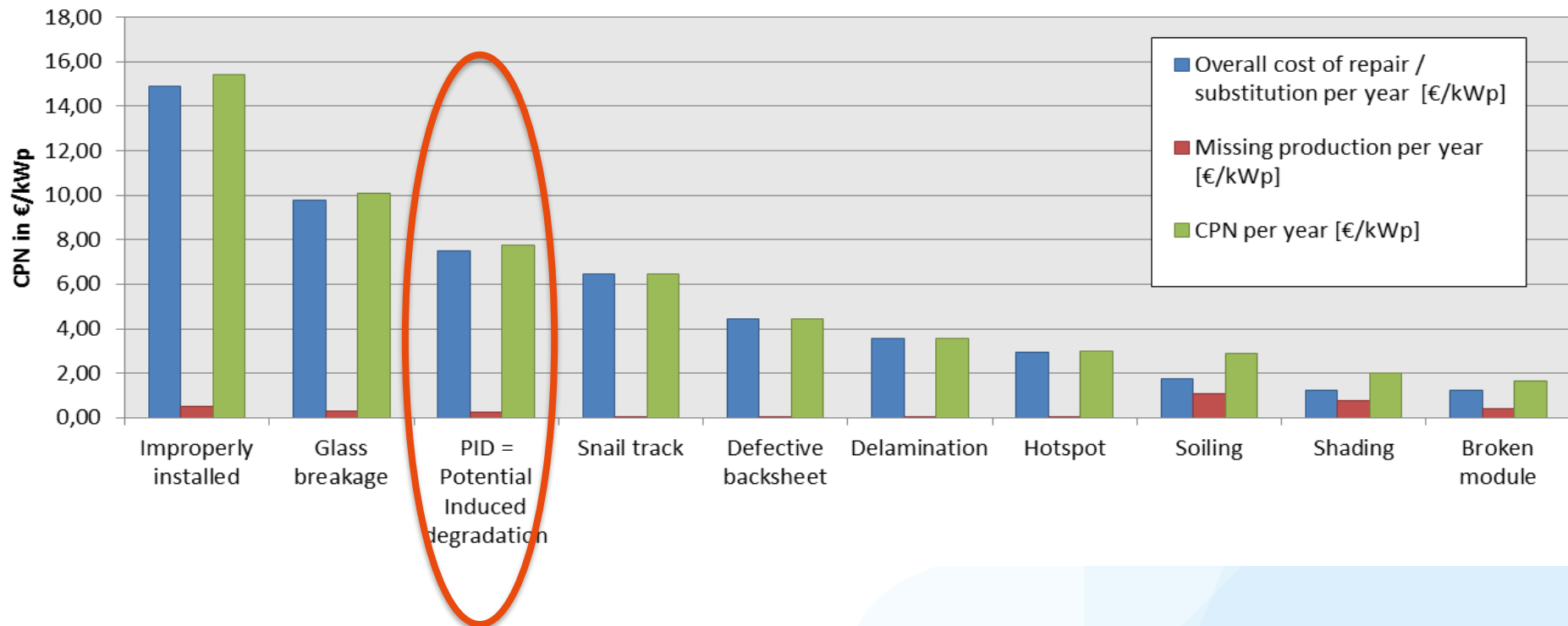


# Top 10 Risks for PV Modules

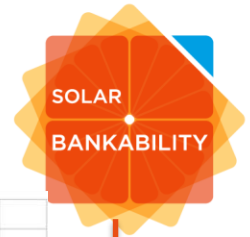


## Modules - top 10 risks

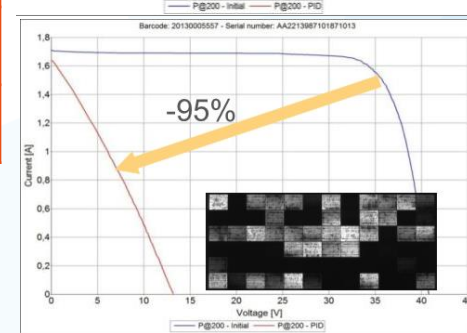
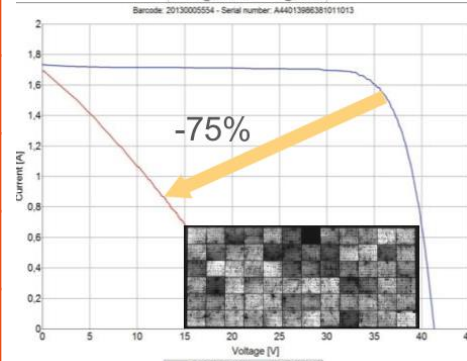
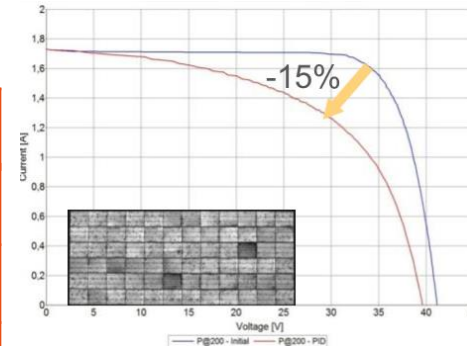


# Potential Induced Degradation - PID

## CPN Parameters – Without Mitigation Measures



PV Modules	CPN: 6.7€/kWp/a
Number of failures/failure rate:	1.7 %
Power loss:	10% - 95%
Time to detection:	3-5 years
Time to repair/substitution:	1 month / module
Repair/substitution time:	30 min / module
Cost of Detection/Mitigation:	0 €
Cost of Transportation:	10 € / module
Cost of Repair:	0 € / module
Cost of Substitution:	100 - 150 € / module



Time

# Mitigation Measures

Measure	Cost
<b>Component testing</b> <ul style="list-style-type: none"> <li>PID testing -1000 V, 25°C, 168 hours</li> <li>Electroluminescence Imaging</li> <li>STC power measurements</li> </ul>	<b>3€ /kWp</b> <ul style="list-style-type: none"> <li>0.6 €/kWp</li> <li>0.6 €/kWp</li> <li>1.2 €/kWp</li> </ul>
