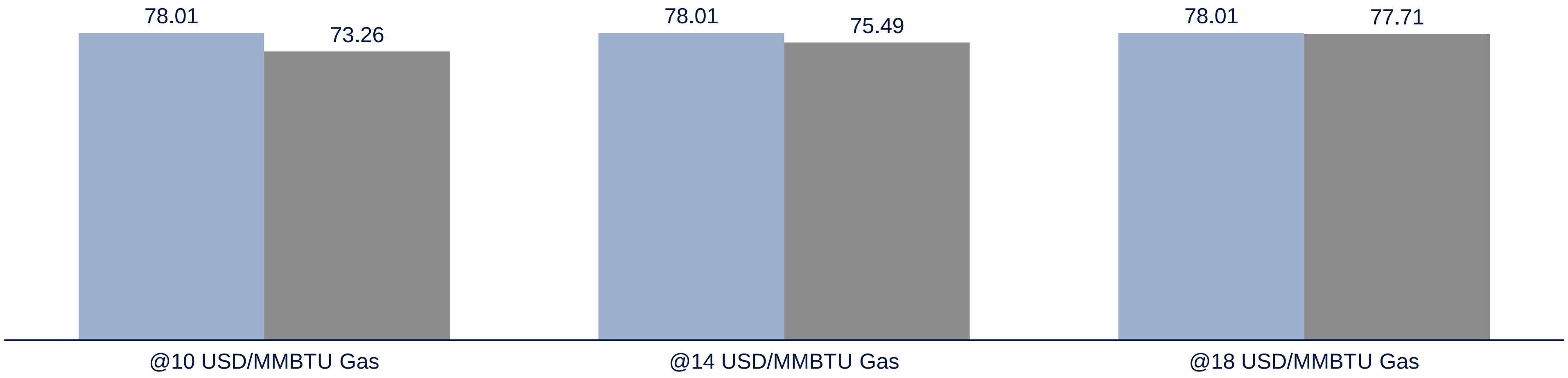
- DAP produced in 2025 with 100% green Ammonia becomes cost competitive with grey ammonia-based DAP at 14 USD/MMBtu gas price
- Currently, production of complex fertilizer like DAP use imported ammonia, this can be replaced with green ammonia produced in India (with govt. support)

Note: Monthly Banking | Solar in Rajasthan
Source: MEC+ Analysis

NPK | Cost of NPK produced by replacing 100% grey ammonia (imported) with 100% green ammonia at different gas prices in a brownfield plant

Comparison of cost of producing NPK with green ammonia vs grey ammonia (2025)
INR/Kg

- NPK produced with 100% green ammonia
- NPK produced with 100% grey ammonia



<u>Green Ammonia 'Model' Plant Spec</u>

Size= 100 kTPA

Target annual PLF= >85%

Target annual shutdown time= <1000 hr

Hydrogen surplus limit= <5%

Commissioning year= 2025

- NPK produced in 2025 with 100% green Ammonia becomes cost competitive with grey ammonia-based NPK at 18 USD/MMBtu
- Currently, production of complex fertilizer like NPK use imported ammonia, this can be replaced with green ammonia produced in India (with govt. support)

Note: Monthly Banking | Solar in Rajasthan
Source: MEC+ Analysis

ToC

System sizing | How the power demand of H2-NH3 plant is calculated and optimized?

Target Ammonia Plant Capacity
in kilo tonnes per annum (kTPA)

[NH_3_Capacity]

