



SolarPACES2018

Solar Power & Chemical Energy Systems

Oct 2-5, 2018 | Casablanca, Morocco

IK4  TEKNIKER
Research Alliance



CENER
ADItech

SMARTCSP: THE INDUSTRY 4.0 APPROACH
FOR AN EFFECTIVE **CSP** COST REDUCTION

Cristóbal Villasante | Casablanca, 3th October 2018

SMARTCSP

THE INDUSTRY 4.0 APPROACH
FOR AN EFFECTIVE **CSP** COST
REDUCTION

Motivation

Introduction

Approach

Results and discussion

Conclusions and future work

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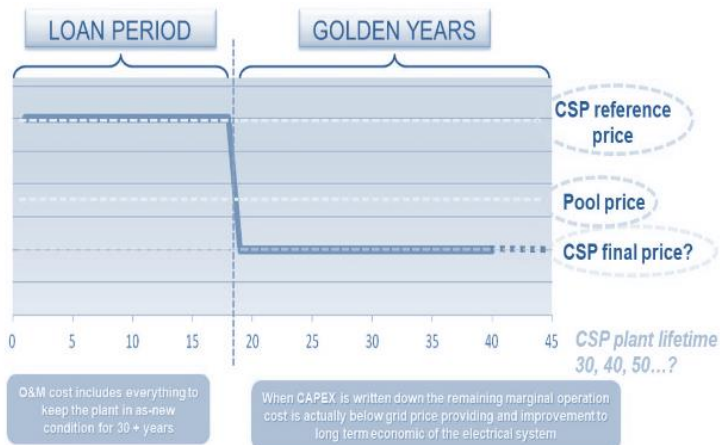
Conclusions and future work

MOTIVATION

CSP still needs **significant cost reduction** to get a large share of the energy market

CSP plants and components incorporate a low degree of **intelligence** and **autonomy**

SMARTCSP: THE INDUSTRY 4.0 APPROACH FOR AN EFFECTIVE CSP COST REDUCTION



COST REDUCTION OPPORTUNITIES

CAPEX: CSP component production do not take full advantage of mass production capabilities
 Cost and quality control can be improved
 Commissioning processes could be further automated

OPEX: In the long term, as the solar resource is free, production cost is reduced to O&M
 O&M costs can be greatly reduced

Operational performance can be enhanced
 Potential of the plant is not fully exploited

MOTIVATION

GLOBAL OBJECTIVE

Reduce levelized cost of electricity (LCoE) by substantially increasing distributed and automated monitoring, control and operation

SPECIFIC OBJECTIVES:

Improve manufacturing of CSP components

Development of self-aware components

Reduction of deployment complexity (Plug-and-Play)

Enhance plant performance

SMARTCSP

SMARTCSP allows us to benefit from the experience in the application of ICT (Information, Communication and Sensing Technologies) or Lean Manufacturing in mature industrial fields such as automotive, communication or manufacturing.