<b>Design verification</b> <ul style="list-style-type: none"> <li>Site evaluation</li> <li>Shadow</li> </ul>	<b>5 €/kWp</b> <ul style="list-style-type: none"> <li>0.4 €/kWp</li> <li>0.16 €/kWp</li> </ul>
<b>Transportation and construction monitoring</b> <ul style="list-style-type: none"> <li>Construction monitoring</li> </ul>	<b>5 €/kWp?</b> <ul style="list-style-type: none"> <li>2.8 €/kWp</li> </ul>
<b>Plant commissioning</b> <ul style="list-style-type: none"> <li>Review of project documentation</li> <li>Shadow</li> </ul>	<b>4.1 €/kWp</b> <ul style="list-style-type: none"> <li>0.2 €/kWp</li> <li>0.16 €/kWp</li> </ul>
<b>O&amp;M</b> <ul style="list-style-type: none"> <li>Trimming</li> <li>Soiling</li> <li>Inspection of the PV plant</li> </ul>	<b>3.5 €/kWp/a?</b> <ul style="list-style-type: none"> <li>0.08 €/kWp/a</li> <li>0.26 €/kWp/a</li> <li>1 €/kWp/a</li> </ul>
<b>Performance monitoring</b> <ul style="list-style-type: none"> <li>Monitoring of the PV plant</li> <li>Monitoring platform</li> </ul>	<b>3 €/kWp/a?</b> <ul style="list-style-type: none"> <li>1 €/kWp/a?</li> <li>2 €/kWp/a?</li> </ul>



