

**HYDROMETALLURGICAL RECYCLING OF THE
SEMICONDUCTOR MATERIAL FROM CDTE
PHOTOVOLTAIC MATERIALS - IEEEPVSC
2009 WORKSHOP PRESENTATION**

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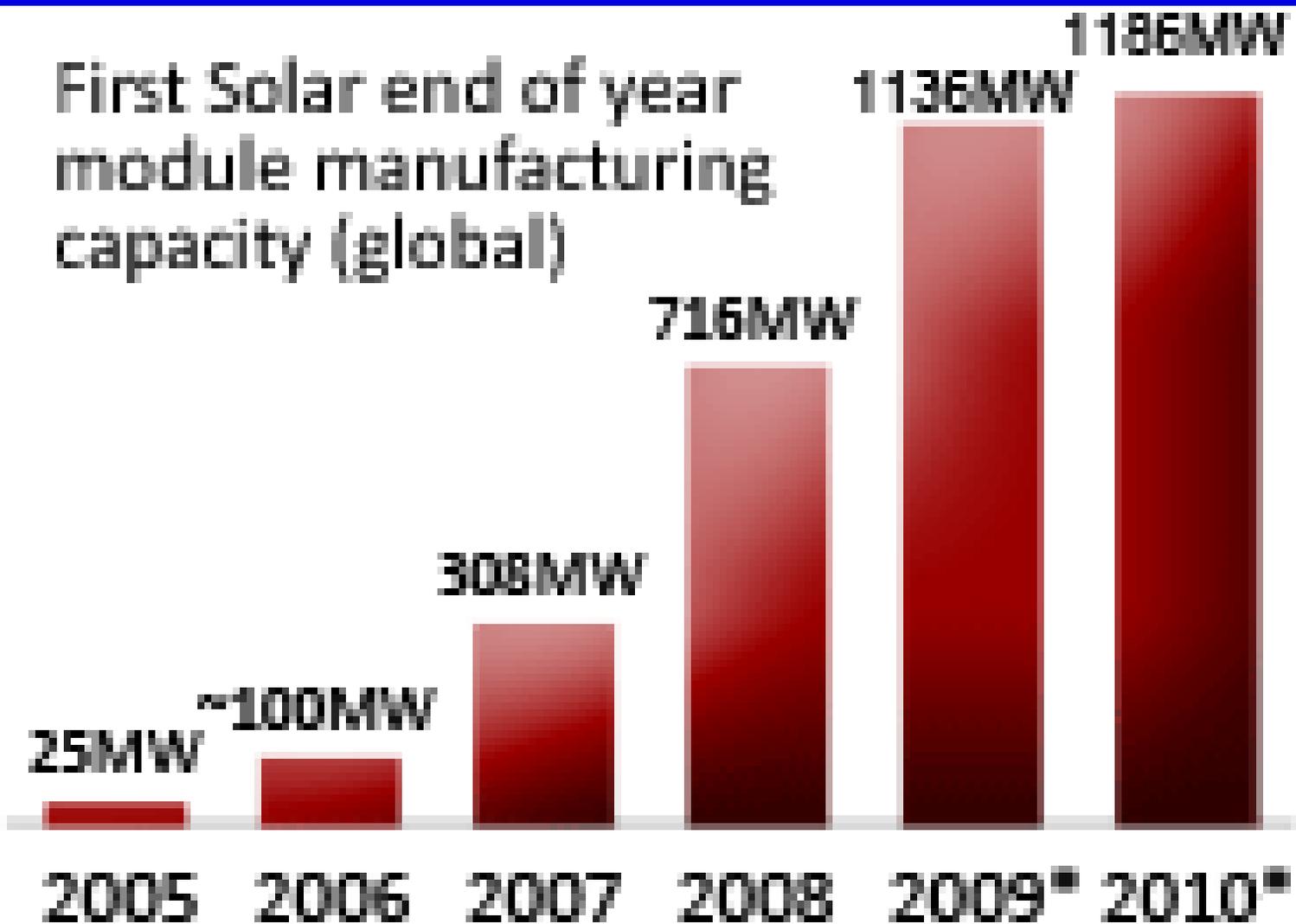


Topics

- **Thin film semiconductor materials & the necessity (= opportunity) for their recycle;**
- **Project broad objectives;**
- **Suitable enabling technology ;**
- **Talk focus: V1.0 PV module scrap recycle project success – i.e. past work;**
- **Look forward – recycle sustainability.**



