INL/MIS-25-83837

# Nuclear Integrated Hydrogen Production Analysis (NIHPA) Tool

*Prepared for LWRS FPOG Stakeholder Meeting Day 1*

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# Nuclear Integrated Hydrogen Production Analysis (NIHPA) tool: Dashboard Representation

## Step-1: Input Specification

| Plant Capacity (HTSE) | Plant Life |
|---|---|
| 500 MW-dc | 20 years |

| Hydrogen Market Price(2023) | Electricity Price (2023) |
|---|---|
| User-defined (uncorrelated with NG and elec price) | User-defined (uncorrelated with NG price) |
| $2.34 | $33.59 |

**Financial Parameters**

| | |
|---|---|
| Weighted Average Cost of Capital | 10% |
| % of Equity Financing | 40% |
| % of Debt Financing | 60% |
| Equity interest rate | 20% |
| Debt interest rate | 4% |
| State Tax | 6% |

**Tool Mode Section**

| | |
|---|---|
| Electrolyzer: | HTSE |
| Energy gen. | H2 production |
| NPP Design Capacity | |

## Step-2: Financial Performance

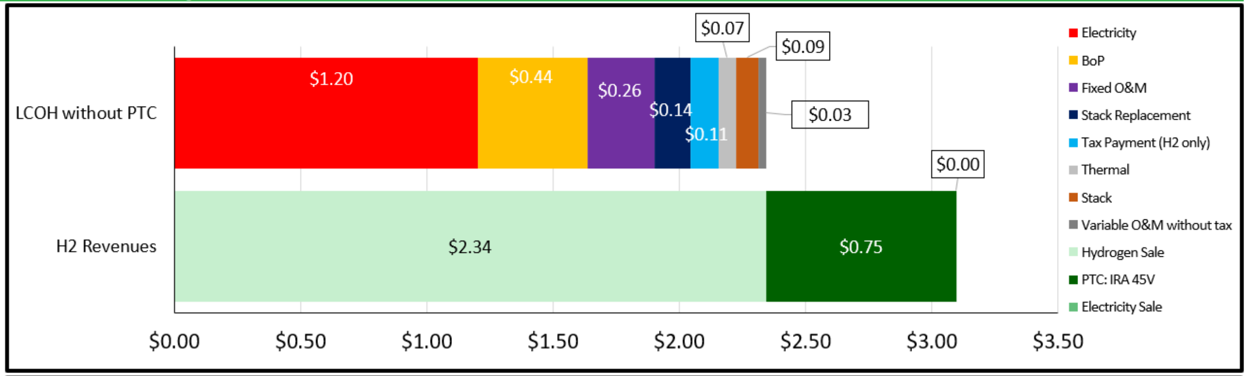
| Tax payments included in the LCOH? | Yes |
|---|---|

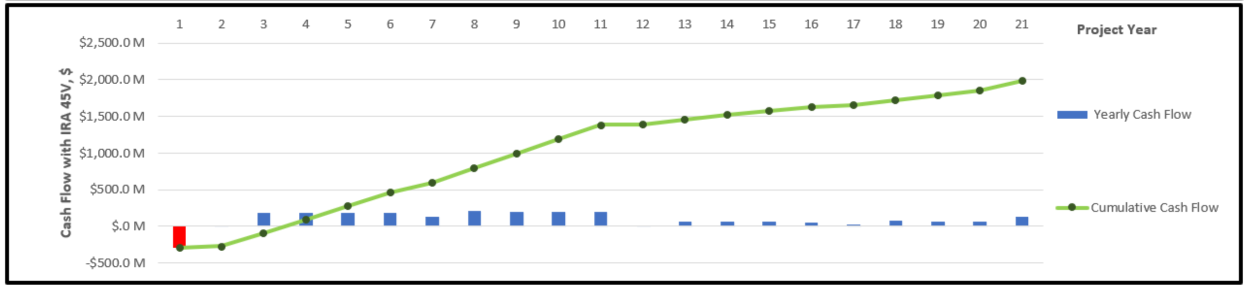
**H2 Production Only**

| | CLICK: Find Breakeven | CLICK: Find Breakeven |
|---|---|---|
| | No tax credits | Tax credit (IRA Sec 45 V) |
| LCOH ($ 2022) | $2.34/Kg-H2 | $1.59/Kg-H2 |
| Internal Rate of Return (%) | 10% | 41% |
| NPVH2 ($ Million) | .0 M | 692.9 M |
| ΔNPV=$NPV_{H2}$-$NPV_{BAU}$ ($ Million) | -48 M | 432 M |
| Daily H2 Production (tonne/day) | 351 | 351 |

**Electricity Production Only (Business-As-Usual)**

| | No tax credits | Tax credit (IRA Sec 45 U) |
|---|---|---|
| $NPV_{BAU}$ ($ Million) | 48 M | 261 M |

