

Application Of Fluorine Source To Chamber Cleaning In The Thin Film Silicon Solar Cell Fabrication

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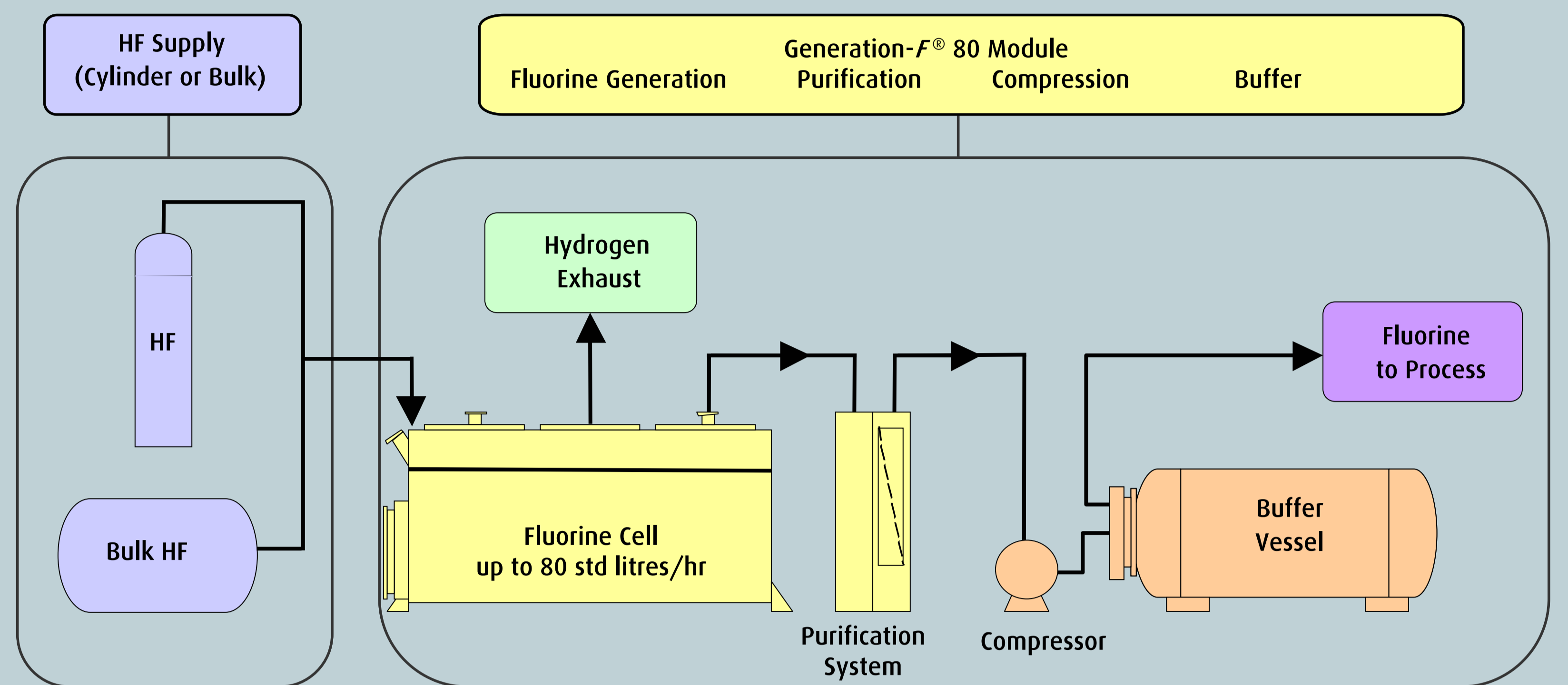
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Properties and generation of fluorine

- Chamber cleaning is an important requirement in thin film silicon solar cell manufacturing technology.
- Cleaning gases such as NF_3 or SF_6 have a significant impact on carbon footprint payback due to their high global warming potential (GWP)
- F_2 has zero GWP impact and zero atmospheric lifetime.
- F_2 requires less energy to dissociate.