# Potential Induced Degradation - PID

## CPN Parameters – Without/With Mitigation Measures

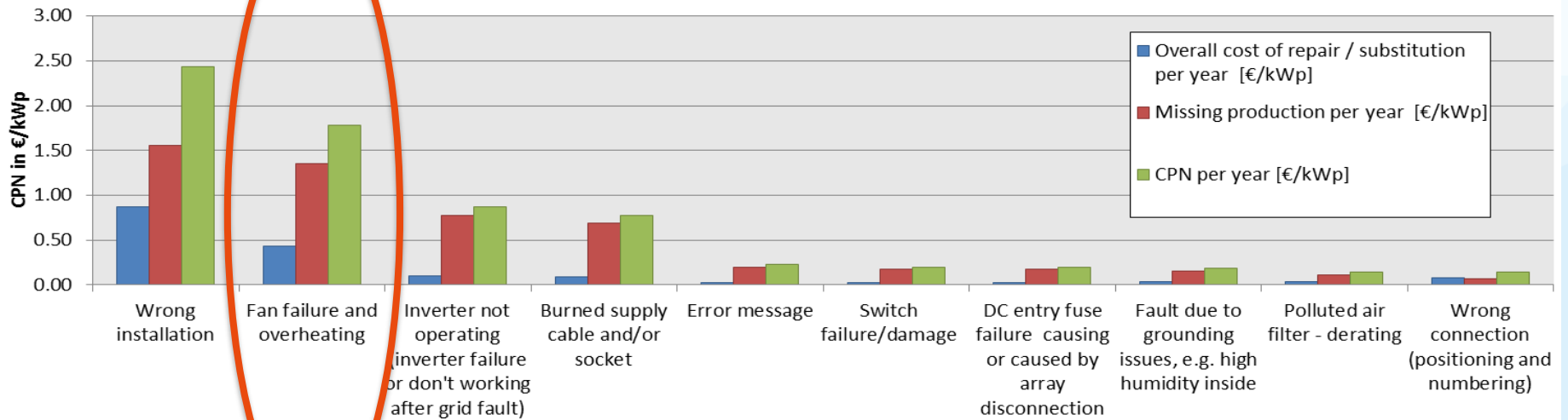
PV Modules	Without CPN 6.7€/kWp	With CPN 0.66€/kWp
Number of failures/failure rate:	1.7 %	*0.17 %
Power loss:	10% - 95%	10% - 95%
Time to detection:	3-5 years	** 6 months
Time to repair/substitution:	>1 month	>1 month
Repair/substitution time:	30 min / module	30 min / module
Cost of Detection/Mitigation:	0 €	**1 € / kWp +*0.6 € / kWp
Cost of Transportation:	10 €/module	10 €/module
Cost of Repair:	0 €/module	0 €/module
Cost of Substitution:	100 - 150 € / module	100 - 150 € / module

\*Laboratory testing, \*\* Inspection of the PV plant

# Top 10 Risks for Inverters



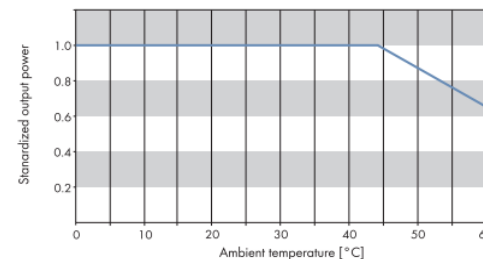
## Total - inverter - top 10 risks



# Inverter – Fan Failure and Overheating

## CPN Parameters – Without Mitigation Measures

Inverters	CPN: 1.54€/kWp/a
Number of failures/failure rate:	5%
Power loss:	1% - 40%
Time to detection:	1 year
Time to repair/substitution:	>1 month
Repair/substitution time:	1 day
Cost of Detection/Mitigation:	0 €
Cost of Transportation:	10 € / inverter
Cost of Repair:	377 € / inverter
Cost of Substitution:	0 €



