FOWLP and Flip Chip Cost Comparison: Impact of the Supply Chain Crunch

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Introduction

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Prior to joining SavanSys, Amy held positions in business development at TOK America and in engineering at Nokia Japan. Amy has a degree in chemistry and spent one year on a Fulbright grant before beginning work at Nokia.

Agenda

- **Introduction**
- **Process Flows**
- **Cost Comparisons**
- **Yield Comparison**
- **Summary**

INTRODUCTION

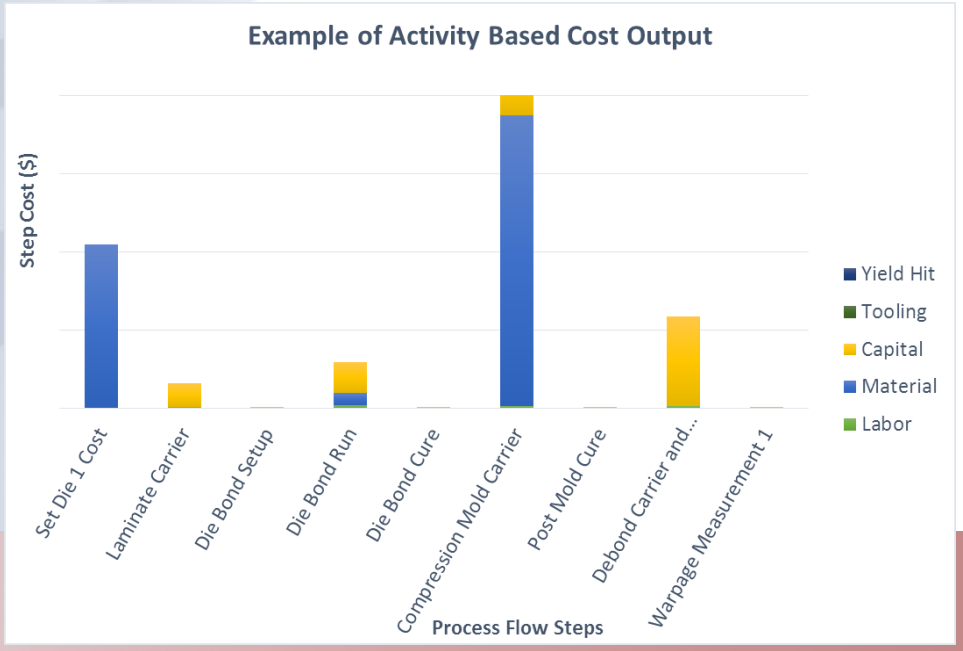
FOWLP, FC, and WB Cost Comparison

- **The question of which packaging technology is the best choice will always exist**
  - Mature versus new technology can be particularly interesting
- **Some factors to consider when choosing a packaging technology**
  - Technical requirements
  - Size requirements
  - Supplier capabilities
  - Cost
- **The right packaging choice is the one that meets design requirements at the lowest cost**
  - 5 years ago, a FOWLP versus flip chip cost comparison was already carried out – But pricing has changed since then
  - Global pandemic → Supply chain issues → Mature technology price increases

Activity Based Modeling Details

Cost Components of each Activity

- The time required to complete the activity
- The amount of labor dedicated to the activity
- The cost of material required to perform that activity – both consumable and permanent material
- Any tooling cost
- The depreciation cost of the equipment required to perform the activity
- The yield loss associated with the activity



Cost vs. Price

Component	Description
Direct Cost	Measured Cost – May be done at the activity level or at the factory level
Indirect Cost	Factory cost that is not directly associated with an activity. Support, quality, manufacturing engineering, utilities, plant, etc.
Overhead	Company cost that needs to covered. Typically G&A, marketing, engineering, etc.
Profit Margin	Usually a percentage on total cost
Risk Factor	A higher than usual margin allocated to new technologies