SMARTCSP

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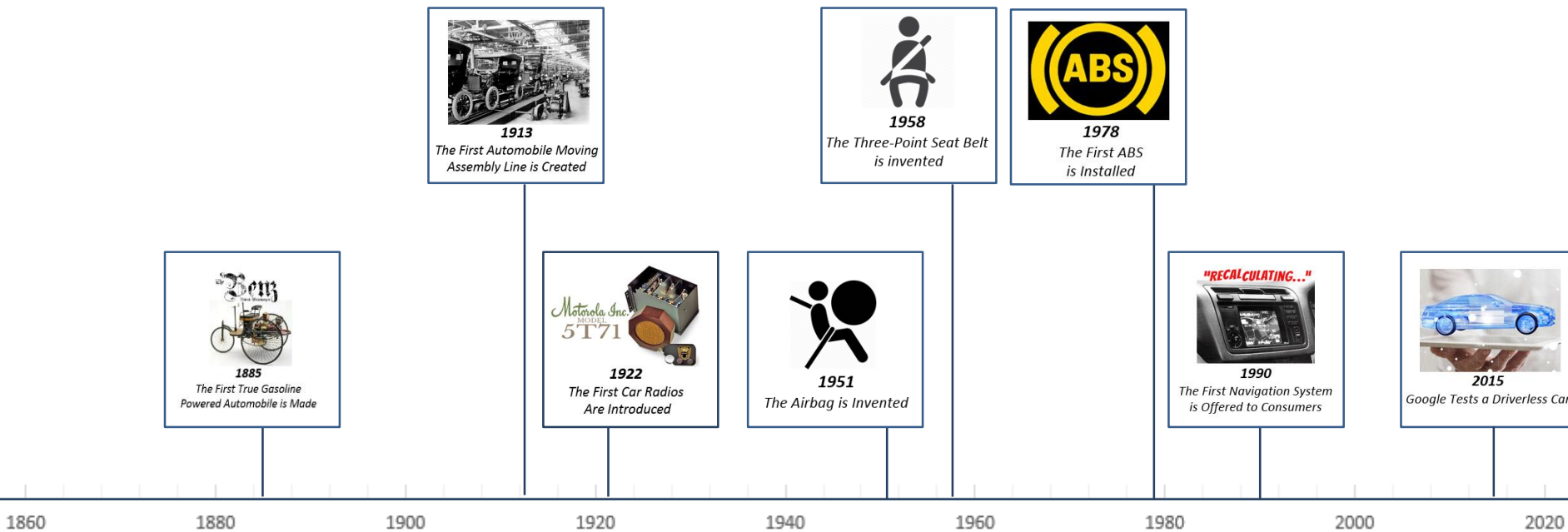
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INTRODUCTION | HISTORICAL EVOLUTION

SMARTCSP: THE INDUSTRY 4.0 APPROACH FOR AN EFFECTIVE CSP COST REDUCTION



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1876
Graham Bell creates the telephone



1910
First Telephone in Car?



1922
The First Car Radios Are Introduced




1973
The First Mobile Car Phone



2000
Over 100 Million Mobile Phones



1999
Phones with Internet Connection



2012
6 Billion Mobile Phones
(87% of world population)

1860 1880 1900 1920 1940 1960 1980 2000 2020

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1885
The First True Gasoline Powered Automobile is Made

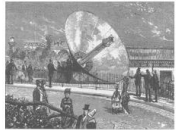


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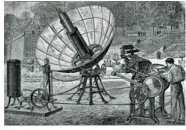


2015
Google Tests a Driverless Car

1860 1880 1900 1920 1940 1960 1980 2000 2020



1878
Mouchot's engine at the Universal Exhibition in Paris



1882
Abel Pifre solar press at the Jardin des Tuileries in Paris



1901
Solar Steam Engine (water pumping near LA)



1913
CSP Experimental Plant Built by Frank Shuman (Cairo)

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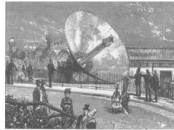


2007-2008
PS10, Andasol (Spain) and Nevada Solar One (US) re-launch CSP

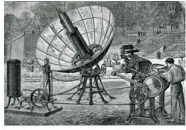


2018
Noor II & Noor III Commissioned
World CSP Capacity reaches 5GW

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1984-1990
354 MW SEGS Solar Complex, California



1981
Solar One Completed
1995
Converted into Solar Two

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SMARTCSP: THE INDUSTRY 4.0 APPROACH FOR AN EFFECTIVE CSP COST REDUCTION

Has CSP evolved as much as others?
Do we build, commission and operate the plants in a different way than 80's?
Did we take advantage of ICT as other industries does?



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INTRODUCTION

BAD NEWS



- **CSP industry behaves isolated**
 - CSP is not incorporating innovations included in other industrial sectors
- **CSP has neither the size nor the investment capacity of other industries**

GOOD NEWS



- **This can and should be changed**
- **Potential market is huge**
- **Arriving late can have some advantages:**
 - We can take advantage of the developments already made by others
 - We don't need to develop them
 - Only a wise integration/use is needed

We don't need to do all the same path but we can jump many steps

E.g. fixed phone line networks are expensive and will never be installed in many countries but they will be directly incorporated into mobile communications.