First Solar end of year module manufacturing capacity (global)



2009

*estimated



The need (=opportunity) for recycle

- Projected 2025;
 - Solar = clean source;
 - Cd/Te from each – the product
- glass and life-cycle



2025;
clean source;
from each –
the product

Project broad objectives

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- **Establish, test, evaluate and implement a PV panel recycling process on commercial scale (V1.0);**
- **Subsequently develop compatible technologies applicable for the potential recovery of recycled metals;**
- **Expand on V1.0 towards:**
 - **Increased throughput / operability @ lower cap/op/ex (V2.0);**
 - **Flexibility / ability to process next generation PV panels as recycle feeds;**
 - **Capture low tonnage-high grade recycle feed (i.e. process intermediates) into the overall process.**



Enabling technology

- **Hydrometallurgy – suitable for the recycle since the recycle “feed” is:**
 - **Low grade;**
 - **Relatively complex.**
 - **Low throughput;**
- **Hydromet meets stringent metallurgical process criteria:**
 - **Robust – proven (“TTT”) as integrated flowsheet;**
 - **Technically feasible unitops;**
 - **Commercially applicable in comparatively short time frame.**

Hydrometallurgy for recycling

- **Hydrometallurgy: extraction of metals using aqueous solutions;**
- **Applicable outside of conventional extractive metallurgy whilst a recycling process renders significant differences:**
 - **Conventional recoveries of 95% vs. 99.5%+ required by First Solar PV recycle Cd roadmap program;**
 - **The real target is not recovery whereas final “cullet grade”**
 - **Example: Cd level ~ 1 ppm or less from ~ 100 ppm Cd “recycle feed” which is >>>greater than a conventional “discharge tail”!!!.**



Key technical challenges

- Advanced extraction of individual materials – i.e. “process chemistry”
- Handling of process materials – coarse
- Equipment selection – i.e. the first V1.0 plant (2006) ~ 8 months
- Designing the “plant” in the context
- Process integration – scale-up - implementation

Fast-track from process selection and testing through design and implementation – i.e. the first V1.0 plant (2006) ~ 8 months

This talk focus: V1.0 PV module scrap recycle project from start to finish

- **Testwork and flowsheet development;**
- **Engineering design and scale-up criteria generation;**
- **Start-up and commissioning;**
- **Project management;**
- **Commercialization status to date.**



Start: conceptual process (V1.0) outline

- **Two basic feed types: Laminated (EVA layer) modules/ Unlaminated submodules;**
- **Shredding + crushing to $\sim 87\%$ - $1/4''$, $\sim 99\%$ of the EVA reporting to the $+1/4''$ fraction (LamMod);**
- **The size reduced feed is leached, screened, washed-filtered and stored as “clean cullet”;**
- **The PLS subjected to Cd and Te recovery.**

Process testwork and flowsheet development

- **Recycle feeds characterization;**
- **Leaching optimization;**
- **Solution purification;**
- **Cadmium and Tellurium recovery;**
- **Engineering data generation (“pro-phys”).**

Recycle feeds characterization

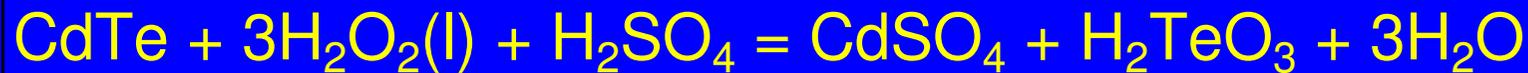
- ~100% CdTe – all starts here, i.e. ~50/50 CdTe;
- Crushed -1/4" nominal PV Modules ~ 200 ppm

➤ *Back to the panels –*
➤ *high tonnage/low*
➤ *grade/high priority*

CdTe Leaching – process chemistry -



T	deltaH	deltaS	deltaG	K	Log(K)
C	kcal	cal/K	kcal		
0	-267	-51	-253	2E+202	202
100	-273	-71	-247	4E+144	145



T	deltaH	deltaS	deltaG	K	Log(K)
C	kcal	cal/K	kcal		
0	-220	-16	-216	9E+172	173
100	-222	-19	-215	7E+125	126