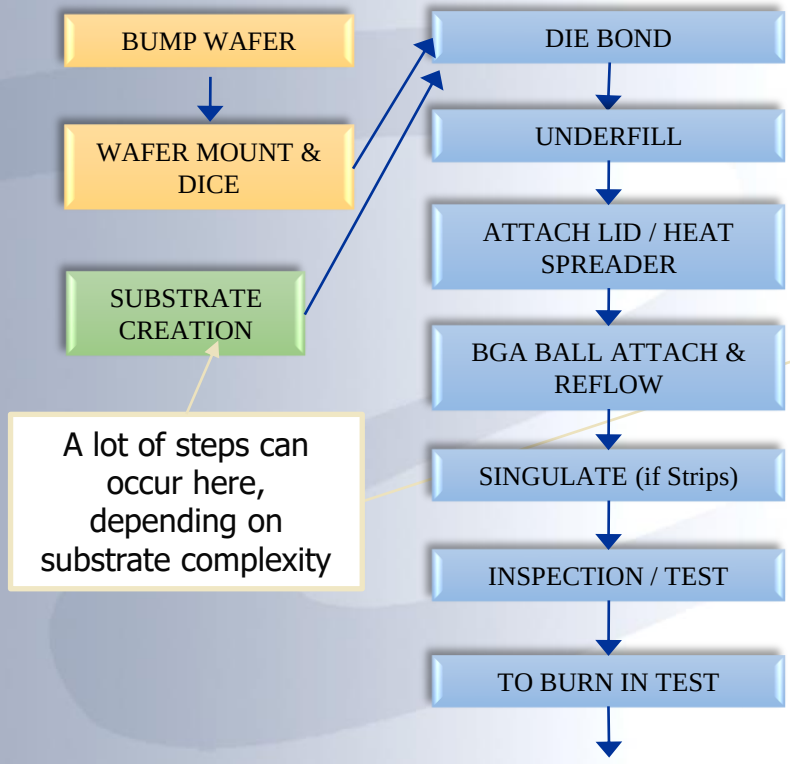
Cost models are used to estimate this directly

While all 4 of these vary widely, their total is driven to a level of consistency by the market. They are usually applied on top of direct cost as a % and per manufacturing object