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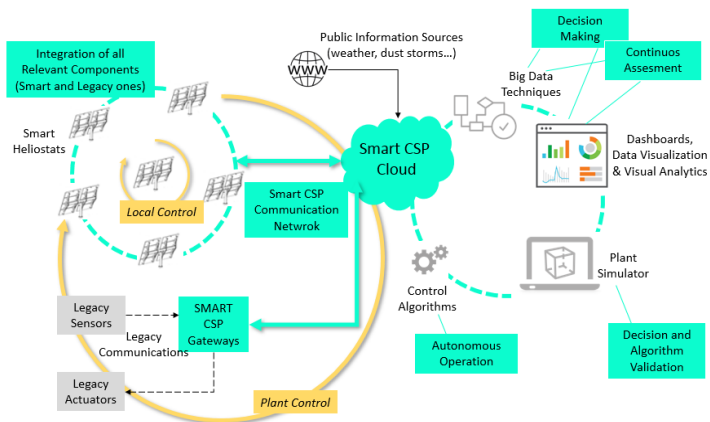
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APPROACH | DEVELOPMENT STATUS

Joint development at IK4-TEKNIKER and CENER has been focused on:

SMARTCSP PLANT concept

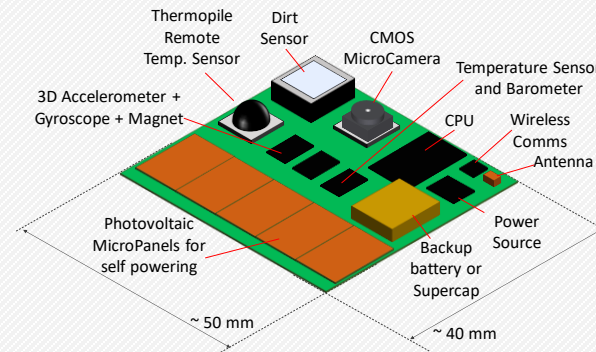


SMARTCSP: THE INDUSTRY 4.0 APPROACH FOR AN EFFECTIVE CSP COST REDUCTION

SMARTCSP

SMARTCSP COMPONENTS

Novel functionalities right from the production line

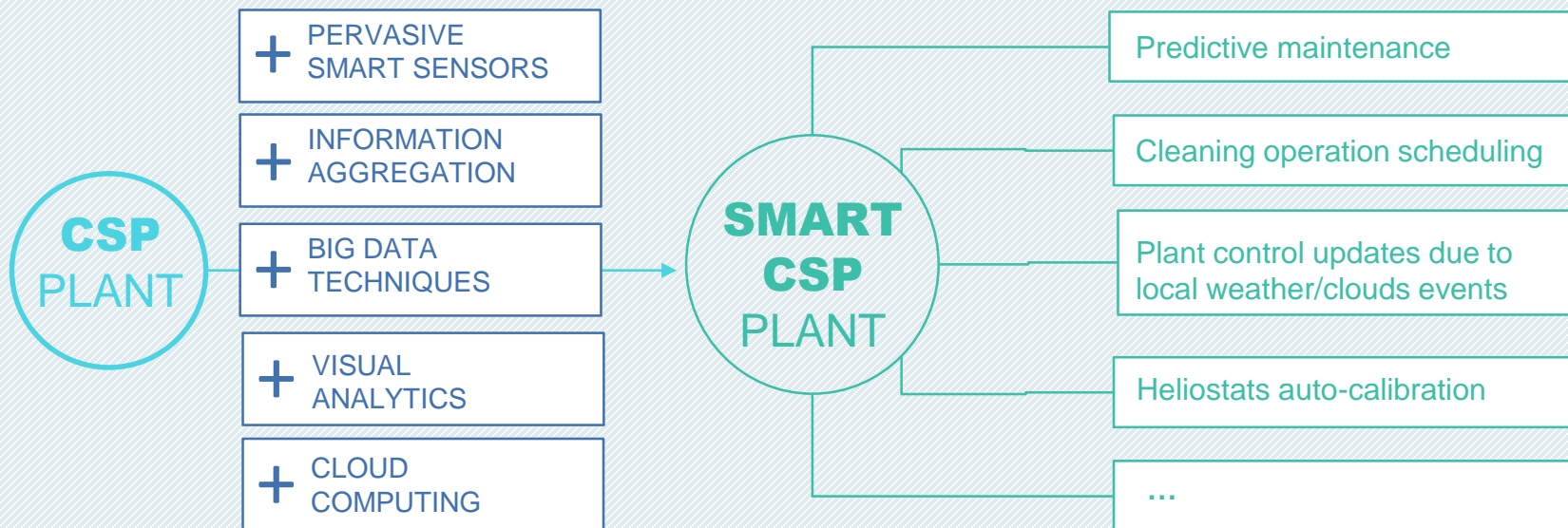


Agreement for the development of certain SMARTCOMPONENTS recently signed → Details for these developments will be skipped

We will **show the concept** and outline **other issues of possible collaboration**

APPROACH | SMARTCSP PLANT CONCEPT

The ambition behind the SMART-CSP-PLANT Paradigm is to replicate the digitalization that is already becoming a reality on markets as Manufacturing (Industry 4.0), Buildings (Smart Buildings) or Energy (Smart Grids).



SMARTCSP PLANT CONCEPT | KEY ACTIVITIES

Integrate all relevant actors:

