# Chapter 7: Verification Conclusion

## 7.1 Verification Checklist

### 7.1.1 Parameter Verification

| Item | Expected | Verified | Status |
|------|----------|----------|--------|
| Discount Rate | 0.0 | 0.0 (base.yaml) | [PASS] |
| Annualization Rate | 0.07 | 0.07 (base.yaml) | [PASS] |
| Annuity Factor | 10.8355 | 10.8355 (CSV) | [PASS] |
| Pump Rate | 1000 m3/h | 1000 (CSV) | [PASS] |
| Shore Pump Rate | 1500 m3/h | 1500 (config) | [PASS] |
| Max Annual Hours | 8000 | 8000 (config) | [PASS] |
| Bunker Volume/Call | 5000 m3 | 5000 (config) | [PASS] |

### 7.1.2 Case 1 Verification

| Item | Expected | CSV Result | Status |
|------|----------|------------|--------|
| Optimal Shuttle | 2,500 m3 | 2,500 m3 | [PASS] |
| NPC (2500) | $237.05M | $237.05M | [PASS] |
| LCO (2500) | $1.01/ton | $1.01/ton | [PASS] |
| Cycle (2500) | 8.1667 hr | 8.1667 hr | [PASS] |
| Cycle (5000) | 12.3333 hr | 12.3333 hr | [PASS] |
| Trips/Call (2500) | 2 | 2.0 | [PASS] |
| Utilization | 100% | 100% | [PASS] |

### 7.1.3 Case 2-1 (Yeosu) Verification

| Item | Expected | CSV Result | Status |
|------|----------|------------|--------|
| Optimal Shuttle | 10,000 m3 | 10,000 m3 | [PASS] |
| NPC (10000) | $747.18M | $747.18M | [PASS] |
| LCO (10000) | $3.17/ton | $3.17/ton | [PASS] |
| Cycle (5000) | 24.7933 hr | 24.7933 hr | [PASS] |
| Cycle (10000) | 36.1267 hr | 36.1267 hr | [PASS] |
| Cycle (15000) | 47.46 hr | 47.46 hr | [PASS] |
| Vessels/Trip (10000) | 2 | 2.0 | [PASS] |
| Travel Time | 5.73 hr | 5.73 hr | [PASS] |

### 7.1.4 Case 2-2 (Ulsan) Verification

| Item | Expected | CSV Result | Status |
|------|----------|------------|--------|
| Optimal Shuttle | 5,000 m3 | 5,000 m3 | [PASS] |
| NPC (5000) | $402.37M | $402.37M | [PASS] |
| LCO (5000) | $1.71/ton | $1.71/ton | [PASS] |
| Cycle (2500) | 15.0067 hr | 15.0067 hr | [PASS] |
| Cycle (5000) | 16.6733 hr | 16.6733 hr | [PASS] |
| Cycle (10000) | 28.0067 hr | 28.0067 hr | [PASS] |
| Vessels/Trip (5000) | 1 | 1.0 | [PASS] |
| Travel Time | 1.67 hr | 1.67 hr | [PASS] |

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## 7.2 Formula Verification Summary

### 7.2.1 Cycle Time Formulas

**Case 1 (Storage at Busan):**

```
Cycle = Shore_Loading + Travel + Setup + Pumping
      = (Size/1500) + 2.0 + 2.0 + (Size/1000)
```

Status: [**PASS**] - All shuttle sizes verified

**Case 2 (Direct Supply):**

```
Cycle = Shore_Loading + Travel_RT + Port_Entry_Exit + (Vessels × Per_Vessel)
      = (Size/1500) + 2×Travel + 2.0 + (Vessels × 8.0)
```

Status: [**PASS**] - All shuttle sizes verified for both Yeosu and Ulsan

### 7.2.2 Cost Formulas

**Shuttle CAPEX:**

```
CAPEX = 61.5M × (Size/40000)^0.75
```

Status: [**PASS**] - Cost breakdown consistent with formula

**Annualization:**

```
Annuity_Factor = [1 - (1.07)^(-21)] / 0.07 = 10.8355
Annualized_CAPEX = CAPEX / 10.8355
```

Status: [**PASS**] - All scenarios show AF = 10.8355

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## 7.3 Discrepancy Report

**No Discrepancies Found**

All verified items match expected values within acceptable tolerance ($< 0.01\%$).

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## 7.4 Recommendations

### 7.4.1 Primary Recommendation

**Case 1: Busan Port with Storage Tank** - Shuttle Size: 2,500 m3 - 20-year NPC: $237.05M - LCOAmmonia: $1.01/ton - Fleet: ~20 shuttles by 2050

### 7.4.2 Alternative Recommendation (if local storage infeasible)

**Case 2-2: Ulsan to Busan** - Shuttle Size: 5,000 m3 - 20-year NPC: $402.37M - LCOAmmonia: $1.71/ton - Premium: +70% over Case 1

### 7.4.3 Not Recommended

**Case 2-1: Yeosu to Busan** - Reason: Distance (86 nm) results in 215% cost premium - Only consider if Yeosu is the only available ammonia source

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## 7.5 Report Validity

| Item | Value |
|------|-------|
| Report Version | 1.0 |
| Date Generated | 2025-01-20 |
| Pump Rate Used | 1000 m3/h (fixed) |
| Discount Rate | 0.0 (no discounting) |
| Data Source | `results/deterministic/scenarios_*.csv` |
| Figures Source | `results/paper_figures/D*.png` |

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## 7.6 Final Verification Status

```
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  VERIFICATION REPORT SUMMARY
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  Case 1 (Busan):     [PASS]
  Case 2-1 (Yeosu):   [PASS]
  Case 2-2 (Ulsan):   [PASS]

  Parameter Check:    [PASS]
  Cycle Time Check:   [PASS]
  Cost Formula Check: [PASS]
```

```
   Annuity Factor:      [PASS]

   Discrepancies:       NONE


===============================
   OVERALL STATUS:      [PASS]
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```

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## 7.7 Archived Documents

The following documents have been archived to `docs/archive/analysis/` as they used different parameters (2000 m3/h pump rate):

- `Ch5_Case1_Analysis.md` - Previous Case 1 analysis
- `Ch6_Case2_Analysis.md` - Previous Case 2 analysis

These documents are preserved for reference but should not be used for current decision-making.

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## 7.8 Next Steps

1. **Policy Decision**: Choose between Case 1 (storage) and Case 2-2 (Ulsan supply)
2. **Sensitivity Analysis**: Review S7 figure for pump rate sensitivity
3. **Stochastic Analysis**: Consider uncertainty in demand growth (S-series figures)
4. **Implementation Planning**: Detailed fleet acquisition schedule