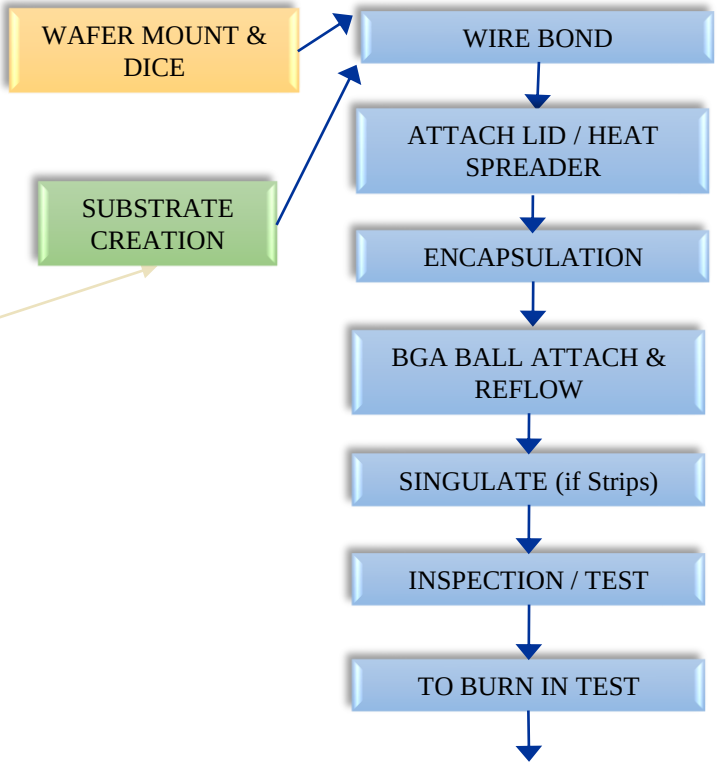
PROCESS FLOWS

Process Flows: FC and WB

Typical Flip Chip Process Flow

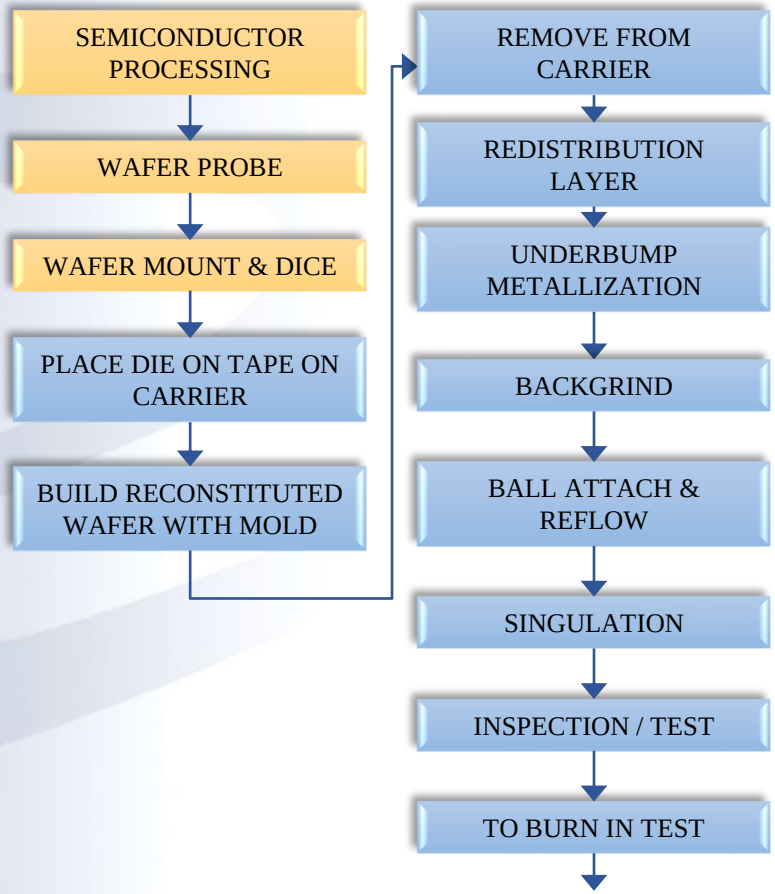


Typical Wire Bond Process Flow



Process Flows: FOWLP

Typical Chip-first Face-down FOWLP



Chip-first face-up and chip-last FOWLP are other variations on the process, not shown

Process Flows: Summary

- **Flip chip and wire bond have two discrete processes: substrate and assembly**
- **FOWLP is a process that essentially combines substrate and assembly processing into one**
- **Major cost drivers**
  - Wire bond
    - *Package size*
    - *Substrate structure*
    - *Wire count & wire material*
  - Flip chip
    - *Package size*
    - *Substrate structure*
    - *Cost of bumping the incoming wafer*
  - FOWLP (chip-first face-down)
    - *Package size*
    - *Number of imaging steps (number of RDLs)*