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# Case Study 500 MWe-dc

| NPP specific inputs | | |
|---|---|---|
| **Parameters** | **Units** | **Simulation Values** |
| NPP Capacity Factor | % | 90.00% |
| NPP Thermal Efficiency | % | 34.00% |
| NPP Design Capacity | MW-th | 3716 |
| NPP power to electrolysis | MW-ac | 538 |
| Remaining electricity to be sold on grids | MW-ac | 725 |

| HYSYS model outputs (for HTSE only) | | |
|---|---|---|
| **Parameters** | **Units** | **Simulation Values** |
| Hydrogen Production Rate per 40 Module | kg/sec | 8.124 |
| Utilities: Cooling Water Rate per 40 Module | kg/sec | 1171 |
| Utilities: Process Water Rate per Module | kg/hr | 6534 |
| Electrical Power Consumption per 40 Module | MW-ac | 1076 |
| Thermal Power Consumption per 40 Module | MW-t | 188 |
| Modular block capacity | MW-dc/Module | 25 |

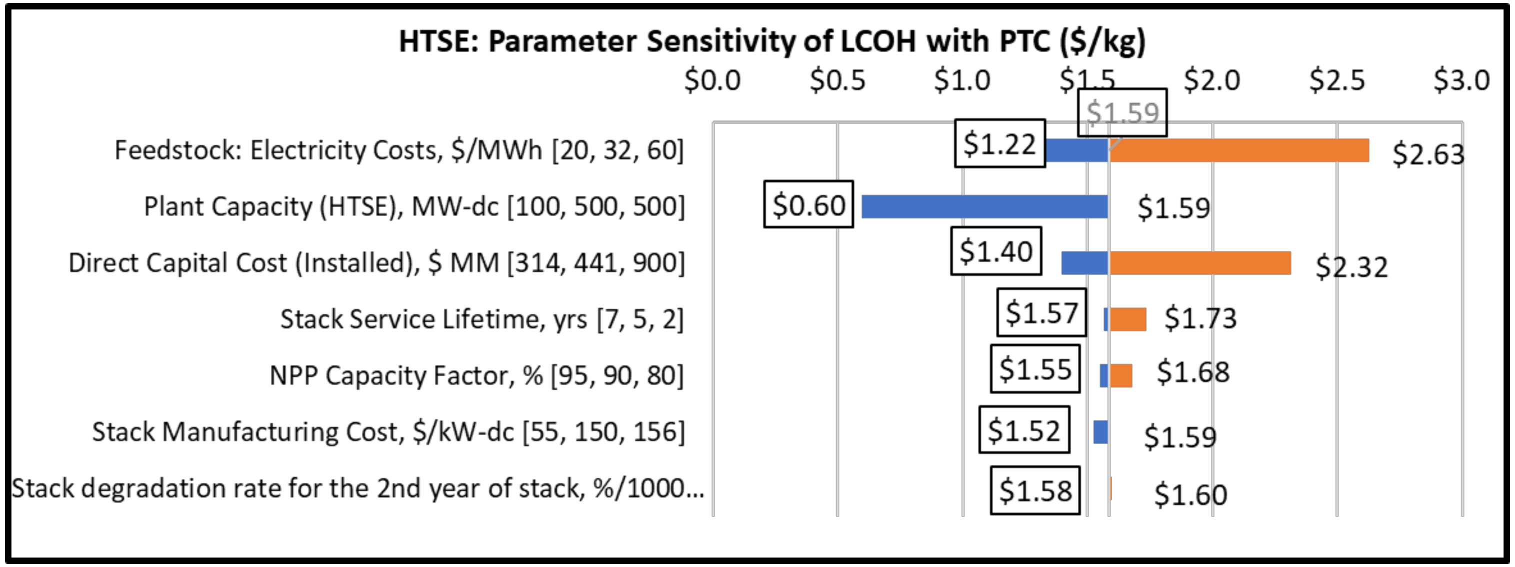
| Electrolyzer Specific Inputs | | |
|---|---|---|
| Plant Capacity (HTSE) | MW-dc | 500 |
| Total Plant Staff | - | 13 |
| Number of Modules | - | 20 |
| Plant Life | yrs | 20 |
| Hydrogen Production Rate per Module | tonne-H2/hr | 0.731 |
| Design Hydrogen Production Capacity | tonne-H2/day | 351 |
| Electrical Power Requirement | MW-ac | 538 |
| Thermal Power Requirement | MW-t | 94 |
| **Stack Replacement Multipliers** | | |
| Stack Replacement Schedule | - | End of Service Life |
| Stack Service Lifetime | yrs | 5 |
| Stack degradation rate for the 1st year of stack | %/1000 hr | 0.00% |
| Stack degradation rate for the 2nd year of stack | %/1000 hr | 0.25% |
| Stack degradation rate for the 3rd year of stack | %/1000 hr | 0.50% |
| Stack degradation rate for the 4th year of stack | %/1000 hr | 0.75% |
| Stack degradation rate for the 5th year of stack | %/1000 hr | 1.00% |
| Stack degradation rate for the 6th year of stack | %/1000 hr | 0.00% |
| Stack degradation rate for the 7th year of stack | %/1000 hr | 0.00% |
| Total Unplanned Replacement Capital Cost Factor | % | 0.50% |
| **Feedstock and Utilities Multipliers** | | |
| Feedstock: Electricity Usage | kWh-e/tonne H2 | 36790.85 |
| Feedstock: Thermal Energy Usage | kWh-t/tonne H2 | 6434.98 |
| Utilities: Density of Process Water | kg/m^3 | 998 |
| Utilities: Density of Cooling Water | kg/m^3 | 998 |
| Utilities: Process Water Rate | kg/s | 36.3 |
| Utilities: Cooling Water Rate | kg/s | 585.5 |
| Utilities: Process Water Usage | gal/tonne H2 | 2365.500 |
| Utilities: Coolant Water Usage | gal/tonne H2 | 38154.277 |
| H2 transportation piping diameter | inch | 0 |

