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Solar photovoltaic technology (and socio-economics)

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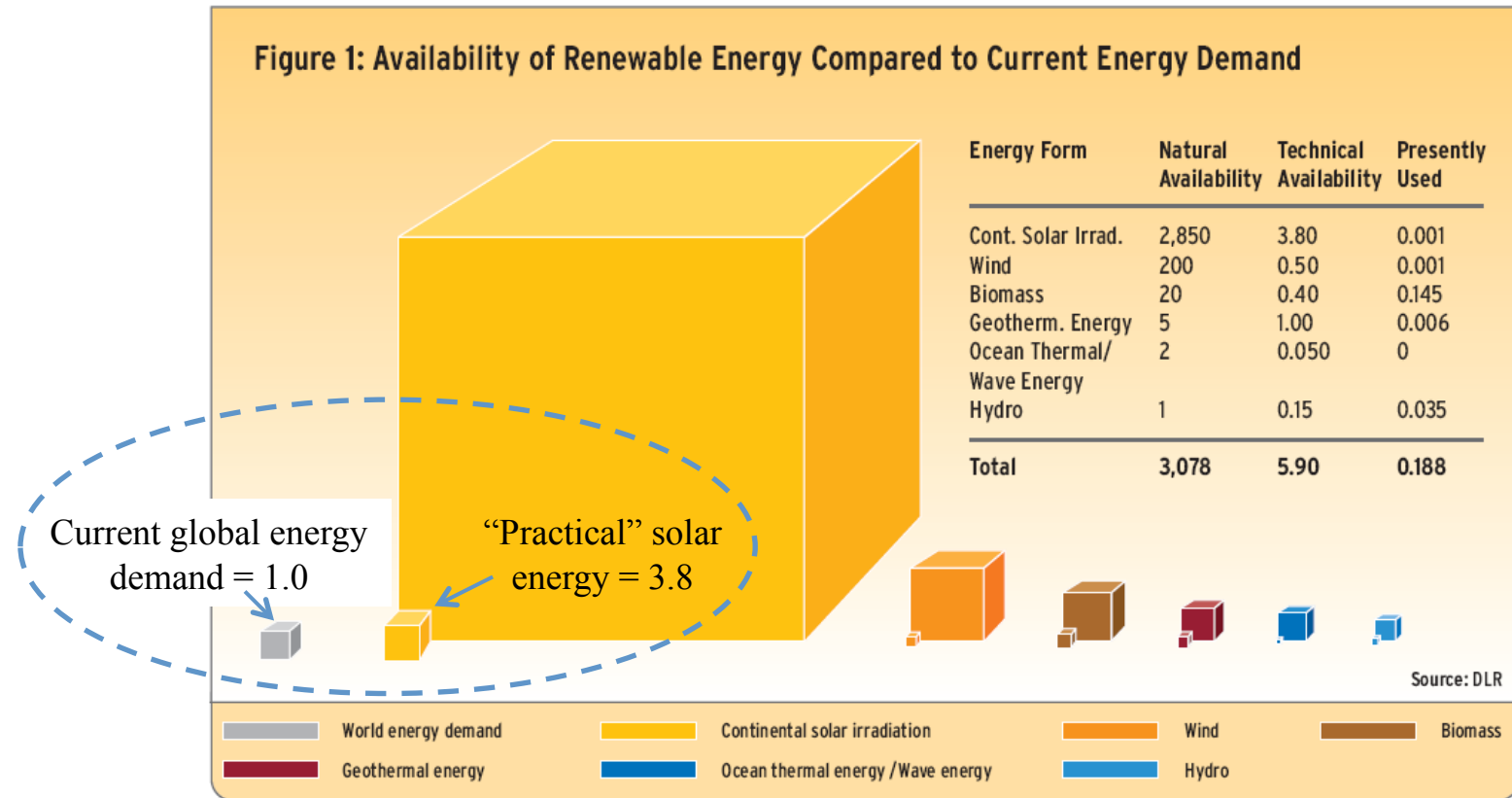
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Agenda

- What is the goal?
- What is the state of the PV industry today?
- Solar photovoltaic technology today
- Socio-economics of large-scale energy infrastructure projects

What is the goal?