- SMART COMPONENTS + legacy systems

Implement Cognition and Big-Data techniques:

- All-source data processing (new and legacy) into a fully integrated O&M.
- Autonomous (closed loop controls) or steered by a human operator (decision support systems).

Enhance simulation environments:

- Enabling off-line load and modification of historic files.
- Allowing to learn from real/hypothetic operating conditions.
- Validating Big Data approaches before real-life plant deployment.

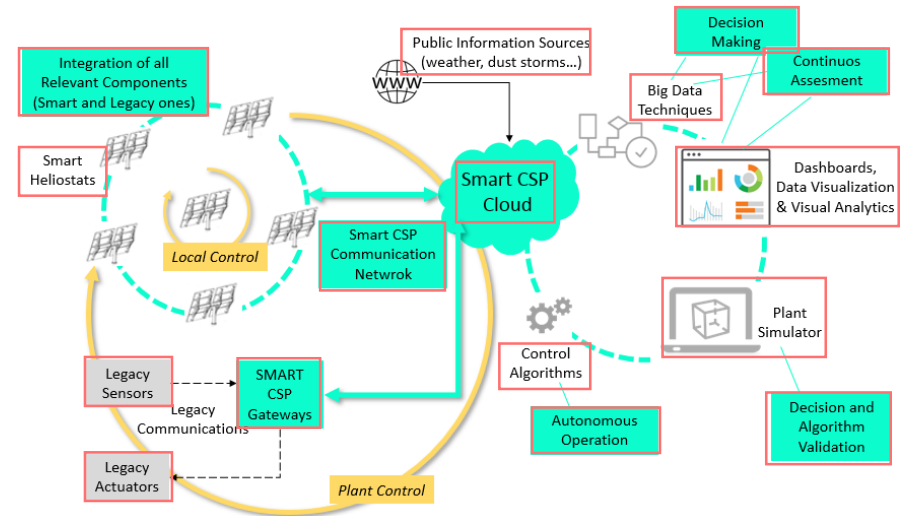
Provide interoperable interfaces for decision support systems:

- Semantic interoperability and user-friendliness.
- Unambiguous and fast interpretation of real-time information displayed.

Integrate the infrastructure system architecture:

- Communication network, gateways, servers, databases, cloud/fog systems should be included.
- Providing means for communication; data collection, formatting, analysis; algorithm execution; system synchronization; low latency command distribution, fast broadcasting, etc.

