

# The International Technology Roadmap for Photovoltaics and the Significance of Its Decade-Long Projections

P. Baliozian<sup>1</sup>, S. Tepner<sup>1</sup>, M. Fischer<sup>2</sup>, J. Trube<sup>3</sup>, S. Herritsch<sup>3</sup>, K. Gensowski<sup>1</sup>, F. Clement<sup>1</sup>, S. Nold<sup>1</sup>, R. Preu<sup>1</sup>

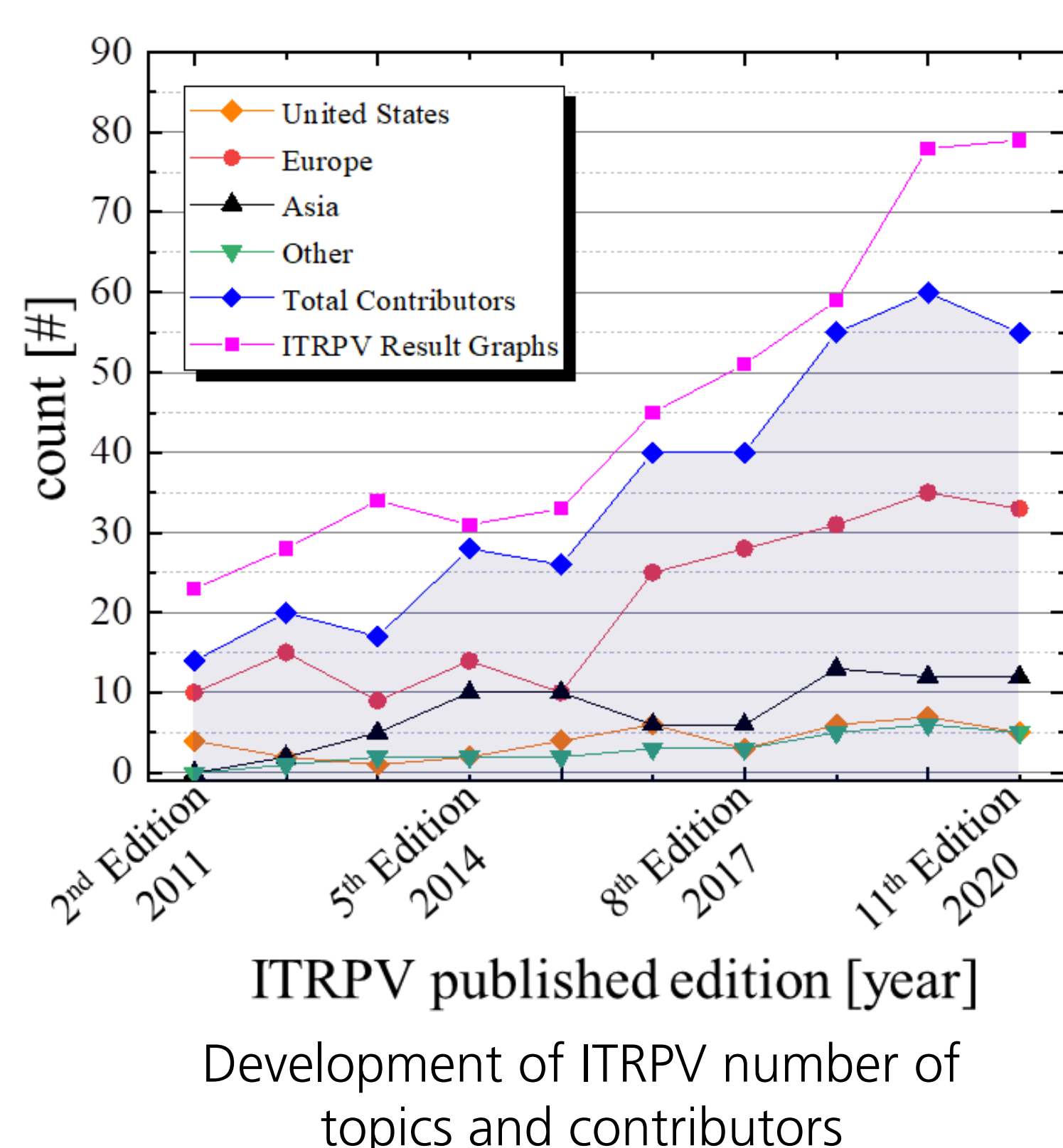
<sup>1</sup>Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany, Phone +49 761/4588-5383, puzant.baliozian@ise.fraunhofer.de