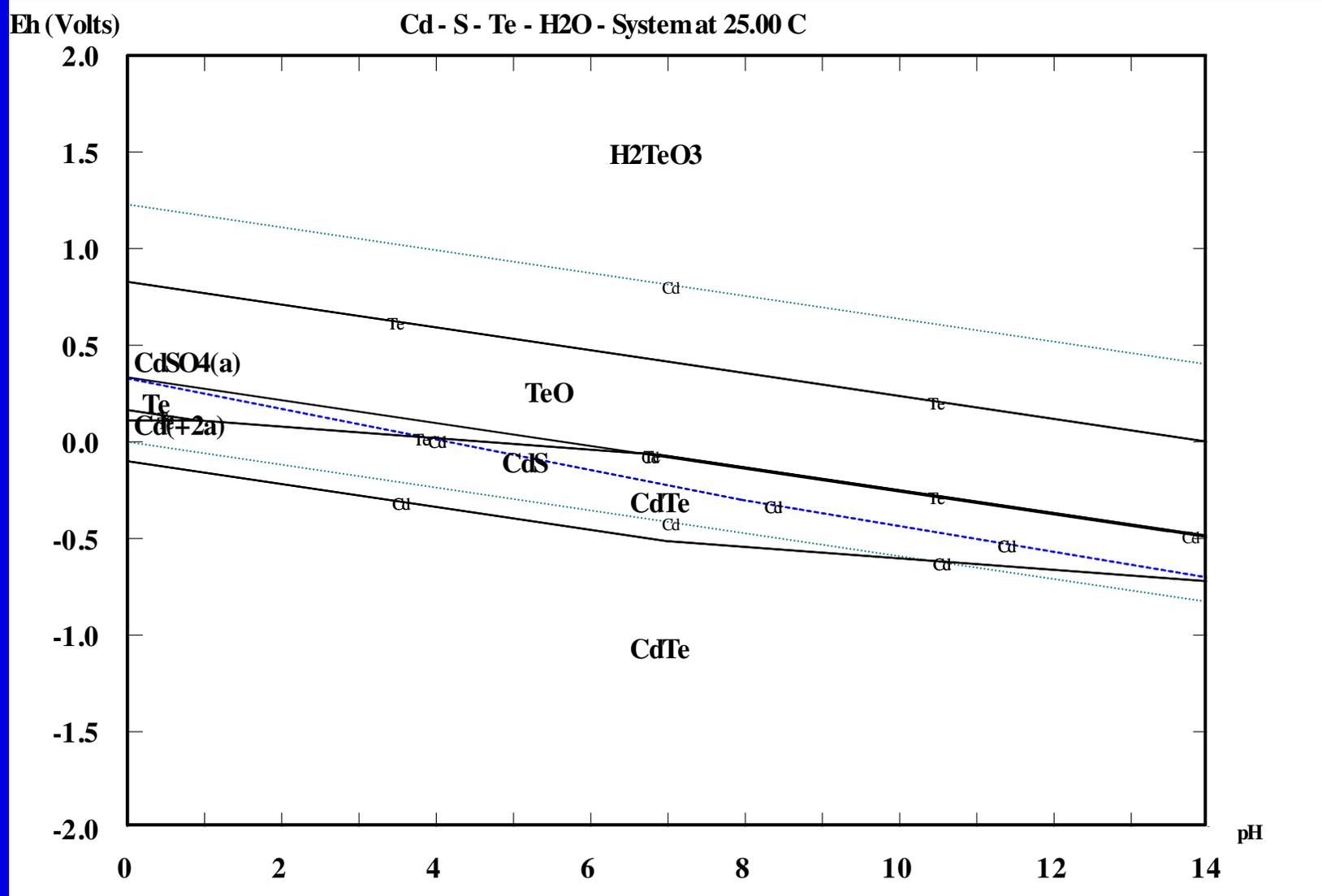


Testwork results summary – 1/4" PV panel leaching

➤ Te and Cd extraction > 99 ppm / < 2 ppm ICP by Mass_Spec with residue (cullet);