COST COMPARISON

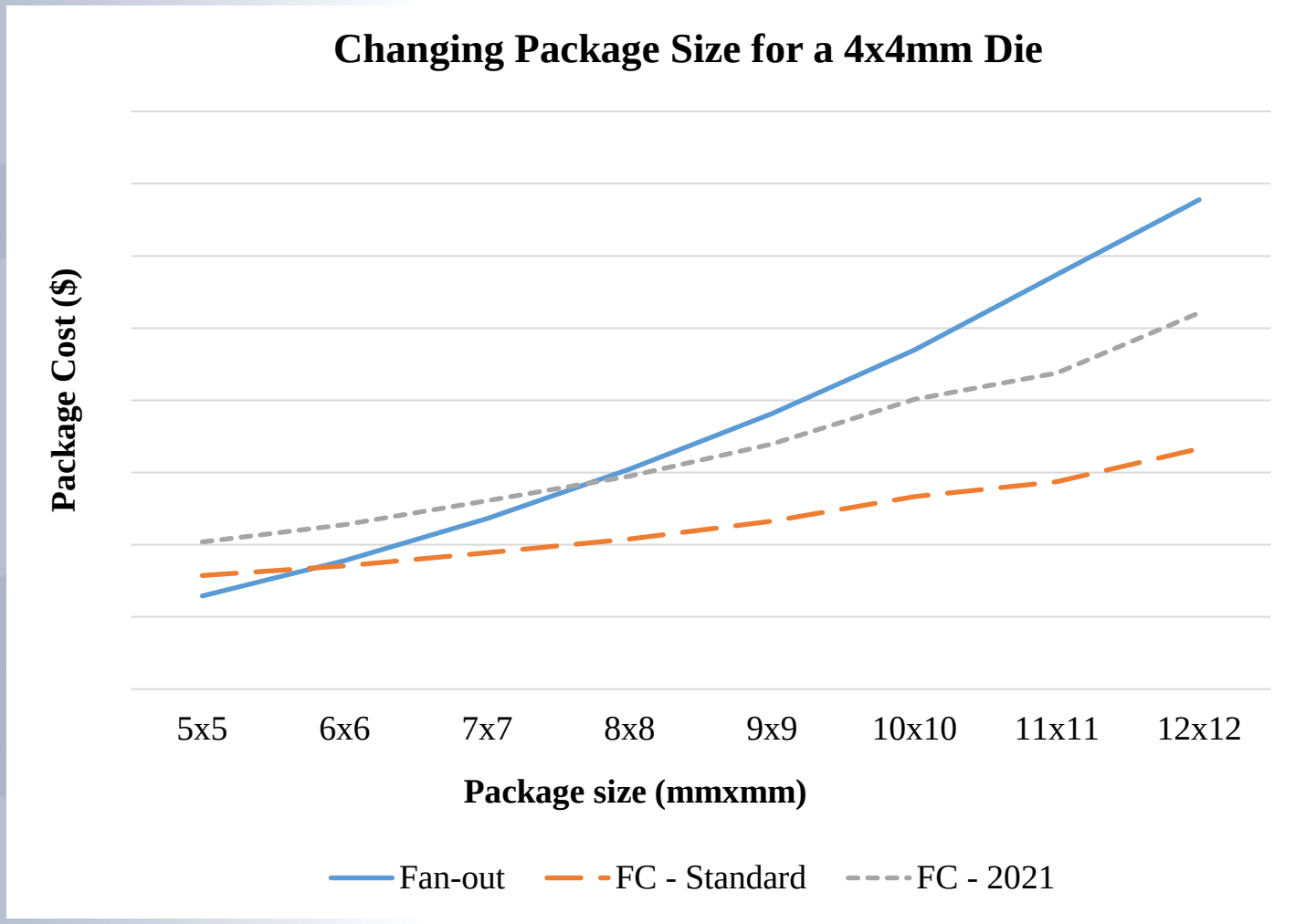
Cost Comparison

- **Design details that impact cost**
  - Package and die size
  - Layer count/substrate structure
  - I/O count, wire count and other wire details
  - Does the incoming die need to be bumped or not
  - Many others
- **Isolate one variable at a time to test its impact on cost**
- **Costs included in the following charts**
  - Direct costs of packaging
  - Costs to prepare the incoming wafer (add bumps, dice, etc.)
  - Overhead/indirect costs
  - Profit margin
  - 1 RDL (FOWLP), 2L substrate (FC and WB)