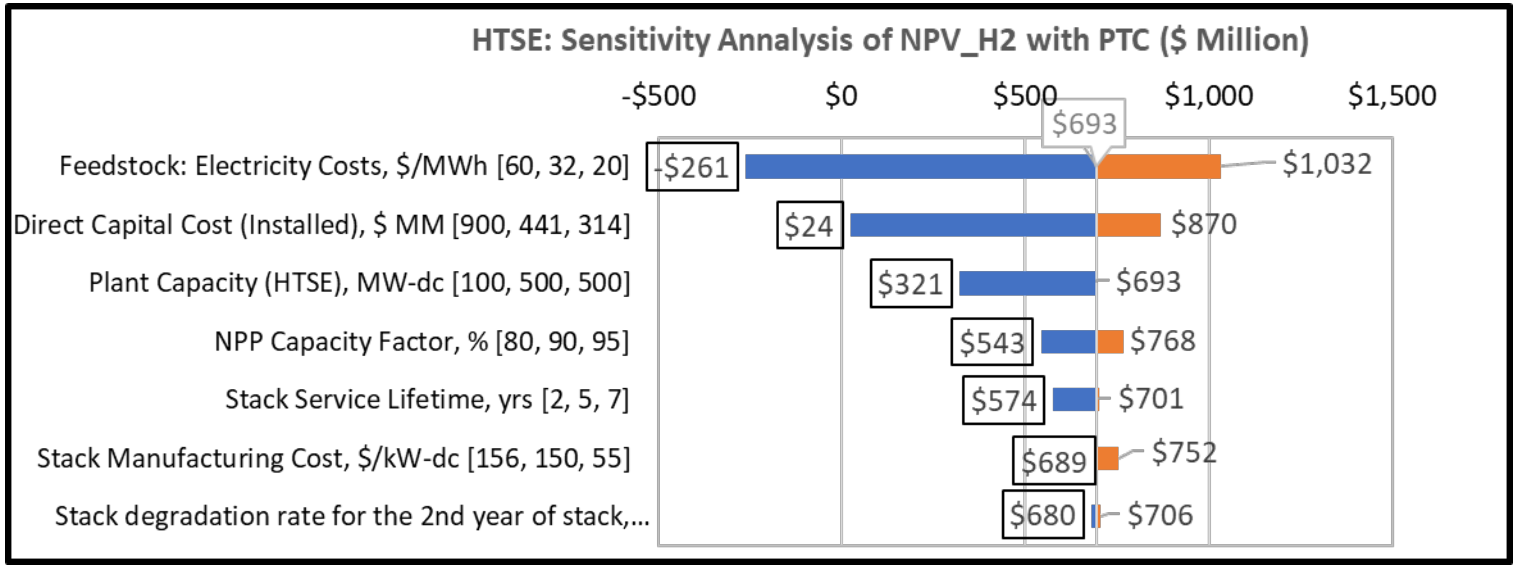
# Case Study 500 MWe-dc (cont.)

| Financial inputs | | |
|---|---|---|
| Depreciation Type | - | MACRS |
| Depreciation Period | yrs | 20 |
| Plant Type | - | NOAK |
| Length of Construction | yrs | 1 |
| Start-up Year | - | 2030 |
| % of Fixed Operating Cost During Start-up | % | 100.00% |
| % of Variable Operating Costs During Start-up | % | 75.00% |
| % of Revenue During Start-up | % | 50.00% |
| Weighted Average Cost of Capital | % | 10.00% |
| Tax Status | - | Profit |
| H2 PTC (IRA 45V): Maximum | $/kg-H2 | $3.00 |
| Last year that IRA 45V that is applicable | - | 2040 |
| elec PTC (IRA 45U): Maximum | $/MWh | $15.00 |
| Last year that IRA 45U that is applicable | - | 2032 |
| % of clean tax reduction | % | 10.00% |
| % of Equity Financing | % | 40.00% |
| % of Debt Financing | % | 60.00% |
| Debt period | yrs | 20 |
| Debt interest rate | % | 3.70% |
| Inflation Rate | % | 1.90% |
| State Tax | % | 6.00% |
| Federal Tax | % | 21.00% |
| Total Tax Rate | % | 25.74% |
| Working Capital | % | 15.00% |