<sup>2</sup>Hanwha Q Cells GmbH, Sonnenallee 17-21, 06766 Bitterfeld-Wolfen OT Thalheim, Germany

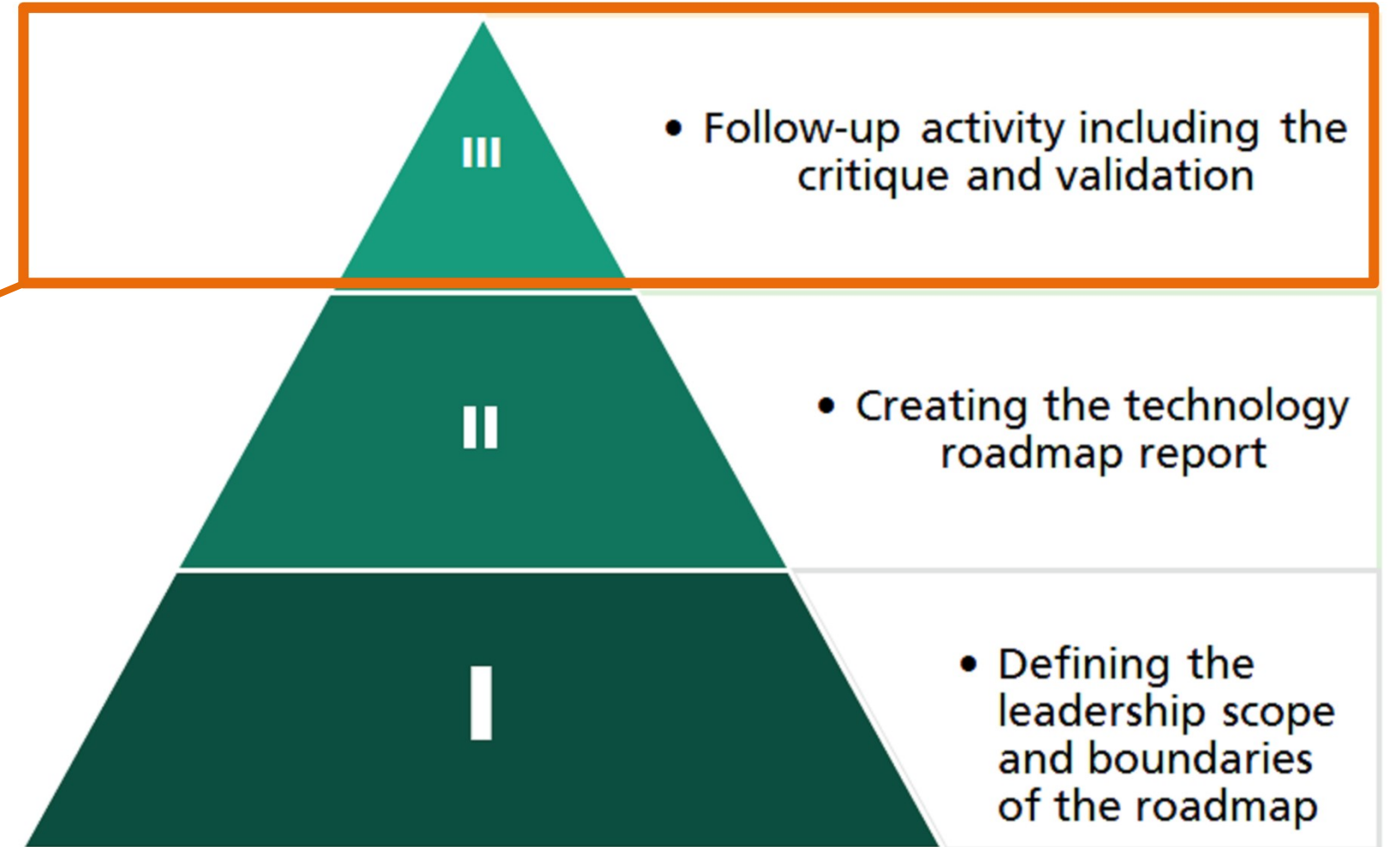
<sup>3</sup>VDMA Photovoltaic Equipment, Lyoner Str. 18, 60528 Frankfurt, Germany