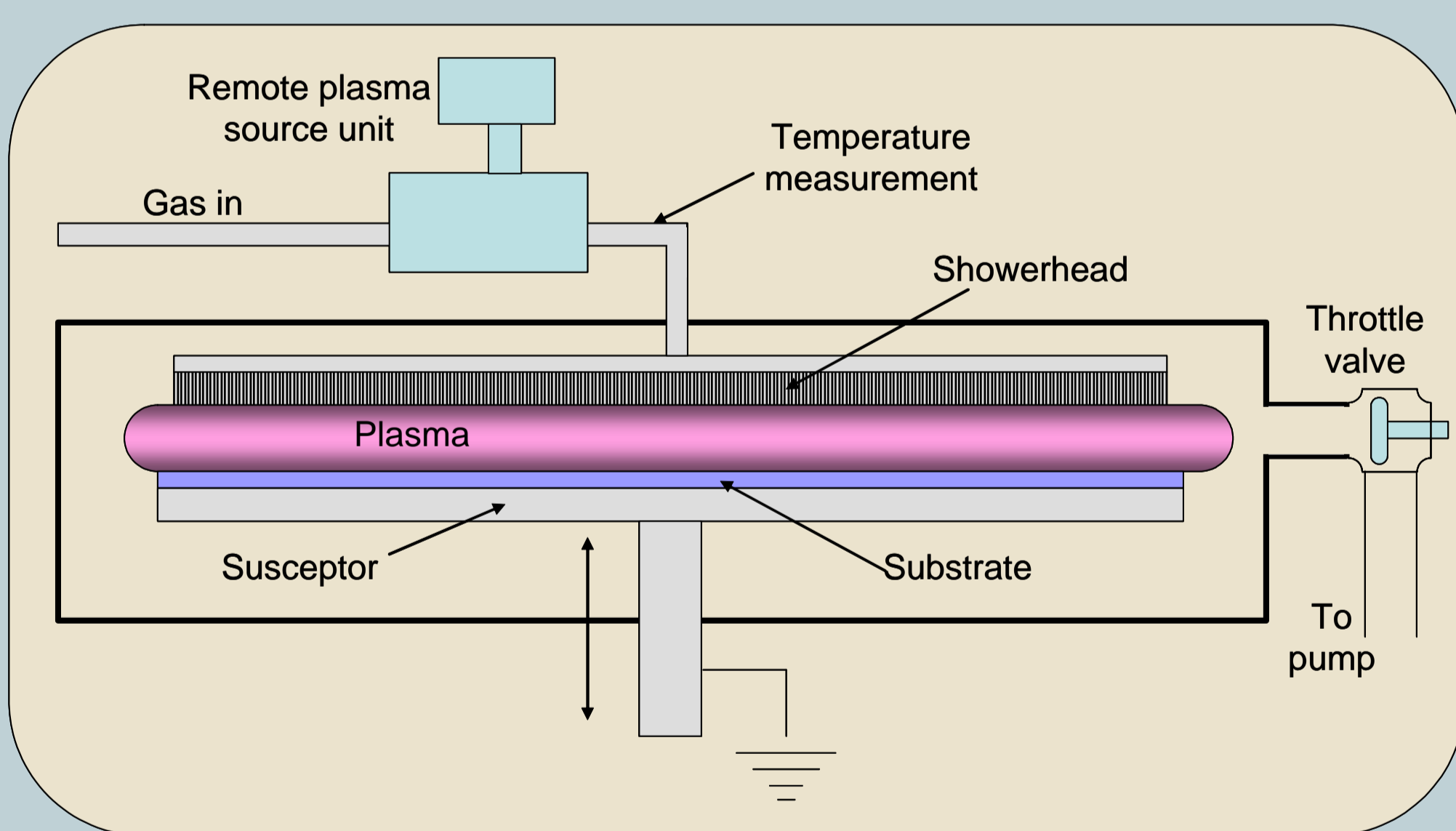
| | SF_6 | NF_3 | F_2 |
|---|---------------|---------------|--------------|
| GWP (for 100 yr) | 22600 | 17200 | 0 |
| Life time (yr) | 3200 | 740 | 0 |
| Dissociation energy (for 1mol of atomic F) (kJ) | 329 | 281 | 79.5 |