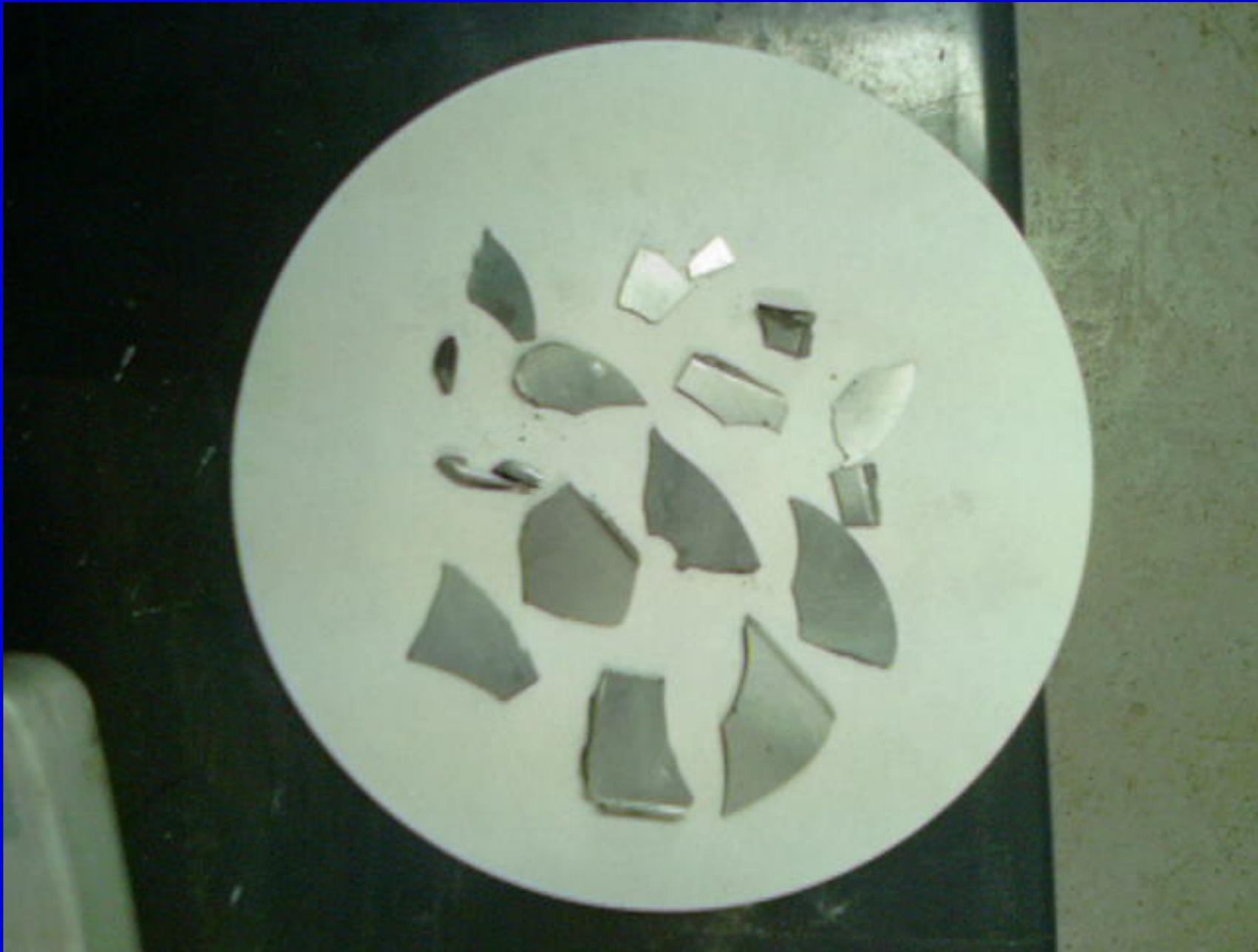
➤ Actual Cd extraction ahead@...commercial ops even better (<1 ppm) ... "scale-up effect" compare to ~0.5 ppm Cd in the Earth's crust...

➤ High efficiency, low cost, low waste, corrosion, separate recycling, product grade and enviro / discharge too many to list.