## INTRODUCTION AND MOTIVATION

- The International Technology Roadmap for Photovoltaics (ITRPV)<sup>[1, 2]</sup>
  - Guidance of the technology progress
  - Published yearly since 2010
  - Includes **projections** of PV value chain items (materials, processes, products)
- ITRPV has developed in terms of topics and contributors
- Accuracy study** enhances the understanding of projected topics and decision-making<sup>[3]</sup>

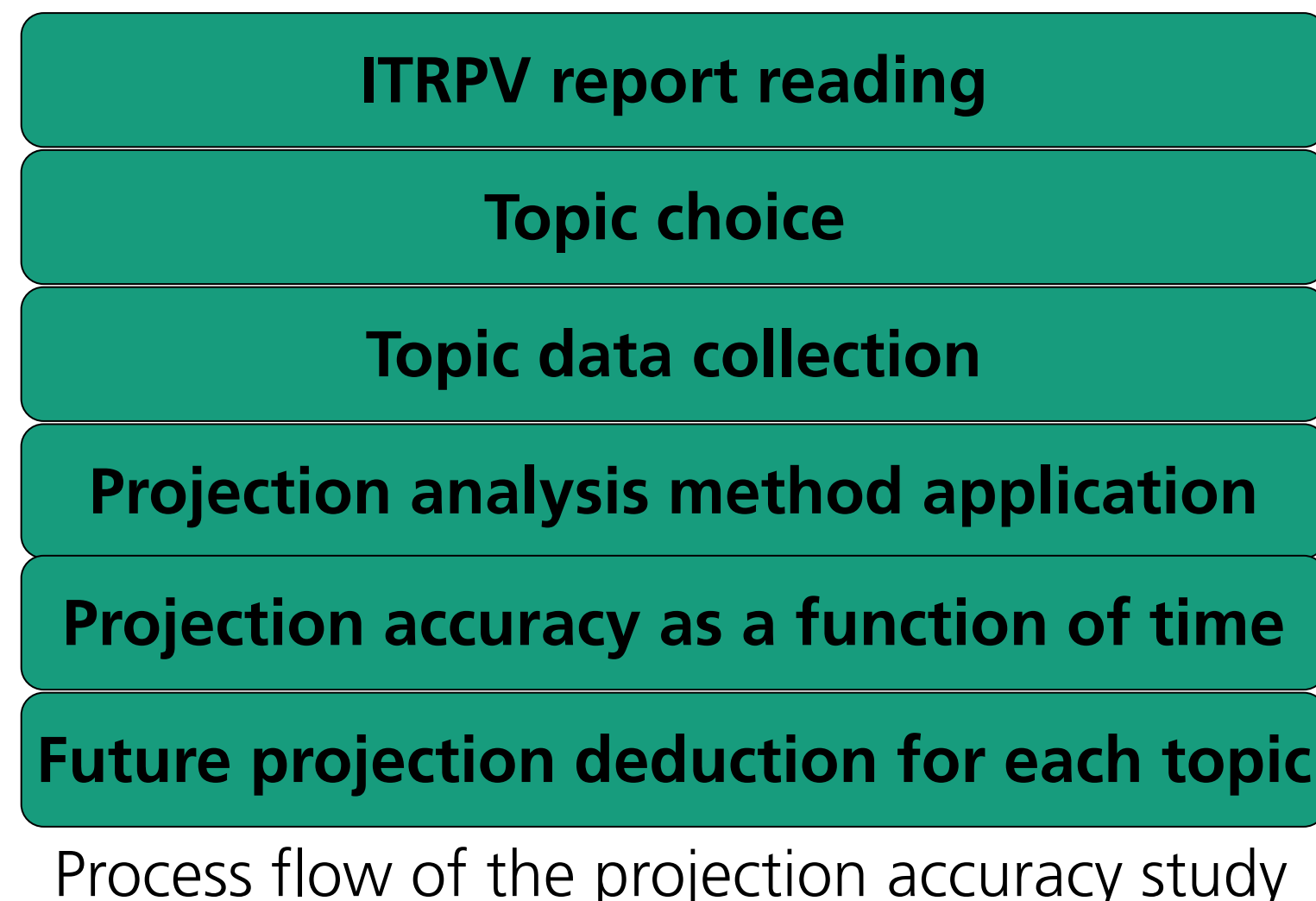


## TECHNOLOGY ROADMAPMING PHASES

- Technology roadmapping process includes three essential phases:
    - definition
    - creation
    - validation**
  - Accuracy study serves phase (iii) validation part
- 
- The three essential phases of technology roadmapping. Own figure drawn according to Ref. [4] definitions.

## PROJECTION ACCURACY STUDY APPROACH

- ITRPV reports investigated starting from 2<sup>nd</sup> Edition up to 11<sup>th</sup> Edition (current)
- Data from eight frequently projected topics are collected:
  - multicrystalline silicon (mc-Si) wafer thickness
  - mc-Si ingot mass
  - bulk recombination current density
  - emitter sheet resistance
  - finger width
  - silver amount per cell
  - screen printing throughput rate
  - market share of half cells



Projection absolute deviation (PAD):

$$PAD = |P - Y|$$

$P$ : projected value

$Y$ : reference value

Projection absolute percentage deviation (PAPD):

$$PAPD = \frac{PAD \cdot (100\%)}{Y}$$

- Calculation of PAD and PAPD for each topic
- Reference values are from the "past"
- Deduction of PAPD as a function of projection time scale for each topic
- Upper and lower limits assuming similar PAPD in future projections

## SUMMARY AND CONCLUSION

- ITRPV is growing in terms of projected topics (results) and contributors
- Projection accuracy studies are necessary for roadmap projection validation
- Projection absolute percentage deviation (PAPD) from reference values
- PAPD as a function of projection time scale
- Based on our projection accuracy study approach:
  - Finger width projections feature the highest projection accuracy ( $1.5 \pm 0.1$ ) %/year
  - Half cell market share feature the lowest projection accuracy ( $8.1 \pm 0.2$ ) %/year
- Projection accuracy is necessary to understand deviations of the past projections and draw conclusions about future ones