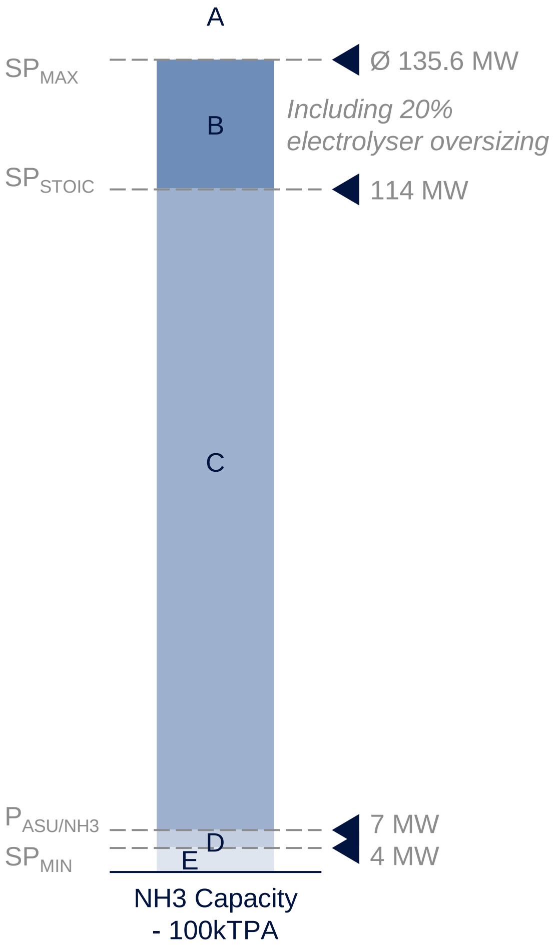
- User Input in Dashboard D1.NH3

E.g.: 100 kTPA

	Production Capacities – Annual	Production Capacities – Hourly	Power Demand – Hourly	Power Demand for 100kTPA NH_3
Ammonia Production (Haber Bosch)	NH_3_Capacity *E.g.: 100 kTPA*	= NH_3_Capacity ⁄ (365*24) *E.g.: 274 TPD*	= Hourly NH_3 production capacity / Specific Energy Consumption of HB process (SEC_{NH3}) *E.g.: 6.28 MW*	6.28 MW
Nitrogen Production (ASU)	Amount of N_2 required to produce the target NH_3 capacity = NH_3_Capacity * (28.134/34.181) *E.g.: 82 kTPA*	Amount of N_2 required every hour = NH_3_Capacity * (28.134/34.181) / (365*24) *E.g.: 226 TPD*	= Hourly N_2 production capacity / Specific Energy Consumption of ASU process (SEC_{ASU}) *E.g.: 0.78 MW*	0.78 MW
Hydrogen Production (Electrolyser)	Amount of H_2 required to produce the target NH_3 capacity = NH_3_Capacity * (6.047/34.181) *E.g.: 18 kTPA*	Amount of H_2 required every hour = NH_3_Capacity * (6.047/34.181) / (365*24) *E.g.: 48 TPD*	= Hourly H_2 production capacity / Specific Energy Consumption of Electrolyser ($SEC_{PEM\ or}$ SEC_{ALK}) *E.g.: 114.27 MW*	114.27 MW
Total plant demand				**114.20 MW**

Hourly operations | System can be in any of the five scenarios based on the RE power (P) generated in any given hour

Nomenclature



Operating scenario

A	$P > SP_{MAX}$	RE generated is more than the maximum power demand of Electrolyser (including oversizing) + NH3 plant
B	$SP_{MAX} > P > SP_{STOIC}$	RE power is less than max power demand but more than demand to run plant at Stoic levels
C	$SP_{STOIC} > P > P_{ASU/NH3}$	RE power is less than Stoic levels but more than needed to run NH3/ASU plant at max demand
D	$P_{ASU/NH3} > P > SP_{MIN}$	RE power is less than what is needed to run NH3/ASU plant at 100% but can run it at >60% PLF (minimum operating PLF assumed in the model for HB-ASU process)
E	$SP_{MIN} > P$	RE power is less than what is needed to run NH3/ASU plant at minimum operational PLF