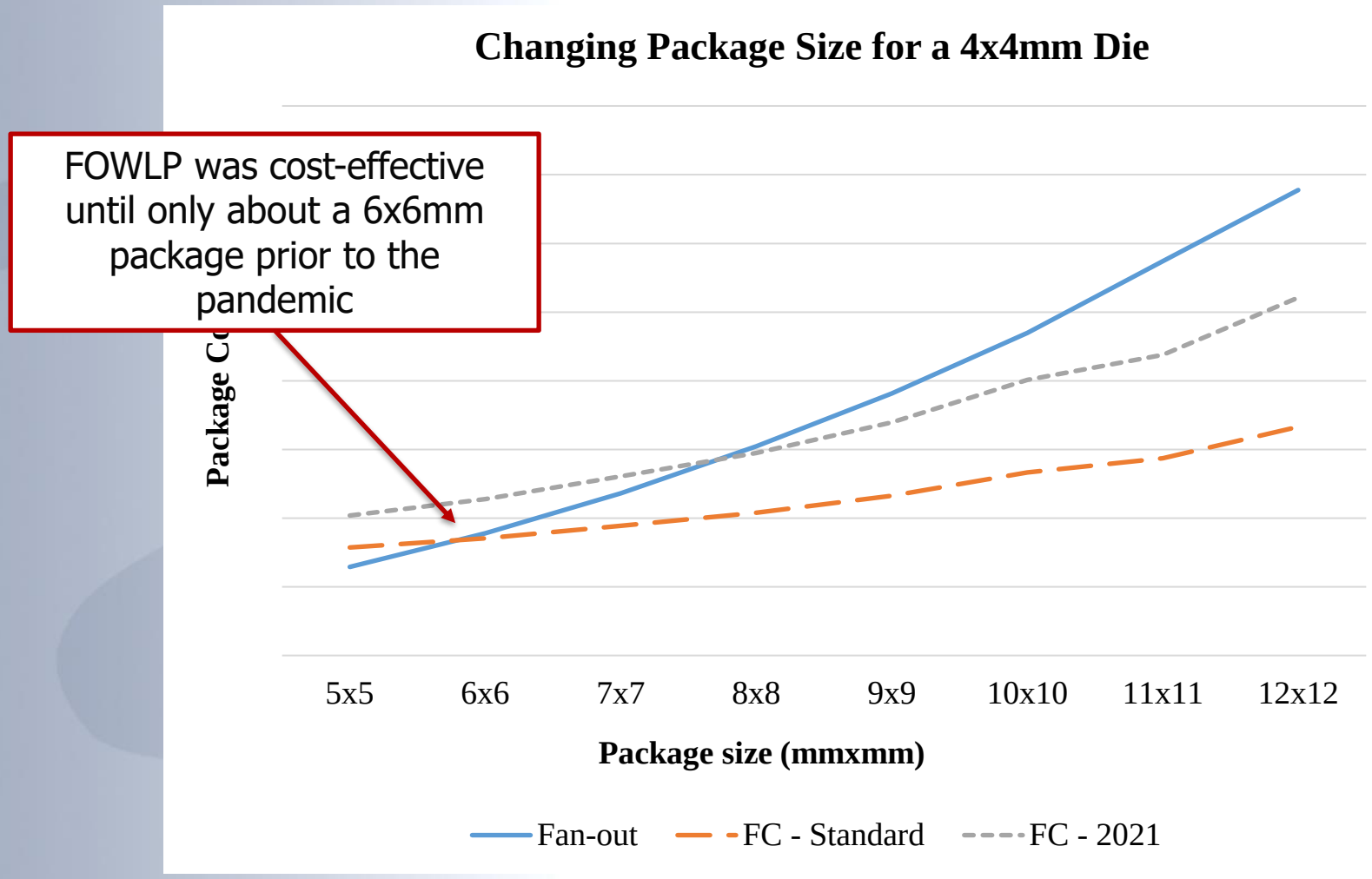
Cost Comparison

- **FC and WB data labelled "standard" is based on average prices prior to 2020**
- **FC and WB data labelled "2021" is based on pandemic pricing, specifically around the first half of 2021**
- **No pricing is truly standard**
  - Different volumes and customers can command very different pricing from the same supplier for a similar product
  - Pre-pandemic and pandemic prices here are as comparable as possible, in terms of comparing a similar volume/end customer in all cases