## RESULTS OF TOPIC PROJECTION ACCURACY

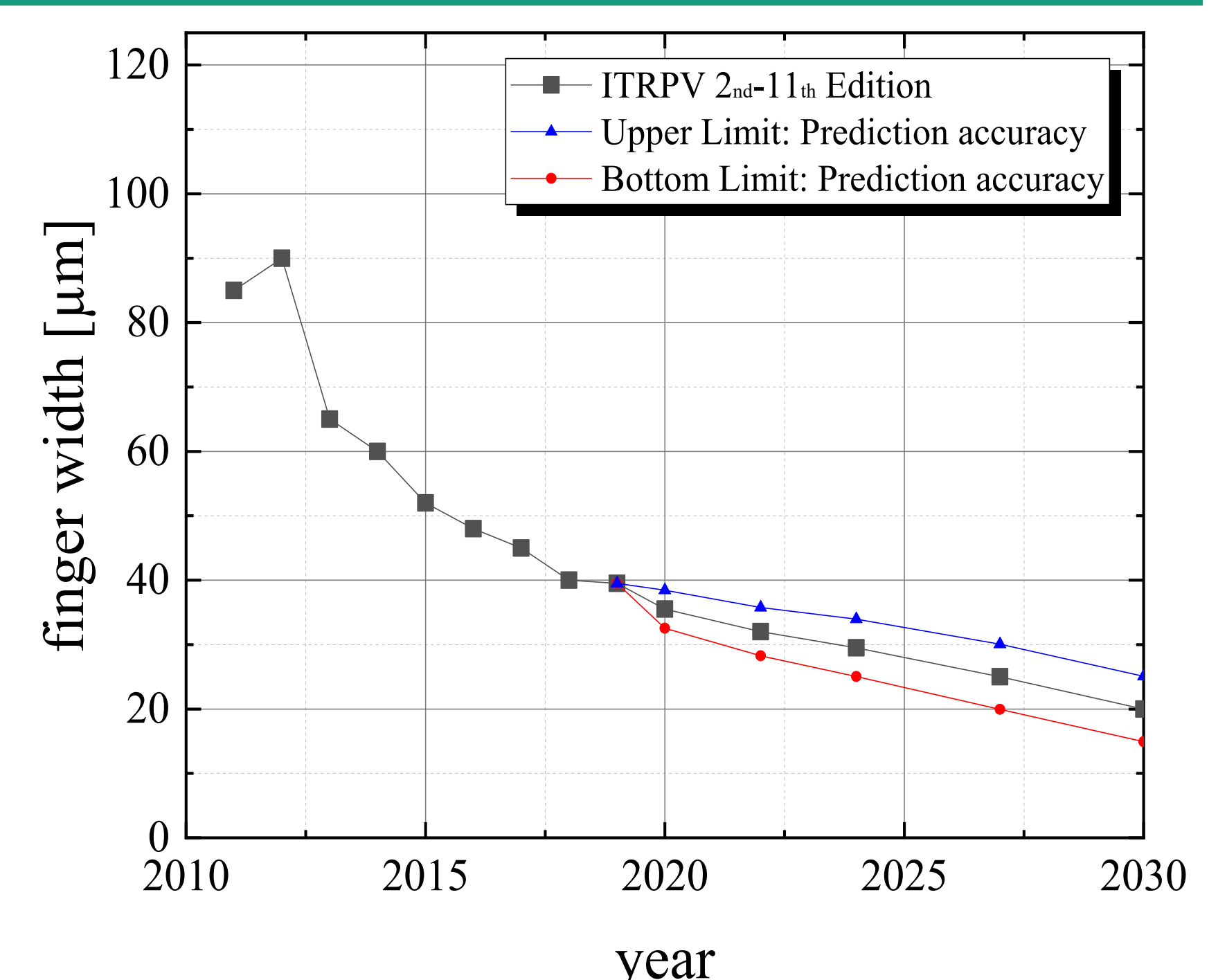
- Time-dependent projection accuracy: (i.e. slope of PAPD vs prediction time scale)
- Expected decrease of projection accuracy with increase of projection time scale
- Finger width extremely accurately projected
- Half cell market share least accurately projected
- Recent editions of ITRPV include more relevant current
  - Projection accuracy of more recent topics can be studied with the frequent inclusion in upcoming reports

Projection accuracy summary of studied topics

Studied topic	Projection accuracy (%/year)	Accuracy rank
Finger width	$1.5 \pm 0.1$	1
Emitter sheet resistance	$1.9 \pm 0.5$	2
Screen printing throughput	$2.9 \pm 0.2$	3
mc-Si ingot mass	$3.1 \pm 0.1$	4
mc-Si wafer thickness for Al-BSF cells	$4.9 \pm 0.1$	5
Bulk recombination current density	$5.7 \pm 0.1$	6
Silver amount per cell	$5.8 \pm 0.1$	7
Half cells market share	$8.1 \pm 0.2$	8

## EXPECTED TRENDS IN FUTURE PROJECTIONS

- Assuming the deviation in the past to be similar to the deviation in the future
- Statistical nature of the deviations does not take physical constraints into account
- As an example finger width projections in the future show expected reduction with upper and lower accuracy limits



Projected values of the finger width from the 11th edition ITRPV 2020 including expected upper and lower limits

[1] VDMA, International Technology Roadmap for Photovoltaic: Results 2019 - 11th Edition 2020 (all the previous editions)

[2] M. Fischer et al., Proc. 27th EU PVSEC, Frankfurt, Germany, 2012

[3] P. Baliozian et al., Proc. 33rd EU PVSEC, Amsterdam, The Netherlands, 2017

[4] O. H. Bray and M. L. Garcia, PICMET, Portland, USA, 1997