| Cost contributors for LCOH | | |
|---|---|---|
| Hydrogen Market Price | $/kg-H2 | $2.45 |
| Natural Gas Price | $/MMBtu | $3.00 |
| Electricity Sale Price | $/MWh | $33.59 |
| Feedstock: Electricity Costs | $/MWh | $31.76 |
| Feedstock: Thermal Energy Cost Rate | $/kWh | $0.01 |
| Utilities: Process Water Cost | $/gal | $0.0027635 |
| Utilities: Coolant Water Cost | $/gal | $0.0000279 |
| Burdened labor cost | $/man-hr | $60 |
| Total Capital Investment (TCI) | $ MM | $642,343,206 |
| TCI per kW-dc | $/kW-dc | $1,285 |
| Total Depreciable Capital Costs | $ MM | $635,983,372 |
| Stack costs contingency | % | 10.00% |
| Stack mark-up costs | % | 30.00% |
| Stack Manufacturing Cost | $/kW-dc | $153 |
| BOP Cost | $/kW-dc | $747 |
| Total DCC per kW-dc | $/kW-dc | $900 |
| Installation factor | - | 1.3335 |
| Direct Capital Cost (Uninstalled) | $ MM | $337,422,387 |
| Direct Capital Cost (Installed) | $ MM | $449,940,907 |
| Salvage Value | $ MM | $64,234,321 |
| Decommissioning cost | $ MM | $63,598,337 |
| Indirect Depreciable Capital Cost | $ MM | $186,042,466 |
| Site Preparation | $ MM | $8,998,818 |
| Engineering and Design | $ MM | $44,994,091 |
| Process Contingency | $ MM | $32,279,211 |
| Project Contingency | $ MM | $32,279,211 |
| Up-Front Permitting Costs | $ MM | $67,491,136 |
| Total Non-depreciable Capital Costs | | |
| Land costs | $ MM | $6,359,834 |
| Total Fixed O&M Costs | $ MM | $28,295,191 |
| Fixed O&M per kW-dc | $/kW-dc | $494 |
| Labor cost | $/yr | $1,625,083 |
| G&A | $/yr | $325,017 |
| Property tax and insurance | $ MM | $12,846,864 |
| Production Maintenance and Repairs | $ MM | $13,498,227 |

# Step-3: Sensitivity Analysis (with PTC)

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# Step-4: Profitability Analysis

**(a) HTSE: Heat map of Internal Rate of Return (IRR)**

IRR — H2 PTC (IRA 45V): Maximum

| Hydrogen Market Price | $0.00 | $0.33 | $0.67 | $1.00 | $1.33 | $1.67 | $2.00 | $2.33 | $2.67 | $3.00 |
|---|---|---|---|---|---|---|---|---|---|---|
| $0.50 | | | | | | | | | | |
| $1.00 | | | | | | | | | | |
| $1.50 | | | | | | | | | | 12.2% |
| $2.00 | -2.3% | 1.1% | 5.0% | 9.2% | 13.4% | 17.5% | 21.6% | 25.5% | 29.3% | 33.0% |
| $2.50 | 13.9% | 17.2% | 20.6% | 24.1% | 27.6% | 31.1% | 34.6% | 38.1% | 41.5% | 44.9% |
| $3.00 | 26.1% | 29.4% | 32.8% | 36.1% | 39.5% | 42.8% | 46.1% | 49.4% | 52.7% | 55.9% |
| $3.50 | 37.0% | 40.2% | 43.5% | 46.7% | 50.0% | 53.2% | 56.4% | 59.6% | 62.7% | 65.9% |
| $4.00 | 47.3% | 50.5% | 53.6% | 56.8% | 60.0% | 63.1% | 66.2% | 69.3% | 72.4% | 75.5% |
| $4.50 | 57.2% | 60.4% | 63.5% | 66.6% | 69.7% | 72.8% | 75.8% | 78.9% | 81.9% | 84.9% |
| $5.00 | 67.0% | 70.0% | 73.1% | 76.2% | 79.2% | 82.2% | 85.2% | 88.2% | 91.2% | 94.1% |