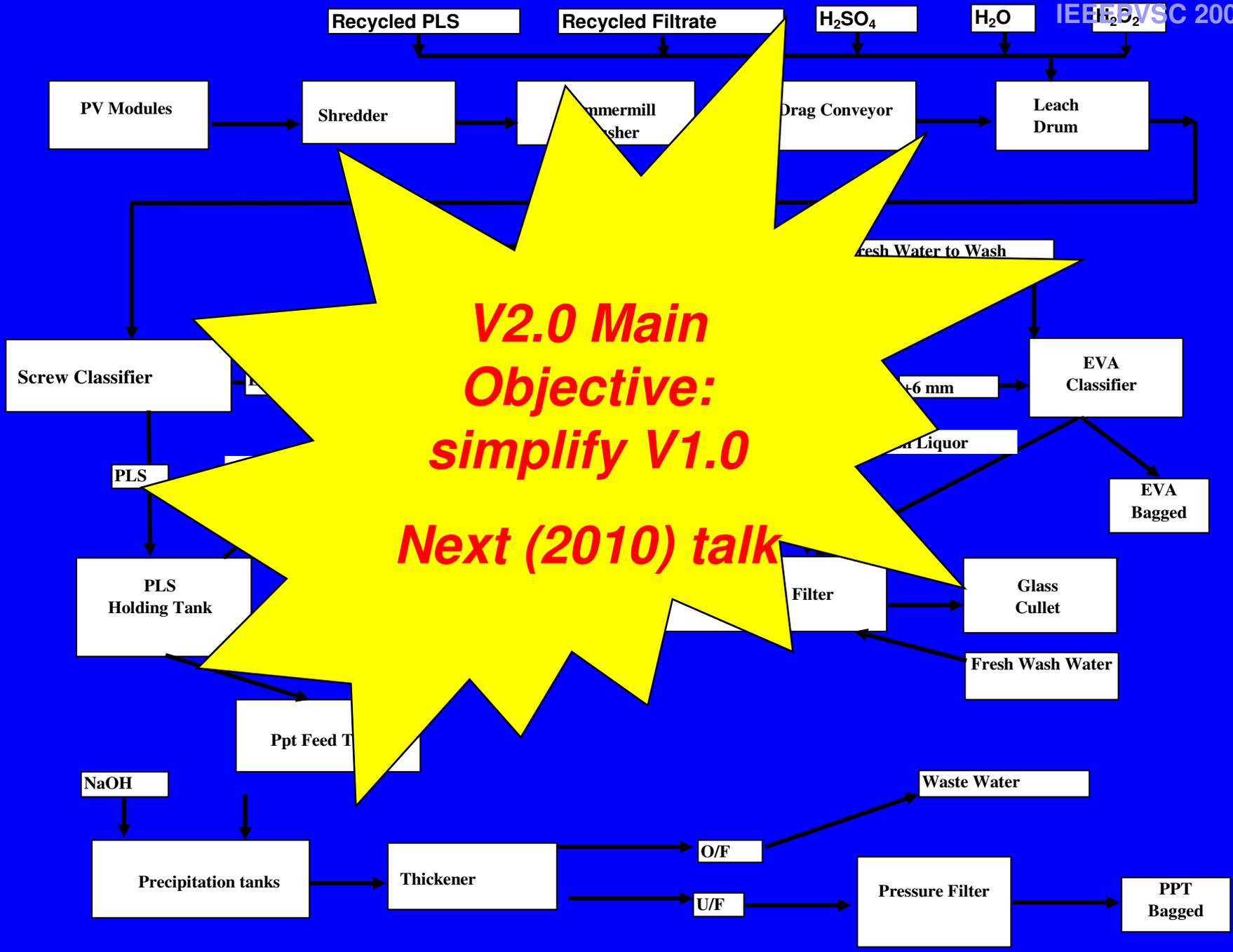
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PV leaching engineering for handling

- Commercial modified
- Discharge convey
- Screen $t/m^2/h$ u feed/mix
- Corros
- Bringing





V2.0 Main Objective: simplify V1.0
Next (2010) talk

Project management Commercialization – 4 phases

- V 1.0 technology precipitation *Client (USA) driven – ECPM*
- Design and start *Local MGM/WF*
- Contract *US/GER Contract&Exeng*
Can – Met/ProEng

Malaysia x 2 (2008) – total ~ 20 t/day.