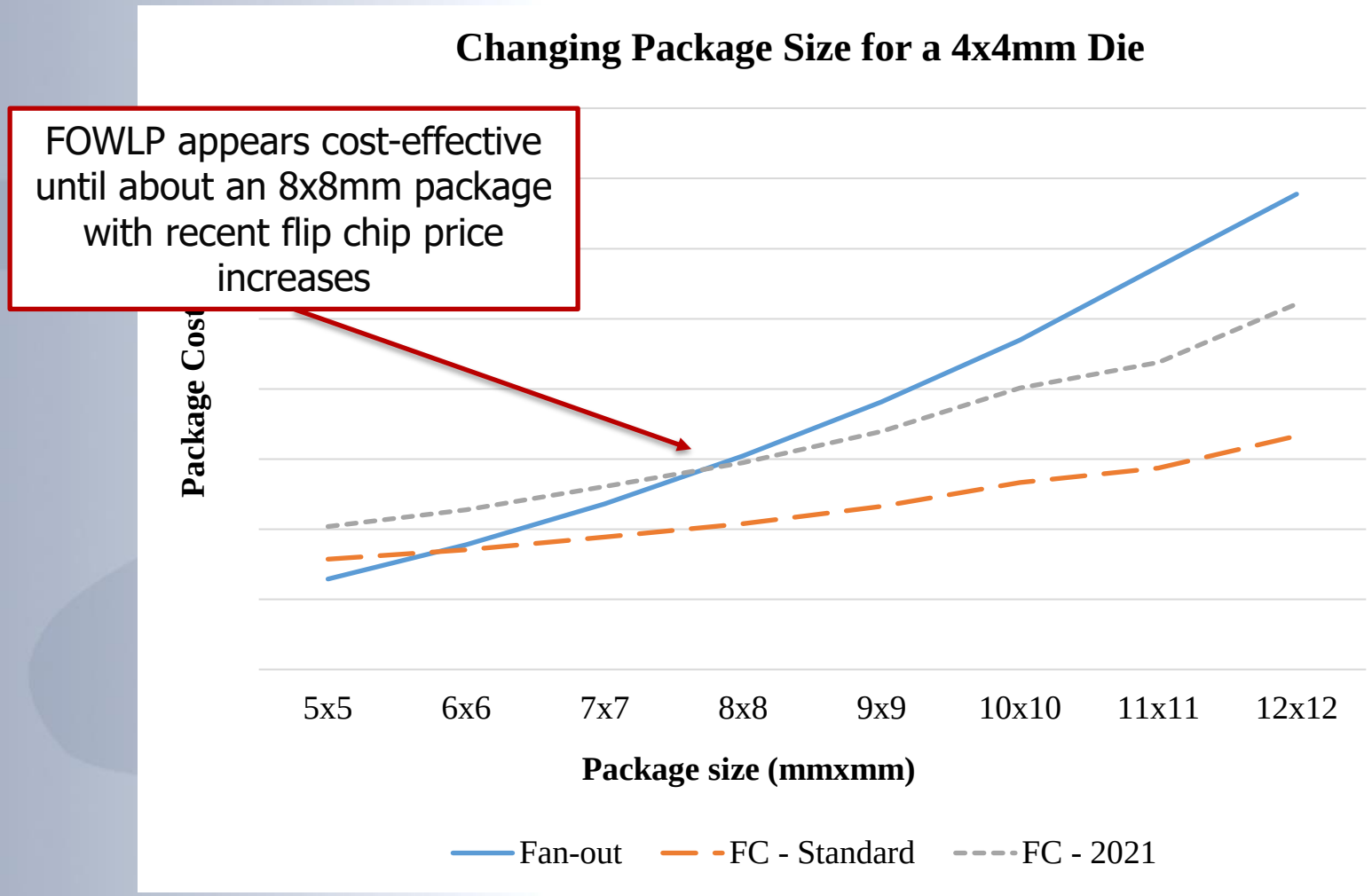
Changing Package Size: FC vs FOWLP