Legend

- P= RE power produced at any hour
- SP_{MAX}= 100% load of the NH_3+ ASU + Oversized Electrolyser plant
- SP_{STOIC}= Power required to continuosly run the NH3 + ASU plant at 100% + $P_{ELECSTOIC}$
- $P_{ASU/NH3}$= Power required by ASU/NH3 plant at 100% load factor
- SP_{MIN}= Power required by ASU/NH3 plant at 60% load factor. It is also the minimum power required to produce NH_3 if H_2 supply can be maintained from storage
- P_{ELEC}= Power required by the oversized Electrolyser to run at 100% (*E.g. 118 MW (135.6 – 7 MW*)
- $P_{ELECSTOIC}$= Power required by Electrolyser to produce hydrogen which continuosly feeds into ASU/NH3 plant without excess H_2 generation (*E.g. 107 MW*)

Source: Research papers- Nayak et al

Hourly operations | Equations for defining power flow from RE plant to calculate amount of ammonia produced

Power supply from RE plant to Ammonia/ASU Plant, Electrolyser and Battery

<table>
<tr><th>Operating Scenario</th><th>Action</th><th>Power to ASU/NH3 plant</th><th>Power to Electrolyser</th><th>Power to Battery (charging)</th><th>Power from Battery (Discharge)</th><th>H2 to Storage</th><th>H2 from Storage</th></tr>
<tr><td>A.

$P > SP_{MAX}$</td><td>- Supply Stoic Power to system
- Charge battery with excess power
- Store excess hydrogen</td><td>$P_{ASU/NH3}$</td><td>P_{ELEC}</td><td>Charge battery with the surplus power, if battery is not fully charged</td><td>0; Not required- plant running at stoic level</td><td>Fill H2 storage by using surplus power, if not already full</td><td>0; Not required- plant running at stoic level</td></tr>
<tr><td>B.

$SP_{MAX} > P > SP_{STOIC}$</td><td>- Supply Stoic Power to system
- Store excess hydrogen</td><td>$P_{ASU/NH3}$</td><td>$P_{ELEC} – (SP_{MAX} – P)$</td><td>0</td><td>0; Not required- plant running at stoic level</td><td>Fill H2 storage if not full</td><td>0; Not required- plant running at stoic level</td></tr>
<tr><td>C.

$SP_{STOIC} > P > P_{ASU/NH3}$</td><td>- Supply power to system
- Draw from hydrogen storage as required to maintain stoic operations
- Make up for power deficit from battery as required</td><td>$P_{ASU/NH3}$</td><td>$P_{ELEC} – (SP_{MAX} – P)$</td><td>0</td><td>Discharge to maintain stoic levels of electrolyser, if battery is sufficiently charged and hydrogen supply from storage is not sufficiently available</td><td>0 0</td><td>Discharge H2 to meet Stoic level (if H2 in storage is > min level), else 0</td></tr>
<tr><td>D.

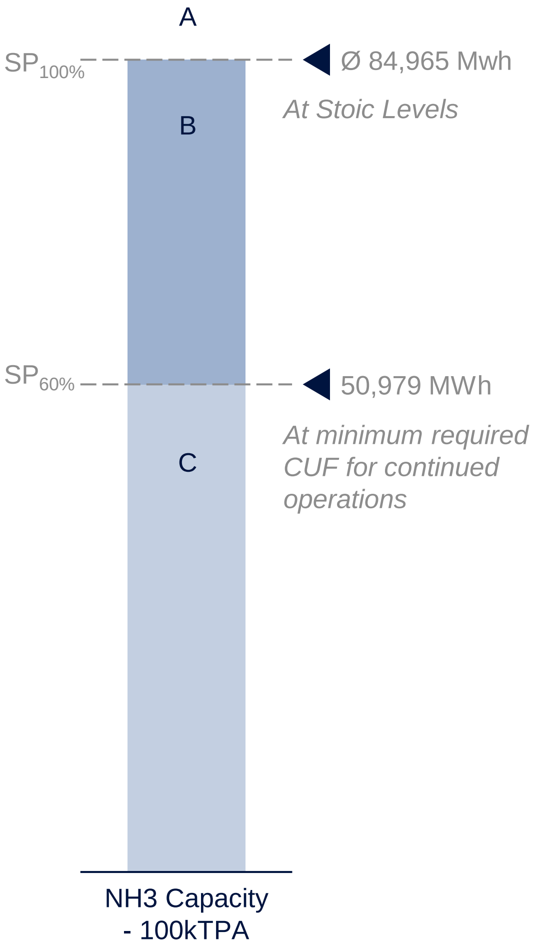
$P_{ASU/NH3} > P > SP_{MIN}$</td><td>- Supply power to system
- Draw from hydrogen storage as required to maintain stoic operations
- Make up for power deficit from battery as required</td><td>P</td><td>0</td><td>0</td><td rowspan="2">Discharge to maintain stoic/min levels of NH3/ASU and electrolyser, if battery is sufficiently charged and hydrogen supply from storage is not sufficiently available</td><td>0</td><td rowspan="2">Discharge H2 to meet minimum load of NH3 (if H2 in storage is > min level), else
0</td></tr>
<tr><td>E.