- Non-Profitable
- Marginal (Breakeven)
- Profitable

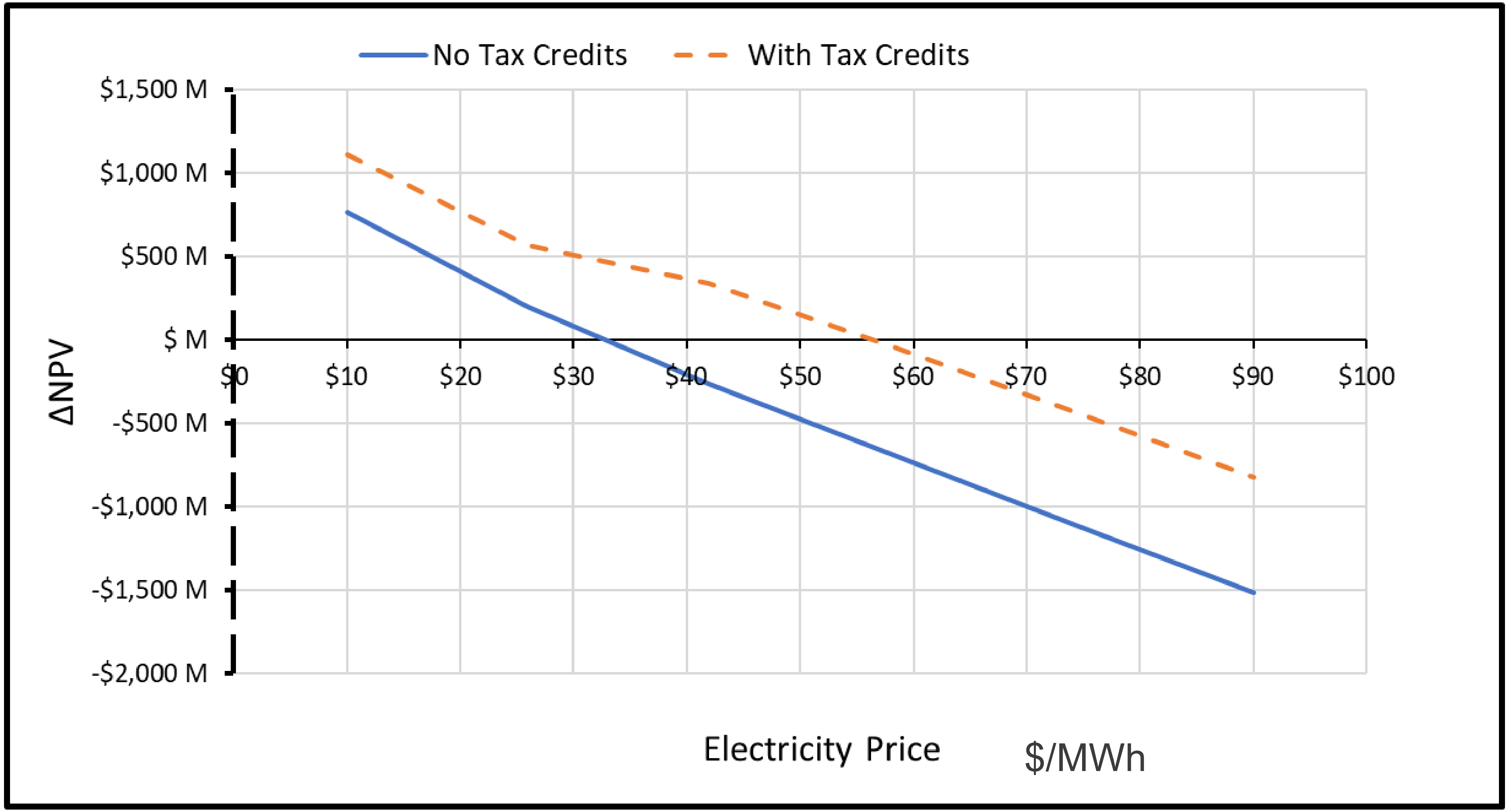
**(b) HTSE: Heat map of Net Present Value (NPVH2)**

$NPV_{H2}$ — H2 PTC (IRA 45V): Maximum

| Hydrogen Market Price | $0.00 | $0.33 | $0.67 | $1.00 | $1.33 | $1.67 | $2.00 | $2.33 | $2.67 | $3.00 |
|---|---|---|---|---|---|---|---|---|---|---|
| $0.50 | -1,589 M | -1,512 M | -1,435 M | -1,358 M | -1,281 M | -1,204 M | -1,127 M | -1,050 M | -973 M | -896 M |
| $1.00 | -1,130 M | -1,053 M | -976 M | -899 M | -822 M | -745 M | -668 M | -591 M | -514 M | -437 M |
| $1.50 | -671 M | -594 M | -517 M | -440 M | -363 M | -286 M | -209 M | -132 M | -55 M | 22 M |
| $2.00 | -240 M | -163 M | -86 M | -9 M | 68 M | 145 M | 222 M | 299 M | 376 M | 453 M |
| $2.50 | 110 M | 187 M | 264 M | 341 M | 418 M | 495 M | 572 M | 649 M | 726 M | 803 M |
| $3.00 | 459 M | 536 M | 613 M | 690 M | 767 M | 844 M | 921 M | 998 M | 1,075 M | 1,152 M |
| $3.50 | 801 M | 878 M | 955 M | 1,032 M | 1,109 M | 1,186 M | 1,263 M | 1,340 M | 1,417 M | 1,494 M |
| $4.00 | 1,142 M | 1,219 M | 1,296 M | 1,373 M | 1,450 M | 1,527 M | 1,604 M | 1,681 M | 1,758 M | 1,835 M |
| $4.50 | 1,483 M | 1,560 M | 1,637 M | 1,714 M | 1,791 M | 1,868 M | 1,945 M | 2,022 M | 2,099 M | 2,176 M |
| $5.00 | 1,824 M | 1,901 M | 1,978 M | 2,055 M | 2,132 M | 2,209 M | 2,286 M | 2,363 M | 2,439 M | 2,516 M |