Safe use of commercial volumes of F_2 requires on-site generation



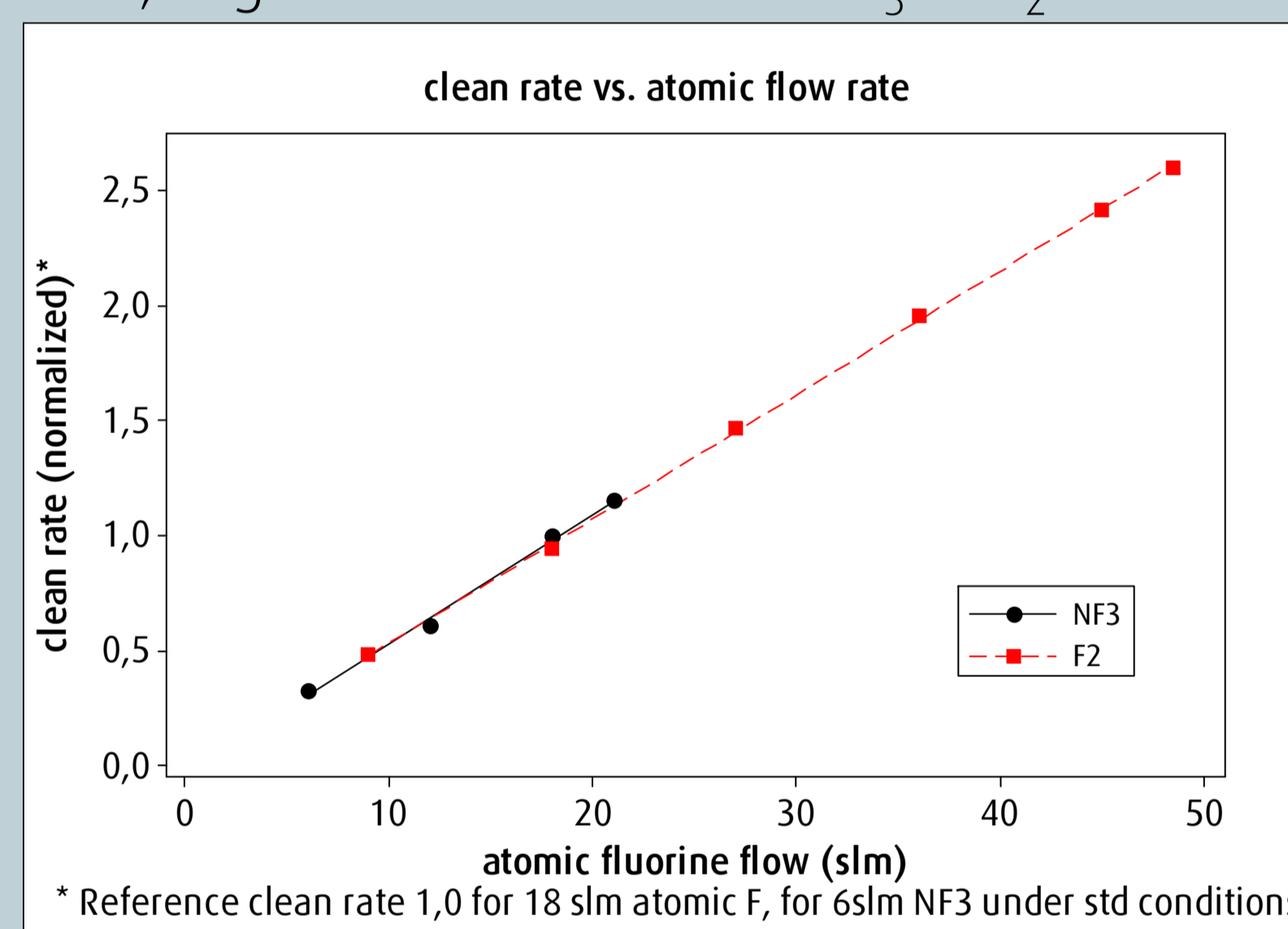
PECVD chamber for cleaning studies

- AKT 15 K PECVD chamber allowing processing of Gen 5 (1300mm x 1100mm) panels.
- Cleaning process done with remote plasma source (RPS) unit.
- No significant modifications required for implementation of fluorine other than ensuring valve materials compatibility.
- Cleaning experiments done on amorphous silicon films.