$SP_{MIN} > P$</td><td>- Supply power to system
- Make up for power deficit from battery, if available, otherwise shut
- Draw from hydrogen storage to maintain minimum/stoic operations</td><td>P</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Source: Research papers- Nayak et al

Monthly settlement | System can be in any of the three scenarios based on the RE power (P) generated in any given month

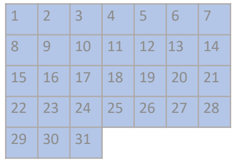
Nomenclature



Operating scenario & Action

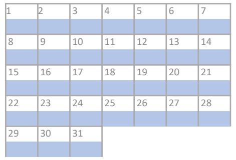
A $P > SP_{100\%}$

RE generated is more than that required for 100% CUF of NH3 – H2 plant in any month. All days run at 100% CUF and no shut downs required



B $SP_{100\%} > P > SP_{60\%}$

RE power generated in the month is sufficient to continuously run the NH3-H2 plant at any CUF between its operating range 100% to 60% CUF. No shut downs required



C $SP_{60\%} > P$

RE power generated in a month is less than requirement to operate the plant at minimum CUF. The plant will be operate at 100% CUF for some days and then shut down

Legend

- P= RE power produced at any hour
- $SP_{100\%}$= Monthly power demand at 100% CUF of NH_3+ ASU + Electrolyser plant. Equal to No of days in month* SP_{STOIC} (Hourly operations)
- $SP_{60\%}$= Monthly power required to continuosly run the NH3 + ASU + electrolyser plant at 60% CUF
- Target monthly CUF (%)

$$= \frac{\sum RE\ generation\ in\ the\ month}{Days\ in\ month}$$

Monthly Operations | Mechanisms – Grid Banking and No Banking

Power supply from RE plant to Ammonia/ASU Plant, Electrolyser and Battery

Monthly Operating Scenario	Action	Grid Banking	No Banking
A. $P > SP_{100\%}$	- Run the entire plant at 100% CUF on all the days in the month - Surplus power is available for seprate sales	- Power >100% CUF at any time/day is banked with the DISCOM - Power is unbanked after paying banking charges (in units) in hours/days when power generated is < 100% CUF	- Power >100% CUF is sold at power exchange - When power < 100% CUF, deficient power is purchased from power exchange - Grid and exchange charges are paid on sale-purchase of power
B. $SP_{100\%} > P > SP_{60\%}$	- Run the entire plant at target CUF(100% > Target CUF > 60%) on all the days in the month - There is no surplus power available	- Power > Target CUF at any time/day is banked with the DISCOM - Power is unbanked after paying banking charges (in units) in hours/days when power generated is < Target CUF	- Power > Target CUF is sold at power exchange - When power < Target CUF, deficient power is purchased from power exchange - Grid and exchange charges are paid on sale-purchase of power
C. $SP_{60\%} > P$	- Run the entire plant at 100% CUF for as many days in the month till the entire generration expected in the month is consumed - Shut down the system, thereafter	- Power >100% CUF at any time/day, when plant is operational is banked with the DISCOM - Power is unbanked after paying banking charges (in units) in hours/days when power generated is < 100% CUF - On days the plant is scheduled to shut down, the power is only banked. No power is unbanked	- Power >100% CUF is sold at power exchange - When power < 100% CUF, deficient power is purchased from power exchange - Grid and exchange charges are paid on sale-purchase of power - On days the plant is scheduled to shut down, the power is only sold at exchange. No power is purchased