<http://www.sma.de/>



# Mitigation Measures

Measure	Cost
<b>Component testing</b> <ul style="list-style-type: none"> <li>• PID testing -1000 V, 25°C, 168 hours</li> <li>• Electroluminescence Imaging</li> <li>• STC power measurements</li> </ul>	<b>3€ /kWp</b> <ul style="list-style-type: none"> <li>• 0.6 €/kWp</li> <li>• 0.6 €/kWp</li> <li>• 1.2 €/kWp</li> </ul>
<b>Design verification</b> <ul style="list-style-type: none"> <li>• Site evaluation</li> <li>• Shadow</li> </ul>	<b>5 €/kWp</b> <ul style="list-style-type: none"> <li>• 0.4 €/kWp</li> <li>• 0.16 €/kWp</li> </ul>
<del><b>Transportation and construction monitoring</b></del> <ul style="list-style-type: none"> <li>• Construction monitoring</li> </ul>	<del><b>5 €/kWp?</b></del> <ul style="list-style-type: none"> <li>• 2.8 €/kWp</li> </ul>
<b>Plant commissioning</b> <ul style="list-style-type: none"> <li>• Review of project documentation</li> <li>• Shadow</li> </ul>	<b>4.1 €/kWp</b> <ul style="list-style-type: none"> <li>• 0.2 €/kWp</li> <li>• 0.16 €/kWp</li> </ul>
<b>O&amp;M</b> <ul style="list-style-type: none"> <li>• Trimming</li> <li>• Soiling</li> <li>• Inspection of the PV plant</li> </ul>	<b>3.5 €/kWp/a?</b> <ul style="list-style-type: none"> <li>• 0.08 €/kWp/a</li> <li>• 0.26 €/kWp/a</li> <li>• 1 €/kWp/a</li> </ul>
<b>Performance monitoring</b> <ul style="list-style-type: none"> <li>• Installation of monitoring system</li> <li>• Monitoring of the PV plant</li> </ul>	<b>3 €/kWp/a?</b> <ul style="list-style-type: none"> <li>1 €/kWp/a?</li> <li>2 €/kWp/a?</li> </ul>



# Inverter – Fan failure and overheating

## CPN Parameters – Without/With Mitigation Measures

Inverters	Without CPN 1.57€/kWp	With CPN 0.16€/kWp
Number of failures/failure rate:	5%	*2.5 %
Power loss:	1% - 40%	1% - 40%
Time to detection:	1 year	** 24 hours
Time to repair/substitution:	>1 month	<1 month
Repair/substitution time:	30 min / inverter	30 min / inverter
Cost of Detection/Mitigation:	0 €	*7.8 €/kWp +**6.5 €/kWp
Cost of Transportation:	10 € / inverter	10 € / inverter
Cost of Repair:	377 € / inverter	377 € / inverter
Cost of Substitution:	0€	0€

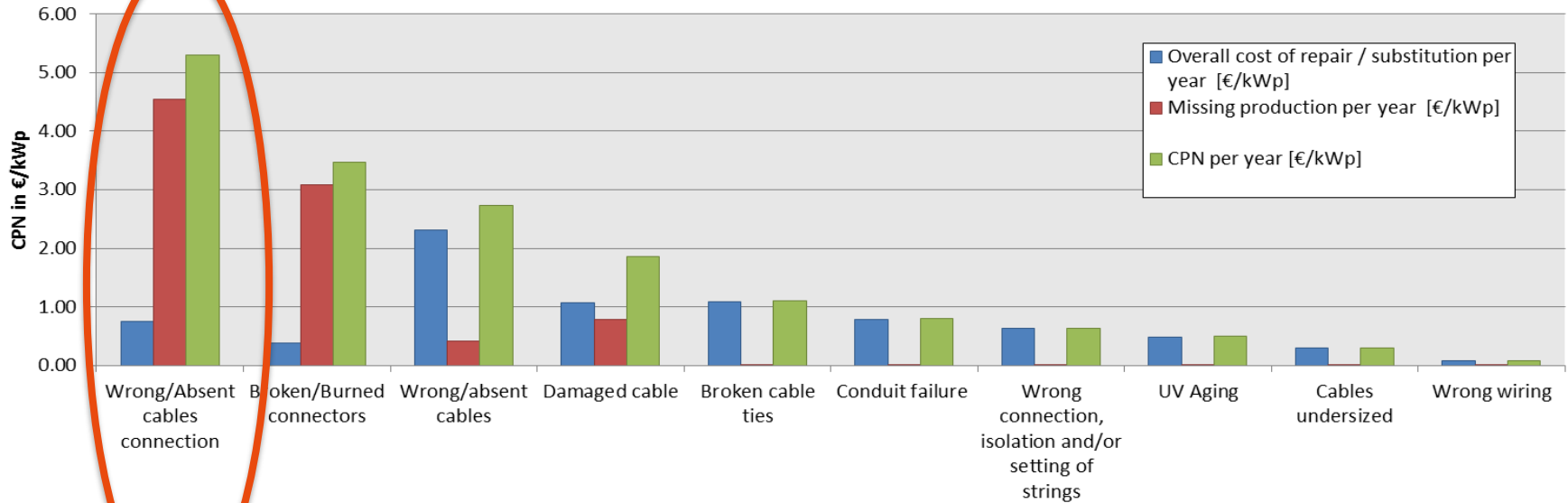
\*Inspection of design and construction phase, \*\* Monitoring and O&M company