SMARTCSP: THE INDUSTRY 4.0 APPROACH FOR AN EFFECTIVE CSP COST REDUCTION



APPROACH | SMARTCSP COMPONENTS

SMARTCSP: THE INDUSTRY 4.0 APPROACH
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**AUTONOMOUS
INTELLIGENT
CONTROL**

**LEAN
MANUFACTURING
CONCEPTS**

**PLUG-AND-PLAY
APPROACH**

APPROACH | SMARTCSP COMPONENTS

SMARTCSP: THE INDUSTRY 4.0 APPROACH
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Components or systems will incorporate sensors, controllers, communication systems, or other devices that allow them to:

- Characterize its own status
- Identify and characterize the status of elements in its surroundings
- Identify environmental conditions
- Make autonomous decisions
- Operate in a collaborative way:
 - Connect and communicate with other elements
 - Generate data of interest for the operation of the plant
- ...



APPROACH | SMARTCSP COMPONENTS

SMARTCSP: THE INDUSTRY 4.0 APPROACH
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Components manufactured and assembled on automated assembly lines:

- Minimum cost, with higher quality standards
- Verification and tuning process included:
 - Necessary precision and reliability guaranteed
- Lean manufacturing concepts applied
- Cheaper and more reliable systems
- Straightforward and reliable commissioning in the field

(Plug-and-Play concept)



SMARTHELIOSTAT AS A REFERENCE CASE

Many systems with potential to improve heliostat performance through additional sensors/intelligence have already been proposed. E.g:

- Heliostat calibration and tracking accuracy improvement
 - Camera based patents (WO2017055663, US2011000478, ...)
 - Robotic systems for autonomous calibration (US2013238271)
 - Posters at SOLARPACES 2018 (B-12 CIEMAT, B-55 CSIRO, ...)
 - ...
- Wind protection
- Dirt mapping
- ...

Practical implementation/integration is still missing since:

- Tedious processes or expensive equipment are required for implementation.
- Individually tailored (solve a particular problem) → potential cannot be fully exploited
- Complex integration
- Risks of damaging the heliostats (e.g. moving already canted mirrors) during installation phase

SMARTHELIOSTAT concept approach aim to overcome these drawbacks

- Sensors are embedded and calibrated at the manufacturing phases
- Sensors are available for additional tasks
- ...



SMARTHELIOSTAT AS A REFERENCE CASE

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SMARTHELIOSTAT WILL:

Embed sensors for self-awareness: Acquire relevant information about status, integrity, performance, surrounding elements and environment.

E.g:

Providing reflector accurate orientation (CMOS camera)

- Enables self-calibration of each heliostat → Maximize plant output
- Periodic calibration → Reduces long-term requirements and costs
- Assist assembly and commissioning → Reduce time.

For additional information see poster B-34 and visit our booth

Sensing mirror dirtiness:

- Allows optimum cleaning scheduling and water savings

For additional information see poster U-04 and visit our booth

Measuring local environmental conditions (CMOS camera and temperature, pressure, or vibration sensors)

- Continuous information at the point of interest (Wind, clouds, etc.)
- Nowcasting and atmospheric attenuation

For additional information see poster R-12 and visit our booth

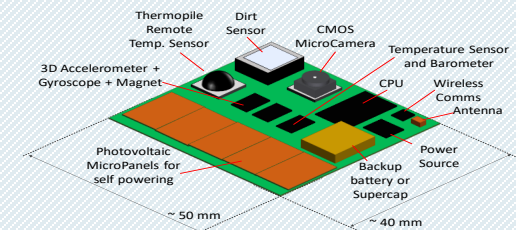
Characterising neighbour elements: (CMOS camera + Machine Vision)

Embed analysis and processing capabilities:

- Generate new valuable information for plant operation
- Take decisions & generate commands (“go to stow position”, “clean”, “bypass the cleaning of a reflector”, “calibrate a heliostat”, etc.)
- Minimize computing and communication requirements of the CSP plant ICT infrastructure (Wireless approach more affordable)

Incorporate communication capabilities:

- Connected to the global plant control system
- Local communication system
 - Clusters of SMARTHELIOSTATS operate in a cooperative and coordinated manner



APPROACH | SMARTCSP COMPONENTS

In order to take full advantage of these concepts, components and systems must be redesigned

RETROFITTING vs. DASHBOARD INTEGRATED DESIGN

Cost? Reliability? Time? User friendly?