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Data Sheets| Power Parameters (I/IV)

	Components	Amount	Units	Description	Source
Solar Farm Parameters	CAPEX - 2022	3,61,00,000	INR/MW	Capex to include turbine equipment, BOS and development cost (incl. land lease etc)	Discussion with developers & investors
	Reference Project capacity for Capex	100000	kW	Project capacity considered to determine per MW capex	
	Scale reduction of Capex per fold of size	10%	%	% Reduction in capex for every fold increase in size	
	Reference Fold increase	10		Decrease in capex increase of capacity	
	No. of Fold increase	0.777	%	%No. of Folds/ increase in size from reference capacity	
	Scale Index	1		Index of scale	
	Capex Reduction Factor	8%	%	% Reduction in Capex due to scaling of capacity	
	Annual decline rate of CAPEX towards 2035	1.99%	%	Annual decline rate till 2035	Discussion with developers & investors
	OPEX - 2023	1.5%	% of CAPEX	Operational expenditure of the wind farm	WEO-2022, Lazard
	Annual escalation rate of OPEX towards 2035	3%	%	Rate of increase in Operational Expenditure till 2035	CERC, HERC
	Annual AEP degradation	0.04%	%	Expected decline in wind turbine efficiency over time	Aurecon - 2021
	Expected useful life	30	Years	Solar plant lifetime	Assumption
	Depreciation rate	3.3%	%	Calculated based on the plant lifetime	

Data Sheets| Power Parameters (II/IV)

Onshore Wind Parameters

Components	Amount	Units	Description	Source
CAPEX - 2022	8,43,28,000	INR/MW	Capex to include turbine equipment, BOS and development cost (incl. land lease etc)	Discussion with developers & investors
Reference Project capacity for Capex	100000	kW	Project capacity considered to determine per MW capex	
Scale reduction of Capex per fold of size	10%	%	% Reduction in capex for every fold increase in size	
Reference Fold increase	10		Decrease in capex every time an increase of capacity	
No of Fold increase	0.403	%	%No. of Folds/ increase in size from reference capacity	
Scale Index	1		Index of scale	
Capex Reduction Factor	4%	%	% Reduction in Capex due to scaling of capacity	
Annual decline rate of CAPEX towards 2035	1.54%	%	Annual decline rate till 2035	Discussion with developers & investors
OPEX - 2023	1.2%	% of CAPEX	Operational expenditure of the wind farm	WEO-2022, Lazard
Annual escalation rate of OPEX towards 2035	5%	%	Rate of increase in Operational Expenditure till 2035	CERC, HERC
Annual AEP degradation	0.1%	%	Expected decline in wind turbine efficiency over time	Aurecon - 2021
Expected useful life	30	Years	Solar plant lifetime	Assumption
Depreciation rate	3.3%	%	Calculated based on the plant lifetime	

Data Sheets| Power Parameters (III/IV)

	Components	Amount	Units	Description	Source
Offshore Wind Farm Parameters	CAPEX - 2022	22,86,00,000	INR/MW	Capex to include turbine, BOP, Development (Incl. land/seabed lease etc)	FIMOI Initiative
	Reference Project capacity for Capex	100000	kW	Project capacity considered to determine per MW capex	
	Scale reduction of Capex per fold of size	10%	%	% Reduction in capex for every fold increase in size	
	Reference Fold increase	10		Decrease in capex every time an increase of capacity	
	No of Fold increase	0.403	%	%No. of Folds/ increase in size from reference capacity	
	Scale Index	1		Index of scale	
	Capex Reduction Factor	4%	%	% Reduction in Capex due to scaling of capacity	
	Annual decline rate of CAPEX towards 2035	5.4%	%	Annual decline rate till 2035	FIMOI Initiative
	OPEX - 2023	2.9%	% of CAPEX	Operational Expenditure of the offshore wind farm	FIMOI Initiative
	Annual escalation rate of OPEX towards 2035	5%	%	Rate of increase in Operational Expenditure till 2035	FIMOI Initiative
	Annual AEP degradation	0.1%	%	Expected decline in wind turbine efficiency over time	FIMOI Initiative
	Expected useful life	30	Years	Offshore wind plant lifetime	Assumption
	Depreciation rate	3.3%	%	Calculated based on the plant lifetime	