# Top 10 Risks for Cables and Connectors



### Total - cabling- top 10 risks



# Cables – Wrong/Absent Cable Connections

## CPN Parameters – Without Mitigation Measures

Cables	CPN: 4.6€/kWp/a
Number of failures/failure rate:	6%
Power loss:	1% - 100%
Time to detection:	3-5 years
Time to repair/substitution:	<1 month
Repair/substitution time:	1 hour / connector
Cost of Detection/Mitigation:	0 €
Cost of Transportation:	1 € / connector
Cost of Repair:	0 €
Cost of Substitution:	1.5 € / connector



# Mitigation Measures

Measure	Cost
<b>Component testing</b> <ul style="list-style-type: none"> <li>PID Testing -1000 V, 25°C, 168 hours</li> <li>Electroluminescence Imaging</li> <li>STC Power measurements</li> </ul>	<b>3€ /kWp</b> <ul style="list-style-type: none"> <li>0.6 €/kWp</li> <li>0.6 €/kWp</li> <li>1.2 €/kWp</li> </ul>
<b>Design verification</b> <ul style="list-style-type: none"> <li>Site evaluation</li> <li>Shadow</li> </ul>	<b>5 €/kWp</b> <ul style="list-style-type: none"> <li>0.4 €/kWp</li> <li>0.16 €/kWp</li> </ul>
<del><b>Transportation and construction monitoring</b></del> <ul style="list-style-type: none"> <li><del>Construction monitoring</del></li> </ul>	<del><b>5 €/kWp?</b></del> <ul style="list-style-type: none"> <li><del>2.8 €/kWp</del></li> </ul>
<b>Plant commissioning</b> <ul style="list-style-type: none"> <li>Review of project documentation</li> <li>Shadow</li> </ul>	<b>4.1 €/kWp</b> <ul style="list-style-type: none"> <li>0.2 €/kWp</li> <li>0.16 €/kWp</li> </ul>
<b>O&amp;M</b> <ul style="list-style-type: none"> <li>Trimming</li> <li>Soiling</li> <li>Inspection of the PV plant</li> </ul>	<b>3.5 €/kWp/a?</b> <ul style="list-style-type: none"> <li>0.08 €/kWp/a</li> <li>0.26 €/kWp/a</li> <li>1 €/kWp/a</li> </ul>
<b>Performance monitoring</b> <ul style="list-style-type: none"> <li>Installation of monitoring system</li> <li>Monitoring of the PV plant</li> </ul>	<b>3 €/kWp/a?</b> <ul style="list-style-type: none"> <li>1 €/kWp/a?</li> <li>2 €/kWp/a?</li> </ul>