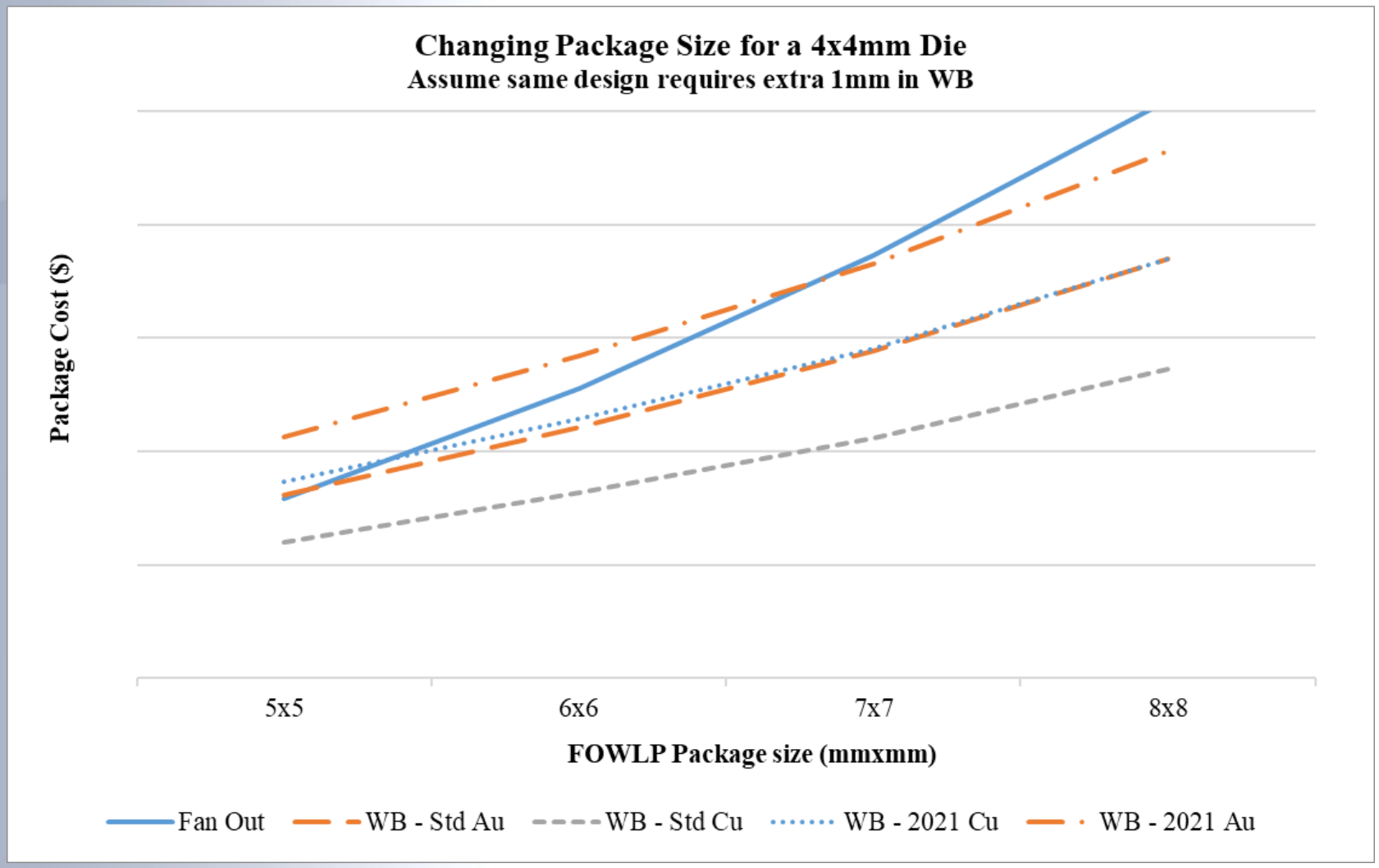
Changing Package Size: FC vs FOWLP