Data Sheets| Power Parameters (IV/IV)

	Components	Amount	Units	Description	Source
Battery Parameters	CAPEX - 2025	9,43,00,000	INR/MW	Capex for 8-hour battery pack	Draft National Electricity Plan
	Annual decline rate of CAPEX towards 2035	4.69%	%	Annual decline rate till 2035	Draft National Electricity Plan
	OPEX - 2023	2.5%	% of CAPEX	Operational Expenditure of BESS	NREL ATB
	Minimum and maximum state of charge	5-100%	%	Minimum charge to be always retained in the battery at any given time	Lazard -2021
	Round trip efficiency	85%	%	Ratio of energy output to input in a complete system cycle	Aurecon - 2021
	Battery replacement cost	65%	% of CAPEX	Cost of replacing the battery after its useful life	NREL ATB
	Battery lifetime	10	Years	Useful life of battery before it needs to be replaced	Lazard - 2021
	Expected useful life of system	25	Years	Total lifetime of a BESS system	Assumption
	Depreciation Rate	4%	%	Calculated based on the electrolyser system lifetime	

Data Sheets| Hydrogen Parameters (I/III)

	Components	PEM	Alkaline	Units	Description	Source
Hydrogen System Parameters	Electrolyser stack SEC at Nominal Load	51.44	51.44	kWh per Kg	Specific Energy Consumption of stack at 100% load	IRENA,NEL ,John Cockerill
	Electricity load from BoP as % of Elec. load	10%	10%	%	Energy consumption of BOP as % of SEC at stack	IRENA,NEL ,John Cockerill
	System SEC at Nominal Load	56.6	56.6	kWh per Kg	SEC of stack +SEC of BOP	IRENA, NEL, Siemens
	Electrolyser Maximum Load	100%	100%	%	Maximum load at which the electrolyser can operate on	IRENA, NEL, Siemens
	Electrolyser Minimum Load	10%	15%	%	Minimum load at which the electrolyzer operate on	IRENA, NEL, Siemens
	Stack replacement time	80,000	80,000	hours	Lifetime of electrolyzer stack	IRENA, IEA, US DOE
	Stack degradation	1%	1%	% per year	Percentage degradation of electrolyser stack	Aurecon-21, ITM Power
	Water requirement of Electrolyser (Deionized)	10	10	Litre per kg	Amount of deionized water required to produce 1 kg hydrogen	IRENA,Siemens
	CAPEX- 2023 incl. Installation	1,10,000	85,000	INR/kW	Capex Includes stack, BOP and installation cost	McKinsey, Lazard, TERI, US DoE
	Reference Project Capacity for Capex	10000	10000	kW	Reference Project Capacity for Capex	McKinsey, Lazard, TERI, US DoE
	Scale Reduction of Capex per fold of Size	10%	10%	%	% Reduction in capex for every fold increase in size	IEA, McKinsey
	Reference fold increase	10	10		Decrease in capex every time an increase of capacity	IRENA, NITI Aayog
	No of Folds	1.13	1.13	INR/kW	%No. of Folds/ increase in size from reference capacity	
	Capex Reduction factor	11%	11%	Years	% Reduction in Capex due to scaling of capacity	
	Scale Index	0.99	0.99	%	For <5 MW: Alkaline=0.69 and PEM =0.79 For >5 MW for both systems n=0.99	