# Cables – Wrong/Absent Cable Connections

## CPN Parameters - Without/With Mitigation Measures

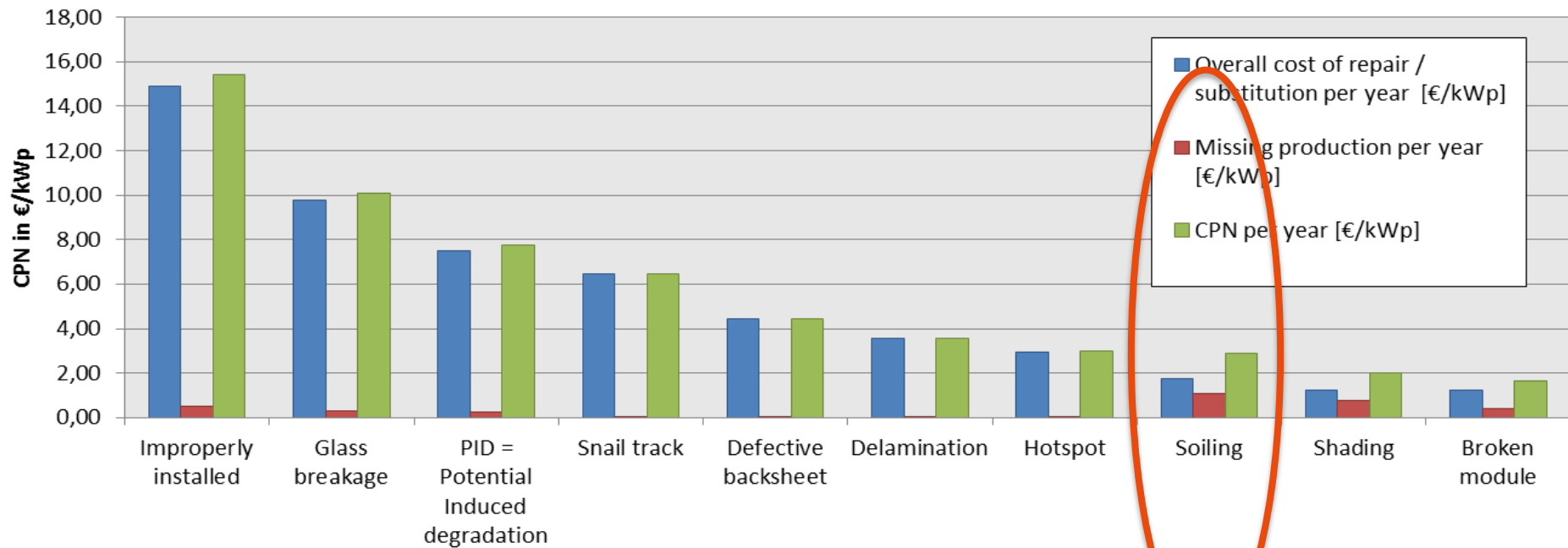
Cables	Without CPN 4.6€/kWp	With CPN 0.21 €/kWp
Number of failures/failure rate:	6 %	*0.6%
Power loss:	1% - 100%	1% - 100%
Time to detection:	3-5 years	** 6 Months?
Time to repair/substitution:	<1 month	<1 month
Repair/substitution time:	30 min / connector	30 min / connector
Cost of Detection/Mitigation:	0 €	*7.8 €/kWp +**1 €/kWp
Cost of Transportation:	1 € / connector	1 € / connector
Cost of Repair:	0 €	0 €
Cost of Substitution:	1.5 € / connector	1.5 € / connector

\*Inspection of design and construction phase, \*\* Inspection of the PV plant

# Top 10 Risks for PV Modules



## Modules - top 10 risks



# Soiling

## CPN Parameters – Without Mitigation Measures

PV Modules	CPN: 2.48 €/kWp/a
Number of failures/failure rate:	8 %
Power loss:	5% - 40%
Time to detection:	1 year
Time to repair/substitution:	>1 week
Repair/substitution time:	1 min / module
Cost of Detection/Mitigation:	0 €
Cost of Transportation:	0 € / module
Cost of Repair:	0.26 € / module
Cost of Substitution:	0 € / module