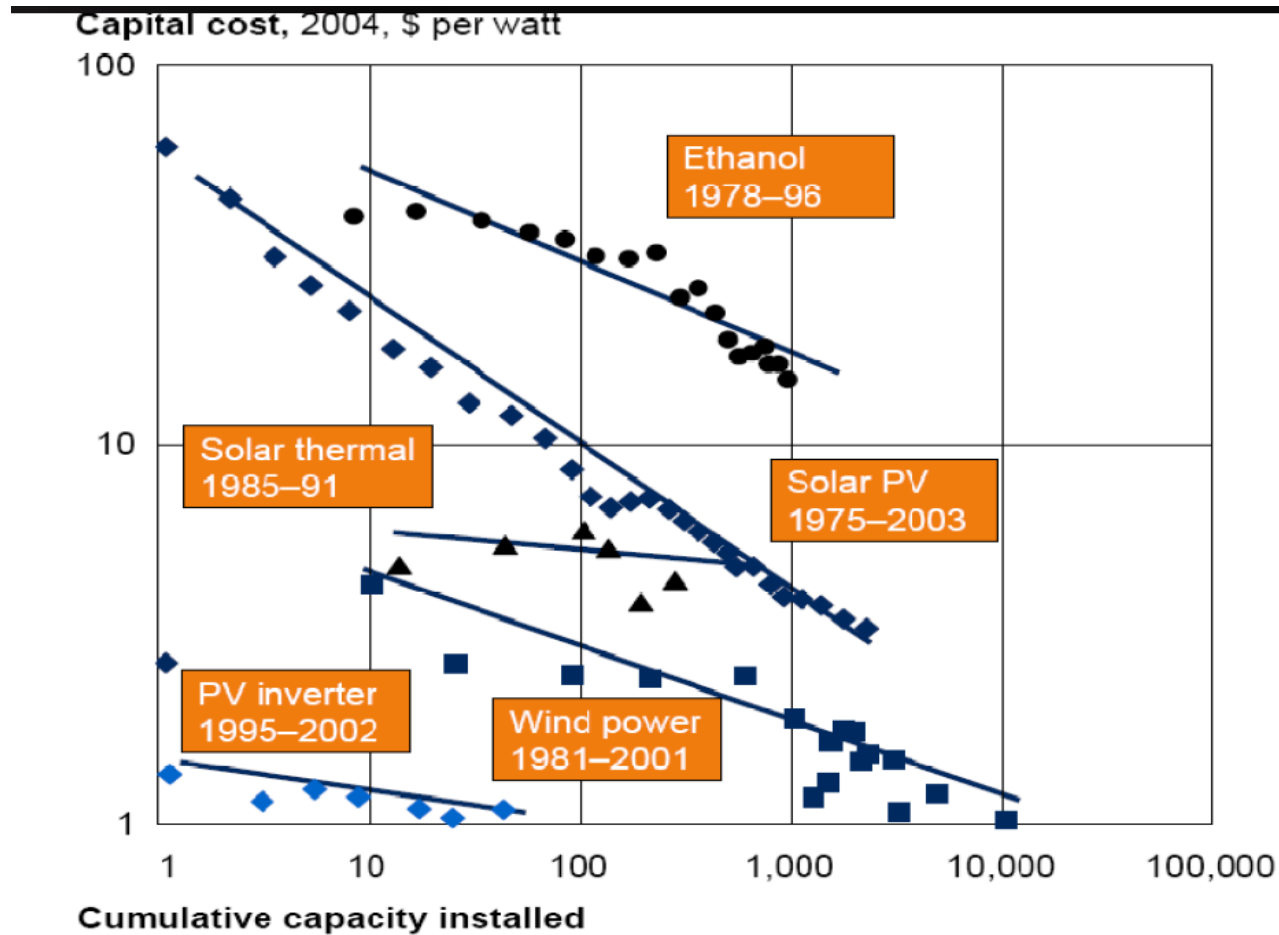
Solar is the most abundant of all renewable energy sources



Rear cubes: The natural availability of renewable energy is extraordinarily large. Front cubes: The technically available energy in the form of electricity, heat and chemical energy carriers exceeds the present-day energy demand (grey cube, left) by a factor of six.