- Non-Profitable
- Marginal (Breakeven)
- Profitable

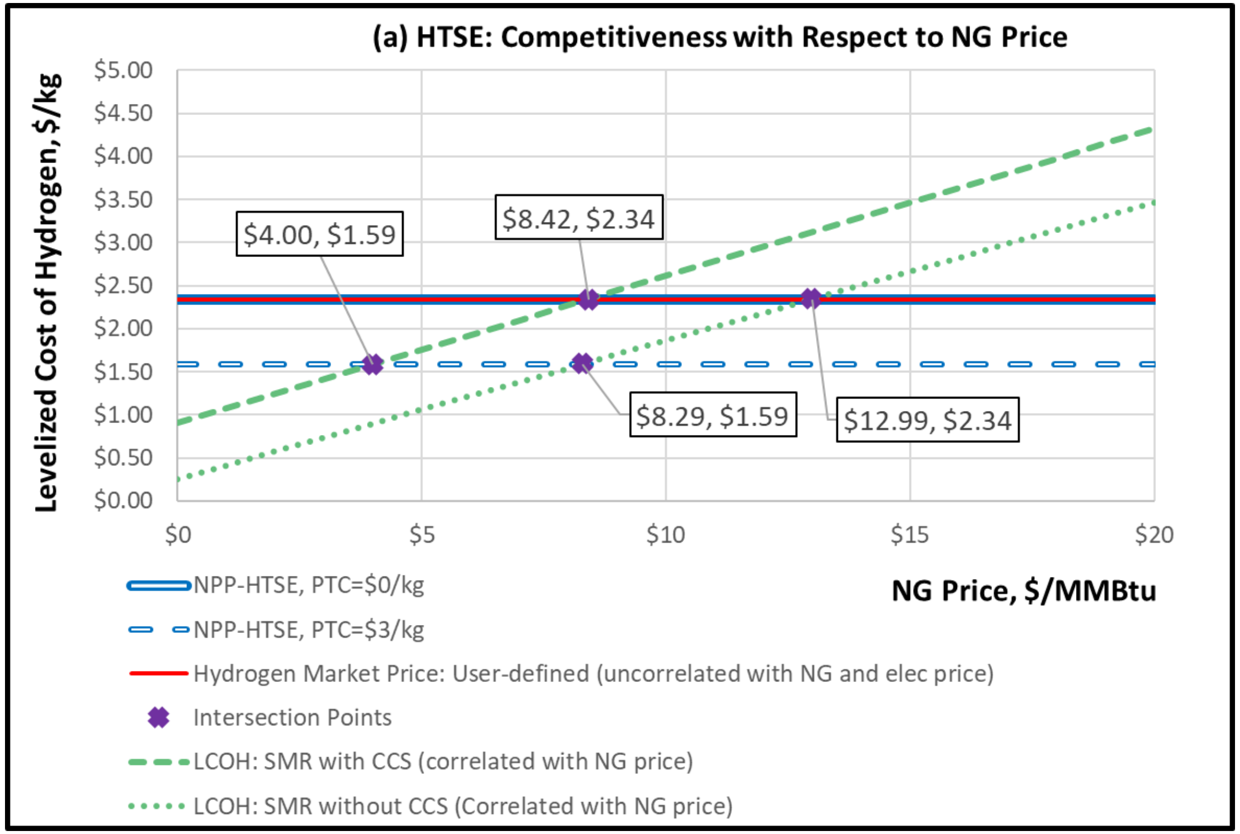
# Step-5: Electricity vs. Hydrogen Production Preference Analysis