# Mitigation Measures

Measure	Cost
<b>Component testing</b> <ul style="list-style-type: none"> <li>PID testing -1000 V, 25°C, 168 hours</li> <li>Electroluminescence Imaging</li> <li>STC power measurements</li> </ul>	<b>3€ /kWp</b> <ul style="list-style-type: none"> <li>0.6 €/kWp</li> <li>0.6 €/kWp</li> <li>1.2 €/kWp</li> </ul>
<b>Design verification</b> <ul style="list-style-type: none"> <li>Site evaluation</li> <li>Shadow</li> </ul>	<b>5 €/kWp</b> <ul style="list-style-type: none"> <li>0.4 €/kWp</li> <li>0.16 €/kWp</li> </ul>
<b>Transportation and construction monitoring</b> <ul style="list-style-type: none"> <li>Construction monitoring</li> </ul>	<b>5 €/kWp?</b> <ul style="list-style-type: none"> <li>2.8 €/kWp</li> </ul>
<b>Plant commissioning</b> <ul style="list-style-type: none"> <li>Review of project documentation</li> <li>Shadow</li> </ul>	<b>4.1 €/kWp</b> <ul style="list-style-type: none"> <li>0.2 €/kWp</li> <li>0.16 €/kWp</li> </ul>
<b>O&amp;M</b> <ul style="list-style-type: none"> <li>Trimming</li> <li>Soiling</li> <li>Inspection of the PV plant</li> </ul>	<b>3.5 €/kWp/a?</b> <ul style="list-style-type: none"> <li>0.08 €/kWp/a</li> <li>0.26 €/kWp/a</li> <li>1 €/kWp/a</li> </ul>
<b>Performance monitoring</b> <ul style="list-style-type: none"> <li>Monitoring of the PV plant</li> <li>Monitoring platform</li> </ul>	<b>3 €/kWp/a?</b> <ul style="list-style-type: none"> <li>1 €/kWp/a?</li> <li>2 €/kWp/a?</li> </ul>



# Soiling

## CPN Parameters – Without/With Mitigation Measures

PV Modules	Without CPN 2.48 €/kWp	With CPN 1.49€/kWp
Number of failures/failure rate:	8 %	8 %
Power loss:	5% - 40%	5% - 40%
Time to detection:	1 year	* 24 hours
Time to repair/substitution:	>1 week	** <1 week
Repair/substitution time:	0 min / module	0 min / module
Cost of Detection/Mitigation:	0 €	*3 € / kWp +*3.5 € / kWp
Cost of Transportation:	0 € / module	0 € / module
Cost of Repair:	0.26 € / module	0.26 € /module
Cost of Substitution:	0 € / module	0€ / module

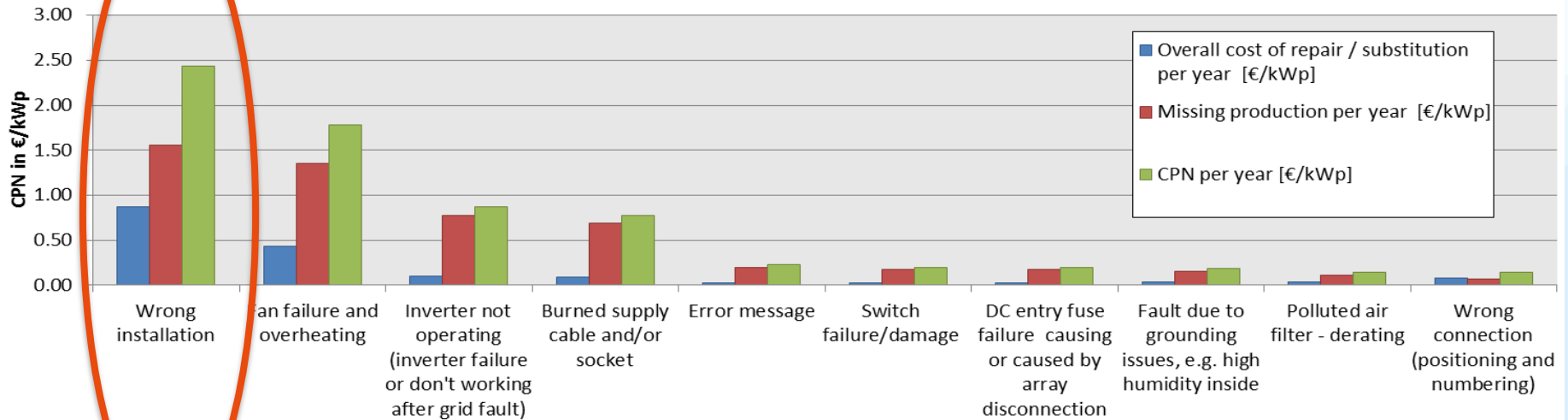
\*Performance monitoring, \*\* O&M company