Data Sheets| Hydrogen Parameters (II/III)

	Components	PEM	Alkaline	Units	Description	Source
Hydrogen System Parameters	Annual decline rate of CAPEX towards 2035	11%	9%	%	Expected annual decline in the electrolyser capex	McKinsey, Lazard, TERI, US DoE
	OPEX- 2023	1.50%	1.50%	% of capex per year	Operational Expenditure of the electrolyser	IEA, McKinsey
	Electrolyser stack replacement cost	36%	36%	%		IRENA,NITI Aayog
	Land Lease cost	43,036	55,000	INR/kW	Land lease cost for setting up the electrolyser plant	Gigastack
	Expected Useful Life	25	25	Years	Electrolyser plant lifetime	Assumption
	Depreciation	4%	4%	%	Calculated based on the electrolyser plant lifetime	

Data Sheets| Hydrogen Parameters (III/III)

	Components	Amount	Units	Description	Source
Desalination Plant	Water desalination CAPEX	9,10,00,000	INR/MLD	Capital Expenditure to include design, installation, supply of components and regulatory studies	Ministry of Environment, TN
	Water desalination OPEX	10%	% of CAPEX	Operational Expenditure includes O&M, consumables and chemicals and power	Ministry of Environment, TN
	Brine as % of water intake	65%	%	Amount of brine produced from total water intake	Ministry of Environment, TN
	Water consumption by H2-NH3 plant	58.36	Litre per Kg of h2	Total water consumption per kg of hydrogen produced	Gigastack-ITM Power, Discussions
	Pipeline water cost	0.06	INR/Litre	Cost of purchasing water for industrial use	State Water Tariffs
	Expected useful life	40	Years	Desalination plant lifetime	Assumption
	Depreciation rate	2.5%	%	Calculated rate of depreciation based on plant lifetime	
Hydrogen Storage	Hydrogen storage CAPEX	41,329	INR/kg	Capital Expenditure for hydrogen storage system	RMI, CEEW
	Hydrogen storage OPEX	1%	% of CAPEX	Operational Expenditure for hydrogen storage system	CEEW, Ikäheimo et al-2018
	Minimum hydrogen storage level	5%	%	Minimum level of h2 to be maintained for safe operations	Assumption
	Expected useful life	25	Years	Hydrogen storage system lifetime	Assumption
	Depreciation rate	4%	%	Calculated rate of depreciation based on system lifetime	

Data Sheets| Ammonia Parameters

	Components	Amount	Units	Description	Source
Ammonia Synthesis	NH3 plant SEC	0.55	kWh/kg	Specific Energy Consumption of NH3 plant	IRENA, Fasihi et al - 2021
	NH3 plant maximum load	100%	%	Highest load at which the NH3 plant can operate	Discussion with experts
	NH3 plant minimum load	60%	%	Lowest load at which the NH3 plant can operate	Discussion with experts
	NH3 synthesis unit CAPEX - 2023	44,000	INR/tonne NH3	Capital expenditure for ammonia synthesis unit	Fasihi et al - 2021
	NH3 OPEX	5%	% of CAPEX	Operational Expenditure for ammonia synthesis unit	Fasihi et al - 2021
N2 ASU	Air Separation Unit SEC	0.23	kWh/kg	Specific Energy Consumption of a Cryogenic ASU	Osman et al – 2020, IRENA
	N2 ASU CAPEX - 2023	4,400	INR/ tonne NH3	Capital Expenditure for Air Separation Unit	IRENA, Fasihi et al - 2021
	N2 ASU OPEX - 2023	5	% of CAPEX	Operational Expenditure for Air Separation Unit	Fasihi et al - 2021
Ammonia Storage	Ammonia storage CAPEX	54,824	INR/tonne NH3	Capital expenditure for ammonia storage system	Fasihi et al - 2021
	Ammonia storage OPEX	4%	% of CAPEX	Operational expenditure for ammonia storage system	Fasihi et al - 2021
	Ammonia storage duration	30	Days	Number of days worth of ammonia production that can be stored	Fasihi et al - 2021
	Expected useful life	50	Years	Useful life of the N2-NH3 complex	Assumption
	Depreciation	2%	%	Calculated rate of depreciation	