4.3 inch TFT LCD Monitor + Rear View Camera



Liislee



**For Hyundai Accent
RB Sedan**



Intelligent Price Manager



VS.



FULL SET / EASY INSTALL ?

APPROACH | SMARTCSP COMPONENTS

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RETROFITTING vs. DASHBOARD INTEGRATED DESIGN
Cost? Reliability? Time? User friendly?



vs.



APPROACH | SMARTCSP COMPONENTS

SMARTCSP: THE INDUSTRY 4.0 APPROACH
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RETROFITTING vs. INTEGRATED DESIGN Cost? Reliability? Time? User friendly?



NEXT STEPS

UNDER
DEVELOPMENT

SMARTCSP

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RESULTS | FORESEEN IMPROVEMENTS

SMARTCSP results in a reduction in LCOE due to a decrease in **CAPEX** and **OPEX** as well as a significant increase in quality of key components and **plant performance**

CAPEX Reduction thanks to	<ul style="list-style-type: none"> • Complete systems are mass-produced in a factory using low-cost, high-quality lean manufacturing. • Inexpensive electronics add functionalities and allow eliminating components as well as relaxing long-term requirements of component since frequent automatic set-up is possible. • Turn-key solutions including intelligent systems and components reduce time and cost. • Reduce technical and financial risk and therefore financial cost thanks to increased reliability.
OPEX Reduction thanks to	<ul style="list-style-type: none"> • Self-manageable components with new features improve reliability and maintenance needs. • Complete, on-line reliable information of components and plant status lead to an easier and more automatic operation while reducing inspection needs. • Maintenance operations can be more optimally scheduled, delaying operations that don't yet add value and anticipating others impacting more on the plant output.
ENERGY PRODUCTION increase due to	<ul style="list-style-type: none"> • Systems quality is improved as complete functional systems are integrated in the factory using lean manufacturing processes under controlled conditions and with higher quality control. • SMART component with additional features will maximize not only its contribution to the energy production but the overall plant efficiency. • Improved plant performance, reliability and availability increases power output & operating hours. • Complete, continuous, on-line reliable information enable to reduce safety margins driving the system closer to its optimum operation point and during more operating hours.

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CONCLUSIONS

Up to now, CSP industry has barely incorporated **ICT innovations**

IK4-TEKNIKER and CENER has developed the SMARTCSP **with potential for cost reduction**

SMARTCSP takes profit of current available knowledge:
ICT as well as **Lean Manufacturing** concepts have a proven track record in **challenging markets** (e.g. automotive, energy, manufacturing or consumer goods industry)

Increasing automated deployment, monitoring, control and operation will maximize overall **efficiency, reliability, availability** as well as **dispatchability**

A relevant **LCOE reduction** could be achieved



CONCLUSIONS |

FUTURE WORK AND PROPOSALS FOR COLLABORATION

SMARTCSP COMPONENTS

Different components under development:

- SMARTHELIOSTAT concept is only one of them
- Agreements reached to develop certain SMART Components

We are open to collaborate with any component and system developers

SMARTCSP PLANT

Developing full potential of SMARTCSP concept requires a **multidisciplinary approach**

We are open to collaboration to bring the concept to full deployment in the shortest time



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RESULTS | FORESEEN IMPROVEMENTS

SMARTCSP expected impact figures for **CAPEX** and **OPEX** reductions

Improvements Summary	CAPEX	OPEX
Efficient plant monitoring and control	--	1.3%
Efficient sun tracking and higher automation	2.5%	1.2%
Software development at component level	3.8%	0%
Software development at system level	--	1.7%
Reduction of construction costs by using automated/improved processes	4.6%	--
Improved and cheaper manufacturing methods and automated components production	10.6%	4%
Advanced cleaning systems and low-soiling surfaces	--	2.5%
Methodology for analyzing and predicting degradation and lifetime	--	2.7%
Improved durability of key components	--	8.3%

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