Solar energy can supply almost 4 times total current global energy demand (including only solar energy that is practical to harness)

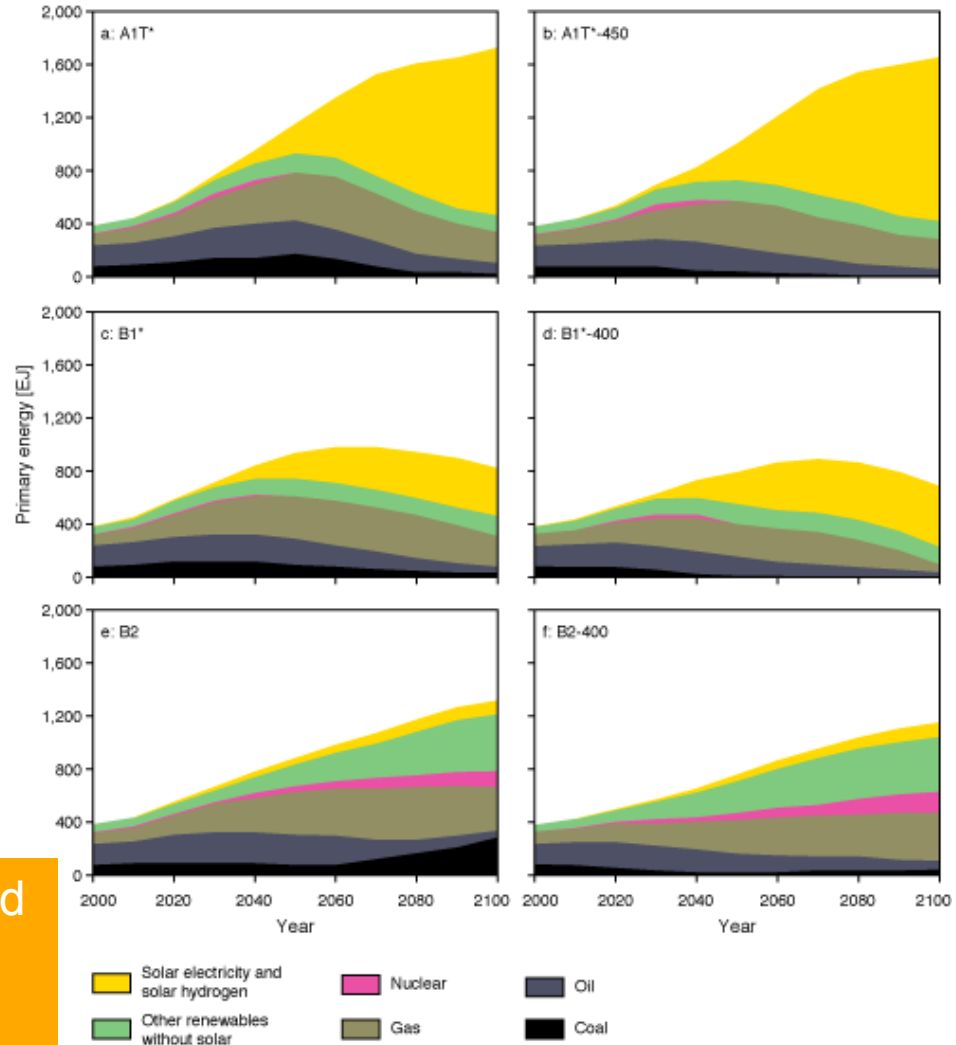
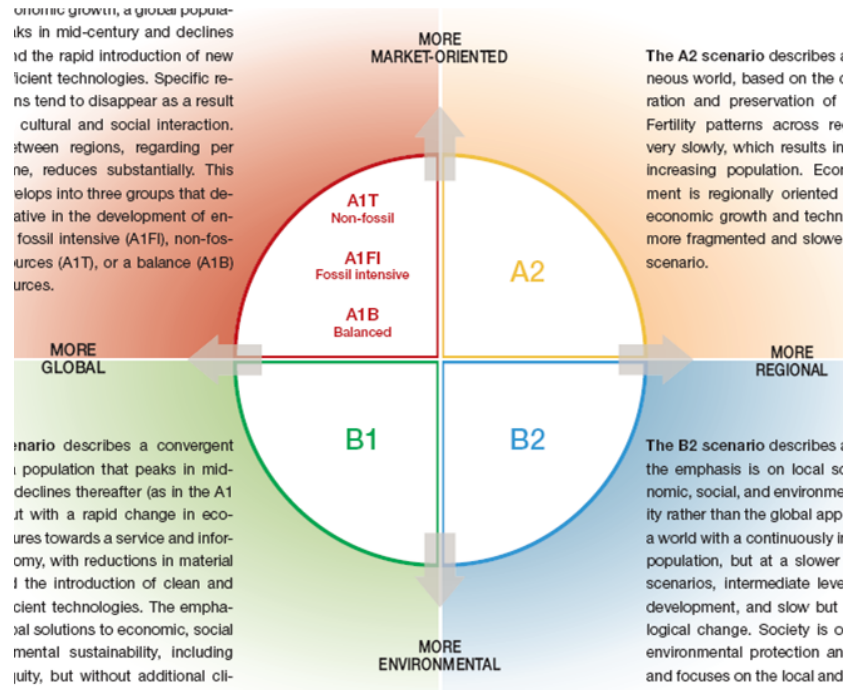
Predictive cost economics