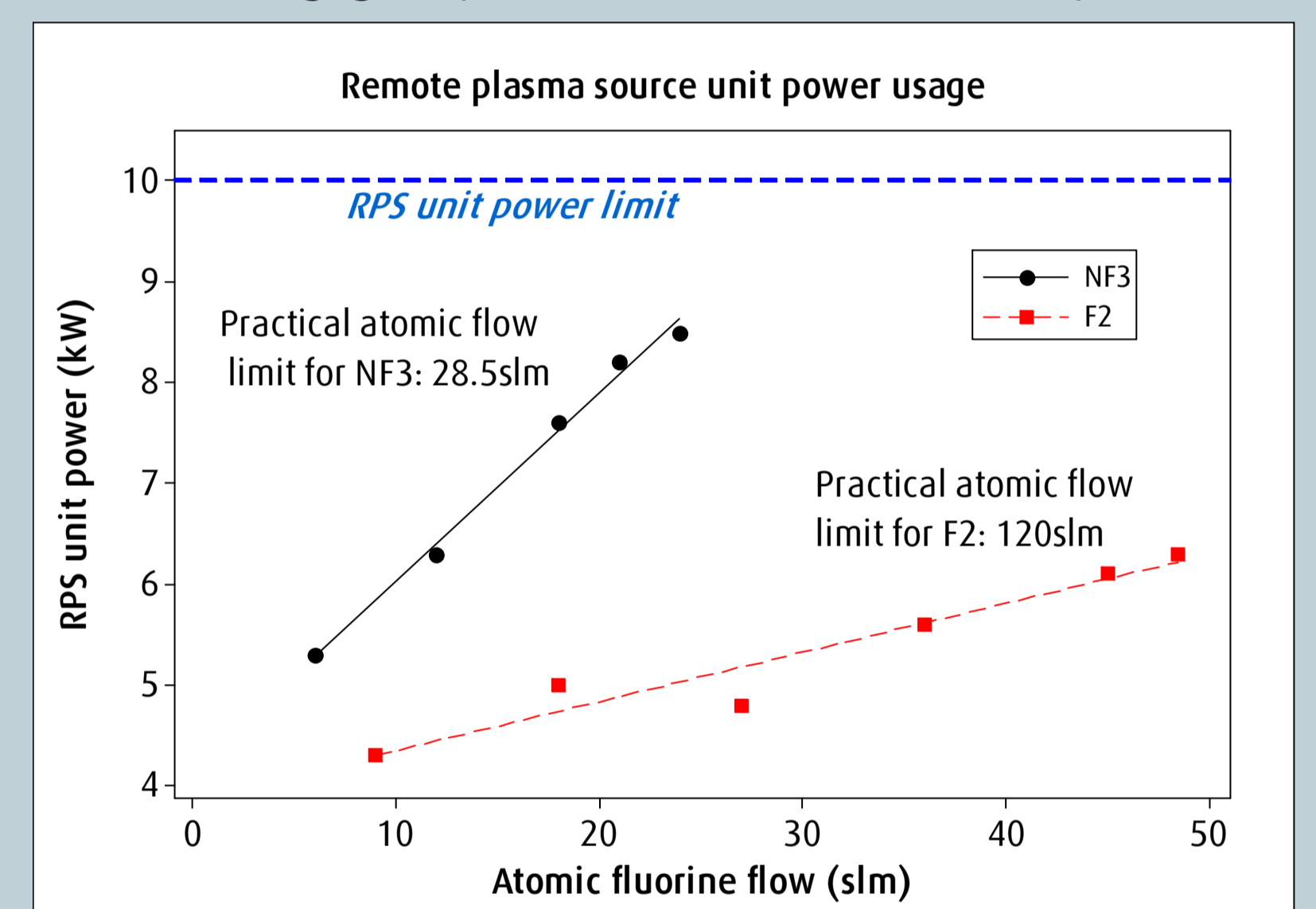


Clean rate performance

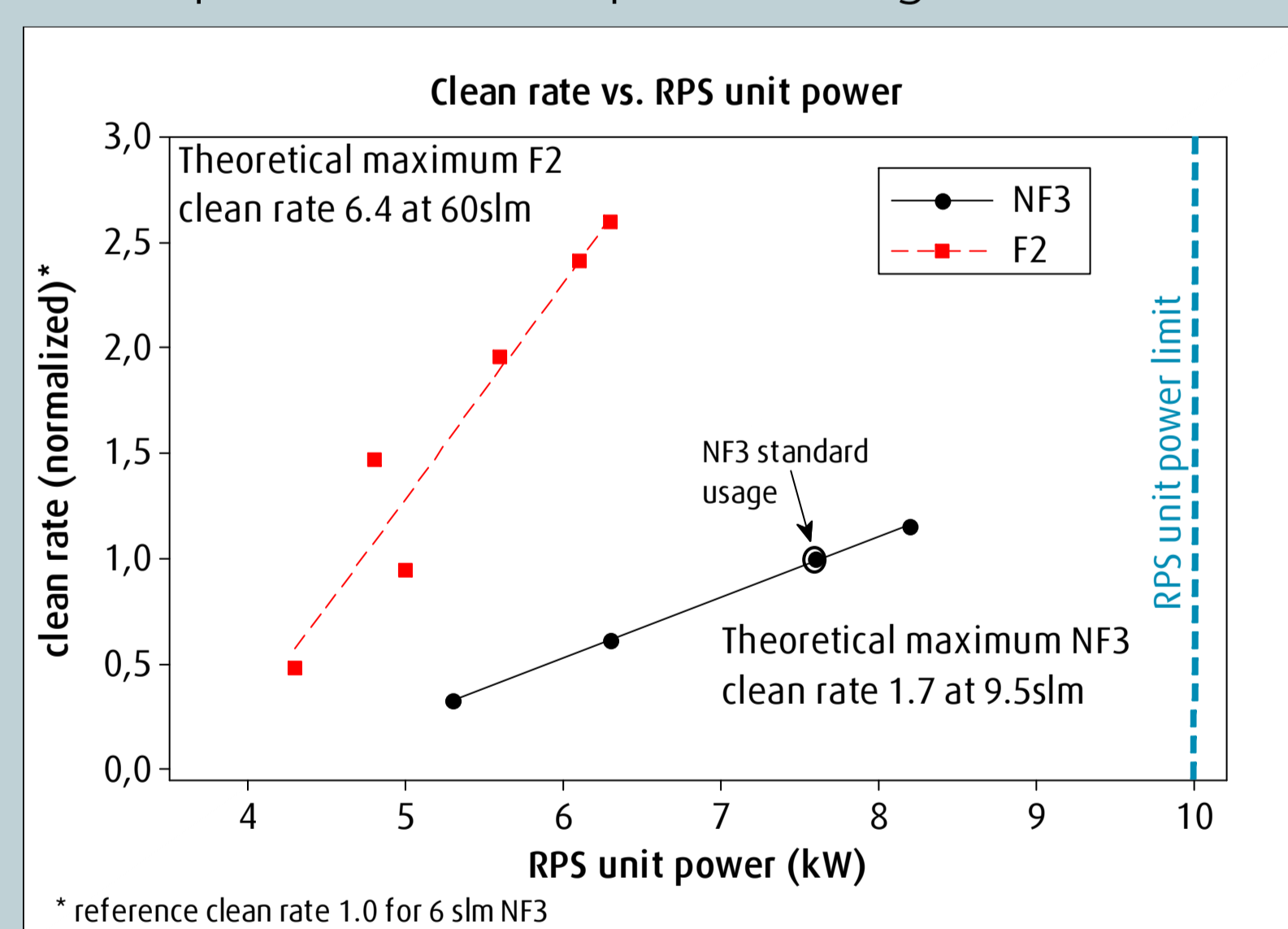
Clean rate depends only on atomic fluorine flow, regardless of whether NF_3 or F_2 is used