FIRST SOLAR PPT-1 2006

DESIGNED AND BUILT BY

SGS MINERALS SERVICES
LAKEFIELD ONTARIO CANADA

COMMISSIONED AT PERRYSBURG OHIO USA

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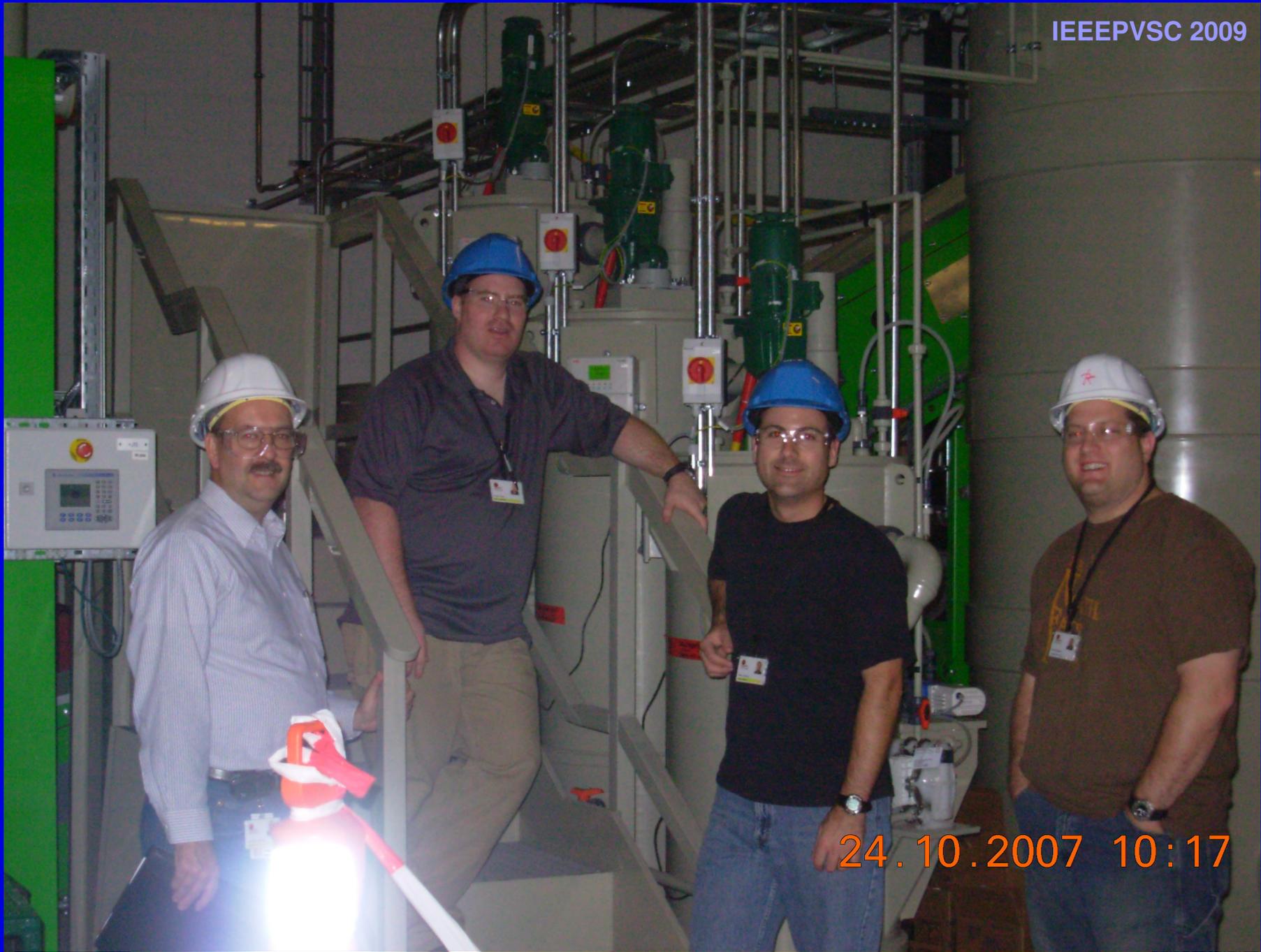
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- ~~25% - 50%~~ Solids - 40%
- mixing - Blending
- VFD? - Yes
- RA Impeller
- Ceramic Coating or better
- 3" or 4" shaft size 2.1m long
- gentle mixing - 1.1 rpm



Suggested reading

- **Mezei. A, et. al.: Hydrometallurgical recycling of the semiconductor material from photovoltaic materials, SME Hydrometallurgy Conference, 2008, Phoenix, AZ;**
- **Spiller, E., Liberate Separate - It works for Mineral Processing and Recycling - The Richards Lecture, SME Annual Meeting in Denver, Colorado February 25, 2009.**