It's not about what it costs today – it's about what it will cost in the future

Solar could account for over 50% of global energy supply

e.g. Intergovernmental Panel on Climate Change, a1T scenario



Once grid parity is achieved, solar could become the majority global energy source by the end of the century

What is the state of the PV industry today?

Modest practical achievements of solar photovoltaics

- It works - The entire system works today, and has for the past 25 years
- It is simple – sun shines and is converted to electricity in a single step
- It is available today – on a global scale
- It can be installed anywhere – site constraints are minimal
- It uses all the available solar radiation – direct and diffuse
- The entire manufacturing supply chain and installation expertise is already proven
- Once built, operating costs are minimal – thus total costs are predictable
- Installation techniques are well known today – no surprises
- It can be installed quickly – think 1MWp per week on a site + minimised project finance construction execution risks
- It is modular - standard components can be bought from multiple competing suppliers
- It is eminently bankable, even in the midst of a credit crisis – reliable for 25 years+
- It is economical in bank-friendly chunks – from \$5m to \$500m+
- Transients do not seem to worry other countries with more PV

Practical hurdles do exist to hinder PV deployment

- Efficiency is somewhat limited – but is improving
- Energy cannot be stored (yet) – but it produces electricity that is well matched with demand
- It is still too expensive, but ...
 - Prices are already falling fast – down 30% in the past six months
 - It is made with semiconductor technology – Silicon is the world’s best understood engineering material, positive elasticity of demand with falling prices is deeply embedded in this industry
 - Up to 60% of system cost was Silicon
 - Prices rose to 10 times production cost due to supply constraints
 - The supply constraints have ended, polysilicon prices have fallen by 60% in six months
 - The entire supply chain is now in oversupply: “11GW supply versus 4GW demand”
 - Silicon is sand, and sand is inherently cheap

PV technology is proven, simple and will be even cheaper in the future

Engineering quality of PV projects

- Certification standards are weak, driven by manufacturers not customers
 - IEC 61215 (crystalline Silicon) does a poor job in predicting real-life energy yield over the longer term
- During the past four years:
 - Many suppliers of badly-engineered products have grown rich
 - New entrants with untested technology were accepted too easily
- Recent trends
 - Long-term growth potential is attracting top-tier global firms
 - Hyundai, Toshiba, Siemens, Bosch etc.
 - More professionalism in systems engineering
 - More discerning customers and bankers
 - Bundled services and cost-optimised systems
 - Consolidation pressures continue to increase

In order to achieve its potential, the PV sector will move into a new phase with realistic full project financing and professionally engineered systems

When is quality built in to a PV project?