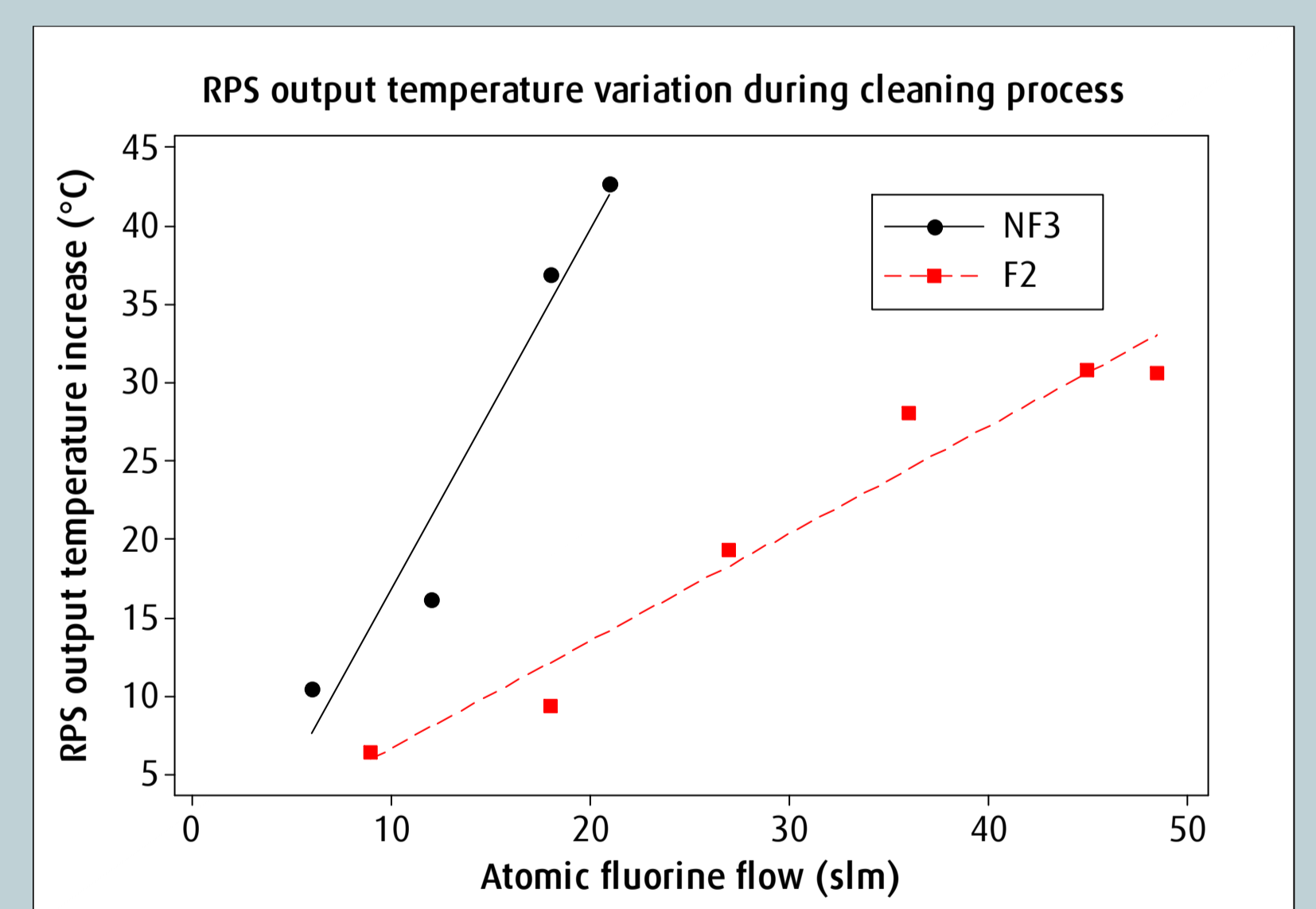
Lower dissociation energy of F_2 results in higher flow of cleaning gas possible for same RPS power



Wider process window for F_2 allows choice of lower power consumption or high-rate cleaning