Data Sheets| Fertilizer Parameters (I/II)

	Components	Amount	Units	Description	Source
Urea	Natural Gas price	14	USD/MMBtu	Cost of natural gas to calculate cost of grey ammonia and urea. Can be changed by user	Yara, Govt. sources
Urea	Ammonia consumption per tonne urea	0.57	MT per MT Urea	Amount of ammonia required for producing 1 MT of urea	Yara, Govt. sources
Urea	Fixed cost of producing Urea	170	USD/MT Urea	Fixed costs incurred in the production of 1 MT of urea	Discussion with experts
Urea	Fixed cost of producing grey Ammonia	68	USD/MT NH3	Fixed costs incurred in the production of 1 MT of grey ammonia	Discussion with experts
Urea	Controlled cost of Urea in India	5360	INR/MT Urea	Regulated price of grey urea	Govt. sources
Urea	Green Ammonia blending % in urea	20%	%	Percentage of green ammonia blended in total ammonia used for urea production	Calculated as per model
CO2	CO2 produced in grey ammonia production	1.9	MT per MT NH3	Total CO2 generated in a grey ammonia plant (pure CO2 stream and flue gas emissions)	Ammofuel
CO2	Price of carbon credit	6,400	INR	Average (12 months) price in UK-EU markets	Ember – Carbon Price Tracker
CO2	CO2 consumption per tonne Urea	0.74	MT per MT Urea	Amount of CO2 required for producing 1 MT of urea	Yara calculator
CO2	CO2 generated in existing NH3-Urea projects	1.3	MT per MT NH3	CO2 generated as pure stream in a ammonia urea plant	Ammofuel
CO2	CO2 available for urea production from green NH3	0.6	MT per MT NH3	CO2 generated as low concentration flue gas	Ammofuel
CO2	Cost of CO2 from recovery unit onsite grey NH3-Urea	4,800	INR per tonne CO2	Cost of capturing the flue gas emissions with an onsite recovery unit	Ammofuel
CO2	Sourcing cost of CO2 from external sources	6,500	INR per tonne CO2	Cost of CO2 capture and transport from an external source	NITI Aayog
CO2	CO2 produced per kg grey hydrogen	9.3	Kg per Kg H2	Amount of CO2 produced per kg of grey hydrogen produced	Forbes

Data Sheets| Fertilizer Parameters (II/II)

	Components	Amount	Units	Description	Source
DAP	NH3 consumption per tonne DAP	0.23	MT per MT DAP	Ammonia required for producing 1 MT of DAP	Govt. sources
	Cost of Phosphoric Acid	80,000	INR/MT	Cost of procuring phosphoric acid	User adjusted assumption
	Phosphoric Acid consumption per MT DAP	0.47	MT per MT DAP	Phosphoric acid required for producing 1 MT of DAP	Govt. sources
	Fixed cost of DAP plant	4,640	INR/MT DAP	Fixed costs associated with producing 1 MT DAP	GPCA
NPK (19:19:19)	Amount of NH3 required	0.23	MT per MT NPK	Ammonia required for producing 1 MT NPK	Discussion with experts
	Amount of Phosphoric Acid required	0.6	MT per MT NPK	Phosphoric acid required for producing 1 MT NPK	Discussion with experts
	Cost of Phosphoric Acid	80,000	INR/MT	Cost of procuring phosphoric acid	Used adjusted assumption
	Amount of K2O required	0.23	MT per MT NPK	Potassium required for producing 1 MT NPK	Industry discussions
	Cost of K2O	60,000	INR/MT	Cost of procuring Potassium	User adjusted assumption
	Fixed cost of NPK Plant	4,640	INR per MT NPK	Assumed fixed cost to be same as for DAP	

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