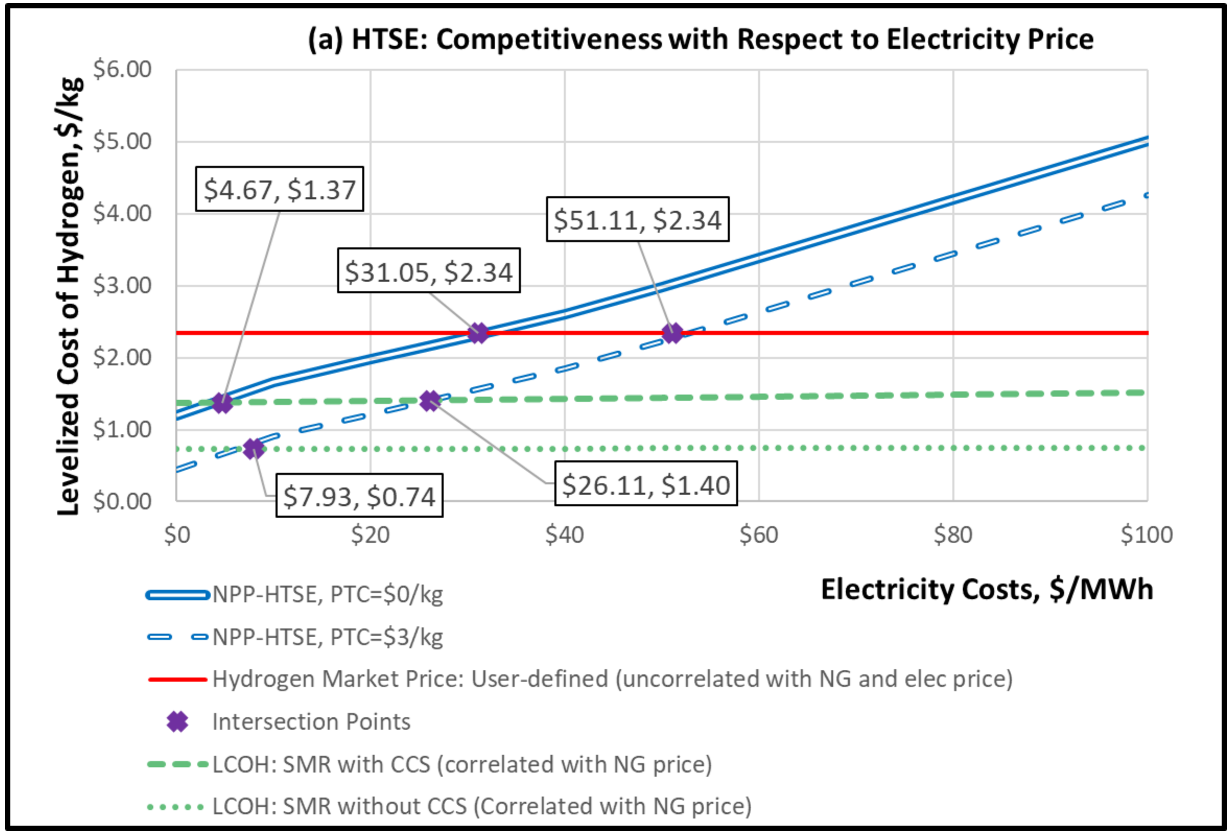



$H_2$ Production

Electricity Sales

# Step-6: Competitive Analysis (NPP-HTSE $H_2$ vs. Steam Methane Reforming)



# Techno-Economic Assessment (TEA) for Nuclear Integrated Hydrogen Production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- Wendt, D.S., Knighton, L.T. and Boardman, R.D., 2022. *High Temperature Steam Electrolysis Process Performance and Cost Estimates* (No. INL/RPT-22-66117-Rev000). Idaho National Lab.(INL), Idaho Falls, ID (United States).
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- Maria A. Herrera Diaz, Todd Knighton, Wen-Chi Cheng, Kathleen P. Sweeney, Frederick C. Joseck, Jack Cadogan, Nahuel Guaita, and Richard D. Boardman, Adarsh P. Bafana, Neeraj C. Hanumante, and Amgad A. Elgowainy, "Hydrogen Generation and Industrial Heat Opportunities for Nuclear Plants in the Gulf Coast", INL/RPT-24-80189, 2024


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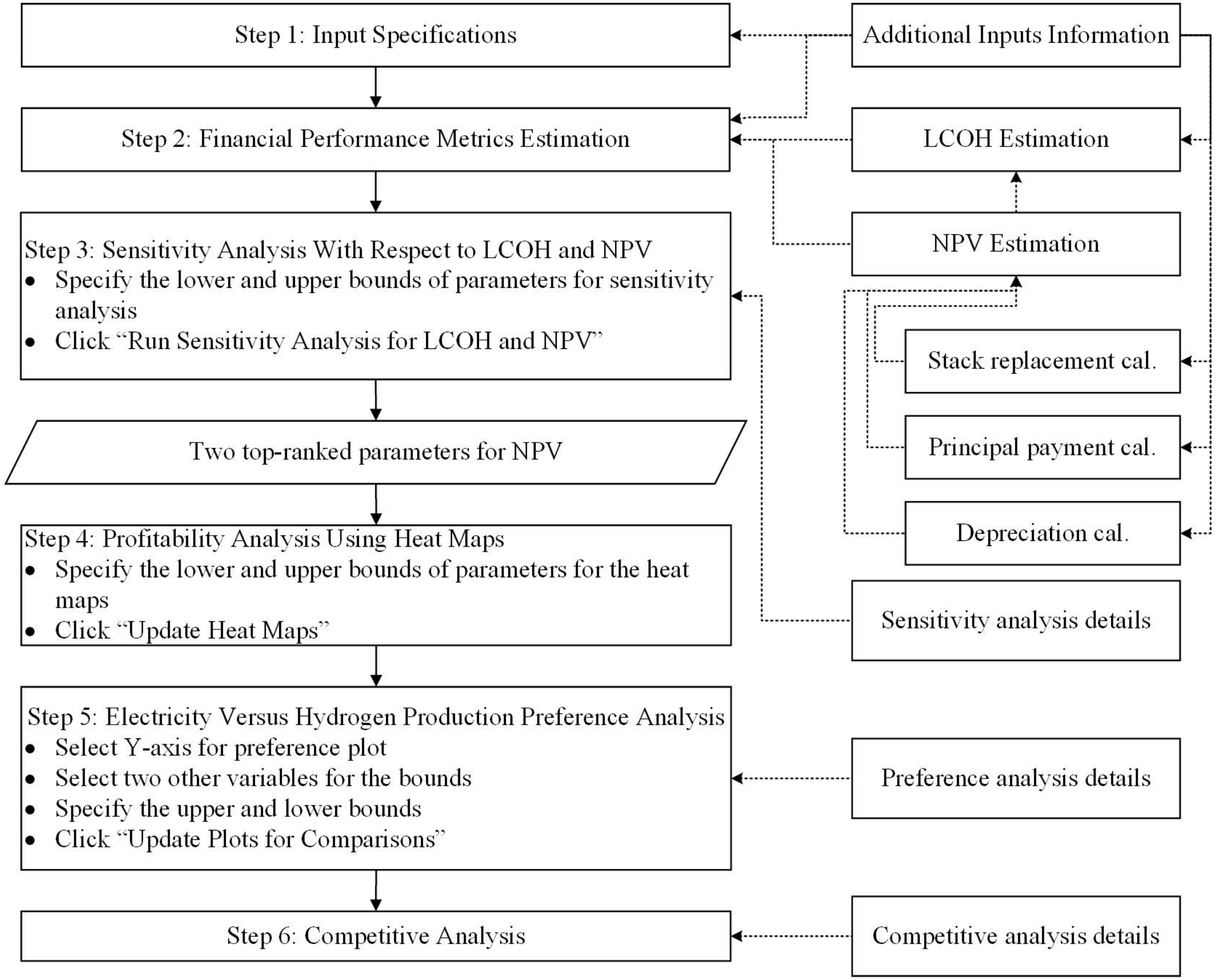
# Nuclear Integrated Hydrogen Production Analysis (NIHPA) tool: Methodology