- Quality emerges from a series of decisions
 - Quality is a process that demands professional answers at the right time
 - We are building long-lived energy infrastructure assets
 - Twenty five years or more of energy production
 - High-quality designs, efficient manufacturing lines, effective quality controls
 - Suppliers with the financial strength to stand behind long-term warranties
 - Partners with the capability to handle the unexpected
 - Professional risk management sufficient to satisfy top-tier bankers
 - Predictable revenues and costs
- Without quality there is disappointment
 - Not just to equity holders, but to community partners

**We are pioneers still early in the rollout of a new technology.
There are no detailed risk maps, but solid commercial and engineering principles still guide the
quality of project execution**

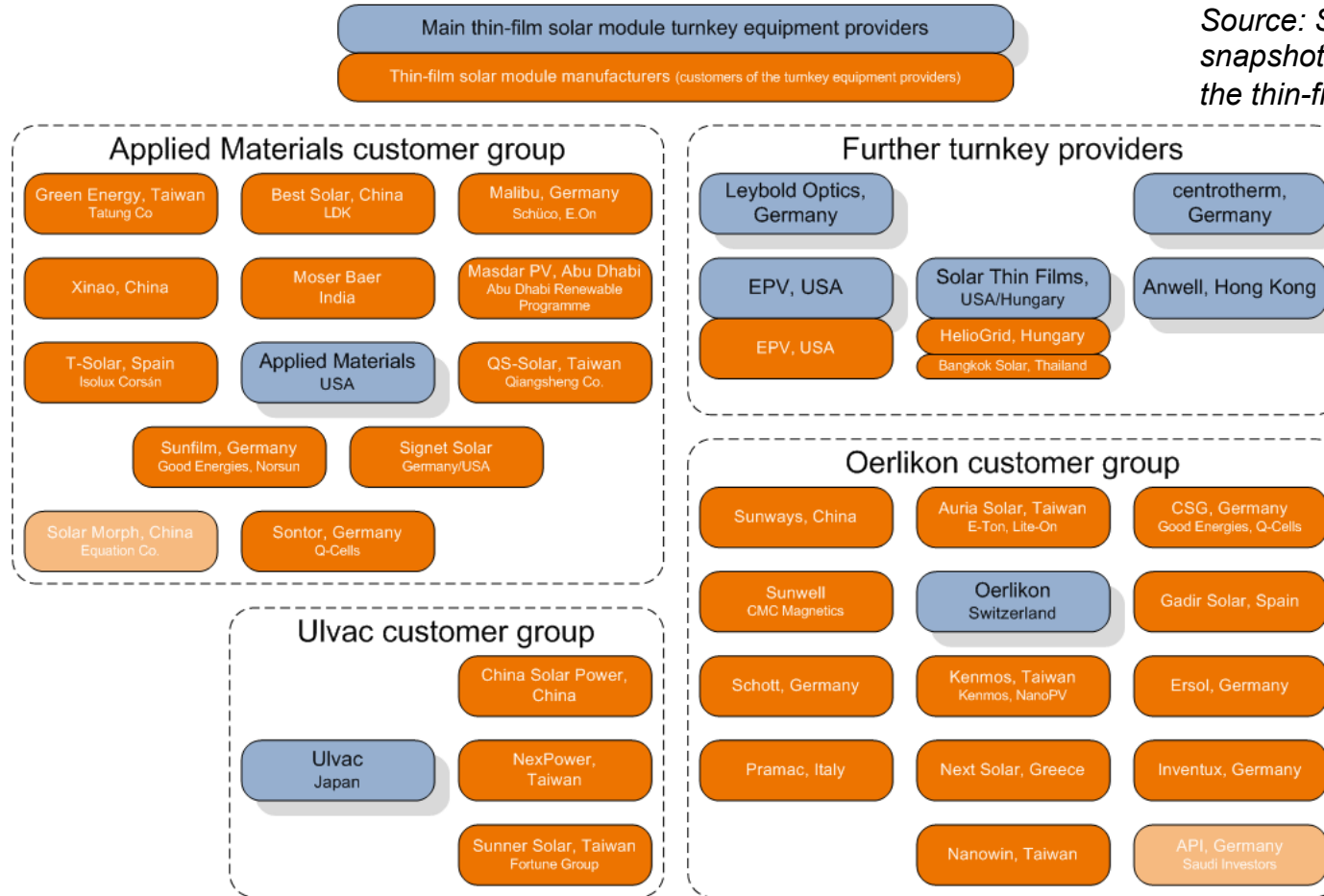
Solar photovoltaic technology today

PV modules – major classes of technology

Technological class of material	Technology “sub-flavours”	Typical efficiency	Manufacturing maturity	Commercial record	Technology roadmap promise
Crystalline silicon (multi- and mono-)	Single-junction, multi- and mono-crystalline	13-15%	Proven technology, scales well, accepted by customers, requires lots of silicon	Dominant technology today – over 90% of market	Mature technology Production learning curve still possible R&D to reduce wafer depth & inc. cell area
	Back-contact cells	18-22%			
	Heterojunction	13-15%	Proven technology, good temp. gradient		
	Amorphous silicon on thin crystalline wafers				
Thin-film solar cells	Amorphous silicon a-Si	6.5%	a-Si is fully proven Multiple other competing thin-film technologies, not yet proven in scale (though CdTe is closest) These technologies either use no silicon or <1% as much as crystalline silicon	Under 10% of market today – but immense R&D effort re-invigorated by demand boom and limited silicon supplies	Early technology development proved problematic Huge R&D promise but timing of market share increase hard to predict
	Micromorph - $\mu\text{c}/\text{a-Si}$ tandem junction	10%			
	CIS/CIGS chalcopyrite <small>Copper, Indium, Gallium and Selenium</small>	10%			
	Cadmium Telluride (CdTe)	10%			
Next-generation solutions	Dye-sensitised cells	Still at research stage Basic physics not yet well understood At least 5 years to full-scale production		Scarcely visible on market but modest R&D continues	Parallel R&D underway in display/printing technology but remains early-stage
	Polymer based cells				

Crystalline Silicon is the dominant and field-proven technology

Thin-film technology – tracking progress in new entrant commercialisation



Source: SunRay, snapshot of one part of the thin-film market

For new entrants, the heritage of the equipment supplier is an important guide

SunRay's view on technology and suppliers

- SunRay is agnostic on technology
 - We will buy whatever is most economical
- We monitor technology closely
(but we are driven by bankability of benchmarked proven technology)
 - Global database on crystalline silicon module producers
 - We also examine solar tracking technology and concentrated PV
 - Our focus is on bankability of technology suppliers