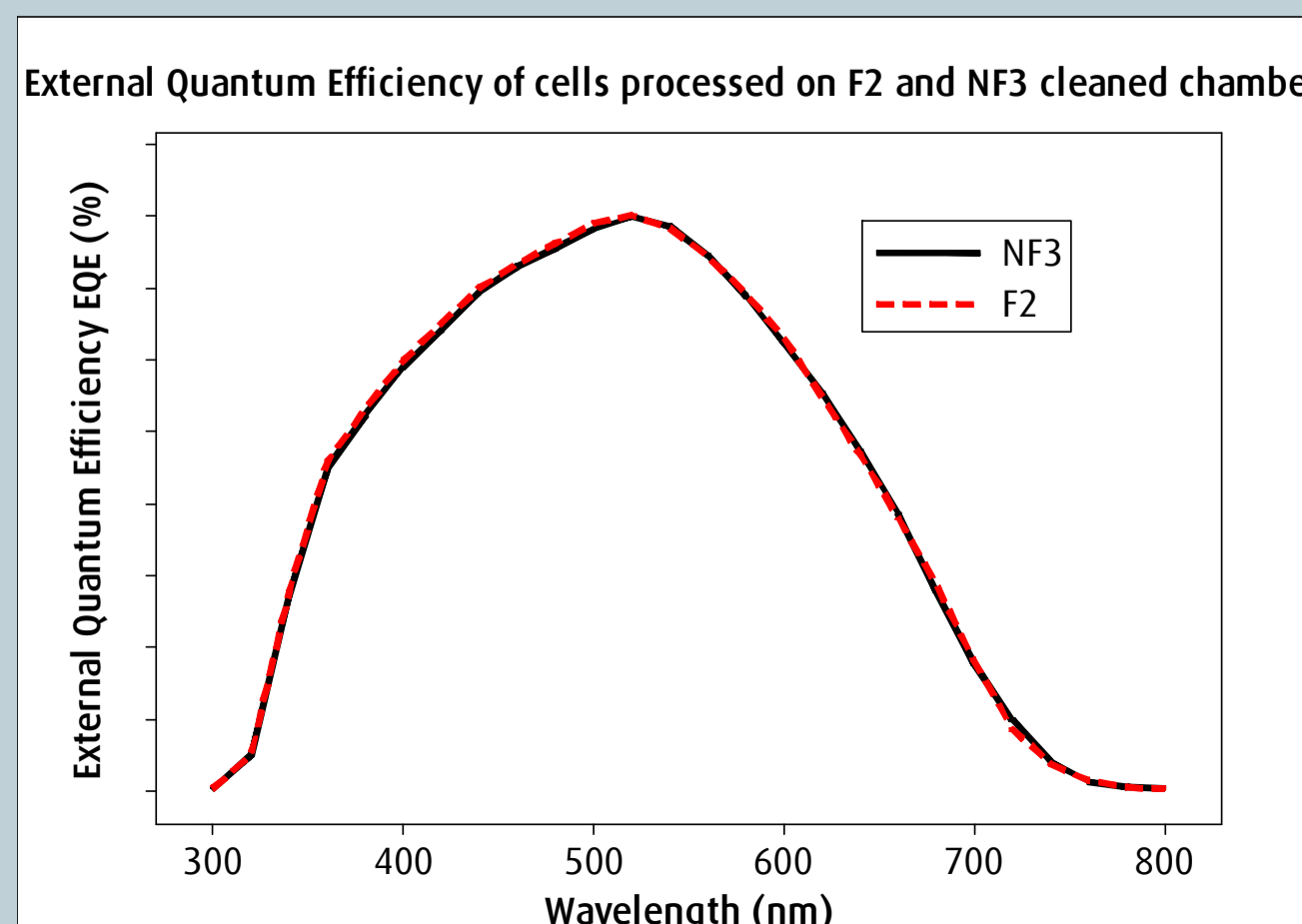
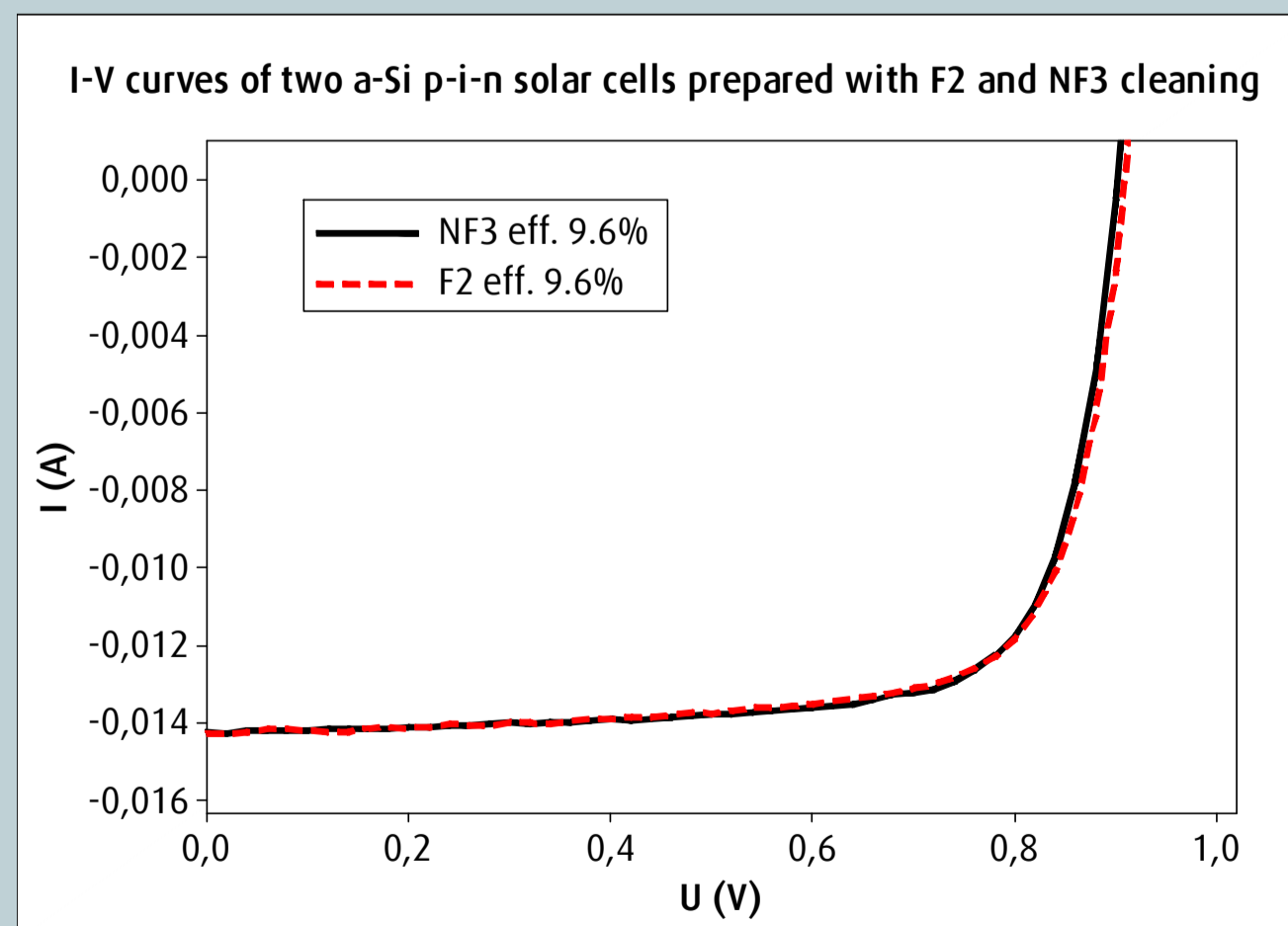


A lower temperature increase at the RPS outlet for F_2 vs NF_3 is beneficial for tool parts lifetime.



Device performance

- High performance a-Si:H p-i-n solar cell produced with F_2 -cleaned chamber.
- No impact on device performance observed when using F_2 instead of NF_3 .
- No impact on chamber parts observed after several month of fluorine usage.
- No long term impact on tool performance observed.



Conclusions

- Successful replacement of greenhouse active NF_3 with F_2 (GWP=0) on a commercial platform for thin film silicon solar cell manufacturing.
- Equivalent clean rate performance has been obtained with F_2 and NF_3 for same atomic fluorine flow.
- Significant RPS power consumption reduction for identical atomic fluorine flow, when molecular fluorine is used.
- Much wider process window for F_2 cleaning process has been demonstrated, allowing further optimization to significantly reduce cleaning time and costs of clean.
- The fluorine cleaning process had no adverse impact on the solar cells and modules produced in the last 5 months.