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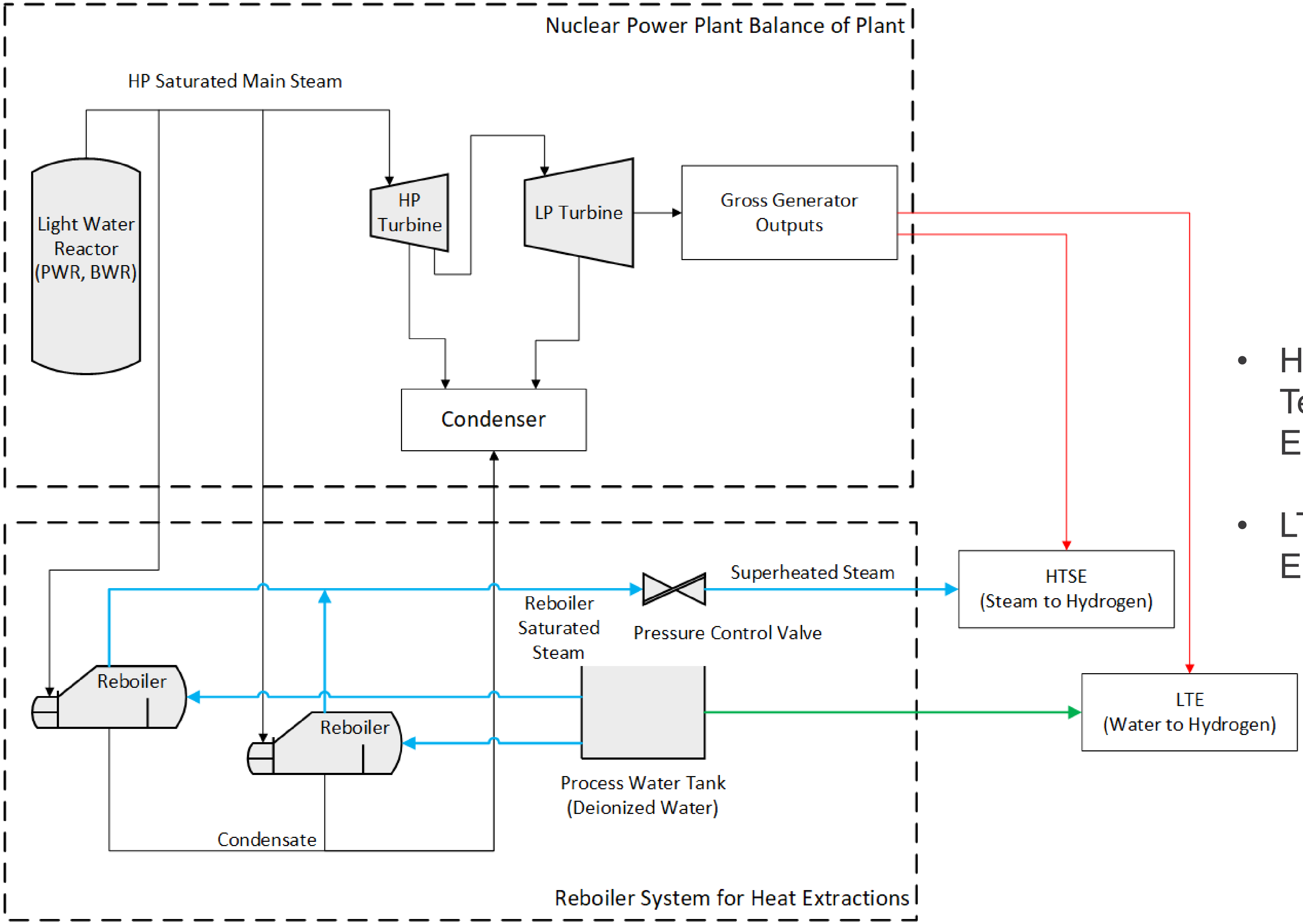
# Nuclear Integrated Hydrogen Production




- HTSE: High-Temperature Steam Electrolysis
- LTE: Low Temperature Electrolysis