# Top 10 Risks for Inverters



**Total - inverter - top 10 risks**





# Inverter – Wrong installation

## CPN Parameters – Without Mitigation Measures

Inverters	CPN: 2.10€/kWp
Number of failures/failure rate:	11%
Power loss:	1% - 10%
Time to detection:	1 year
Time to repair/substitution:	>1 month
Repair/substitution time:	1 day
Cost of Detection/Mitigation:	0 €
Cost of Transportation:	10 € / inverter
Cost of Repair:	377 € / inverter
Cost of Substitution:	0 €

# Mitigation Measures

Measure	Cost
<b>Component testing</b> <ul style="list-style-type: none"> <li>• PID testing -1000 V, 25°C, 168 hours</li> <li>• Electroluminescence Imaging</li> <li>• STC power measurements</li> </ul>	<b>3€ /kWp</b> <ul style="list-style-type: none"> <li>• 0.6 €/kWp</li> <li>• 0.6 €/kWp</li> <li>• 1.2 €/kWp</li> </ul>
<b>Design verification</b> <ul style="list-style-type: none"> <li>• Site evaluation</li> <li>• Shadow</li> </ul>	<b>5 €/kWp</b> <ul style="list-style-type: none"> <li>• 0.4 €/kWp</li> <li>• 0.16 €/kWp</li> </ul>
<del><b>Transportation and construction monitoring</b></del> <ul style="list-style-type: none"> <li>• <del>Construction monitoring</del></li> </ul>	<del><b>5 €/kWp?</b></del> <ul style="list-style-type: none"> <li>• <del>2.8 €/kWp</del></li> </ul>
<b>Plant commissioning</b> <ul style="list-style-type: none"> <li>• Review of project documentation</li> <li>• Shadow</li> </ul>	<b>4.1 €/kWp</b> <ul style="list-style-type: none"> <li>• 0.2 €/kWp</li> <li>• 0.16 €/kWp</li> </ul>
<b>O&amp;M</b> <ul style="list-style-type: none"> <li>• Trimming</li> <li>• Soiling</li> <li>• Inspection of the PV plant</li> </ul>	<b>3.5 €/kWp/a?</b> <ul style="list-style-type: none"> <li>• 0.08 €/kWp/a</li> <li>• 0.26 €/kWp/a</li> <li>• 1 €/kWp/a</li> </ul>
<b>Performance monitoring</b> <ul style="list-style-type: none"> <li>• Installation of monitoring system</li> <li>• Monitoring of the PV plant</li> </ul>	<b>3 €/kWp/a?</b> <ul style="list-style-type: none"> <li>1 €/kWp/a?</li> <li>2 €/kWp/a?</li> </ul>



# Inverter – Wrong installation

## CPN Parameters – Without/With Mitigation Measures

Inverters	Without CPN 2.10€/kWp	With CPN 0.21€/kWp
Number of failures/failure rate:	11%	*1,1%
Power loss:	1% - 10%	1% - 10%
Time to detection:	1 year	**6 months
Time to repair/substitution:	>1 month	**<1 month
Repair/substitution time:	1 day / inverter	1 day / inverter
Cost of Detection/Mitigation:	0 €	*7.8 €/kWp +**3.5 €/kWp
Cost of Transportation:	0 € / inverter	0 € / inverter
Cost of Repair:	377 € / inverter	377 € / inverter
Cost of Substitution:	0 €	0€

\*Inspection of design and construction phase, \*\* O&M and inspection of the PV plant