 - We also examine system-level economics
- We meet and deal with key suppliers
 - As a high volume credible and creditworthy purchaser, quality suppliers are now approaching us directly with their best offers
- We monitor industry news flow very carefully
 - Presentations, average price data and even contracts by quoted companies
 - Local project and competitor news flow in each country

Socio-economics of large-scale energy infrastructure projects

SunRay – How we work in each country

- Hire top-quality country managers and empower them
 - Sensitivity to local culture and relationships
 - Choose the right regions within each country
 - E.g. Supportive mayors seeking vote-winning projects from green energy
- Project decisions are always made locally
 - We focus on the local community, which influences project approvals
 - We are willing to give something back to the community
 - Education or training, modest public contributions e.g. 2% of revenues to local authority
 - Manage land acquisitions to minimise distortions to prices
- We see benefits from building and maintaining local expertise
 - A reputation for quality project execution gets rewarded
 - We learn of and can respond quickly to opportunities before others

Successful relationships need the right attitude

- Technical and financing solutions are necessary
 - But they are not the entire story
- The “community experience” is also a vital factor
 - How can we integrate a PV project into daily lives?
 - Begin by clarifying local priorities
 - SunRay wants to create a positive community experience
- How does this work?
 - Mutual information sharing, so that we can define and shape the project (in the broadest sense) together as it emerges and grows
 - Recognise that it will take ongoing effort to maintain the focused energy needed to drive an ambitiously broad project
- PV projects bring the opportunity for real partners to leverage their mutual skills and to change their local world

Success factors for large infrastructure projects

- Failure is not an option: each project must succeed on its own local merits
- Projects become successful not because of economics alone, but because they are desired by and meet the needs of the local community
- Large projects require constant involvement and technical expertise
 - Because not everything will go according to plan
 - Because environmental impact concerns need to be addressed at the planning stage
- Good projects must be popular and gain support from the wider community
 - Flexibility is needed from both sides during the planning and construction stages

Summary

- Solar energy has the potential to make a major contribution towards a world of cleaner energy
- We are dealing with high-technology which is field-proven over decades
- SunRay has chosen a strategy based on high-quality engineering and founded on local community support
- SunRay and Montalto di Castro are pioneers together, aiming to change our local world
- We believe that the Montalto di Castro projects demonstrate the power of SunRay in the community:
 - Italy's largest solar PV project, delivered on-time and on-budget
 - Top-tier global engineering quality, from SunPower