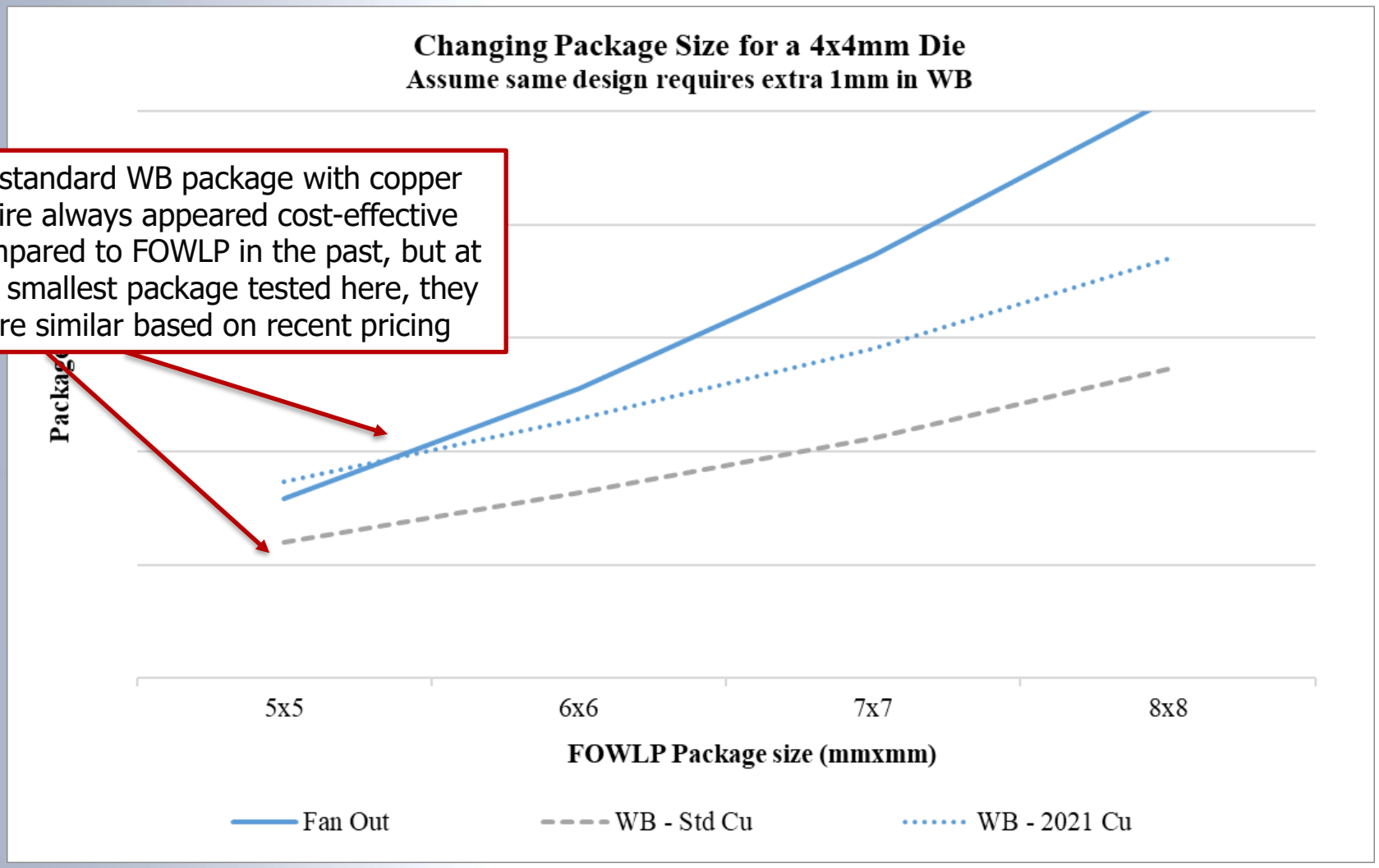
Changing Package Size: FC vs FOWLP



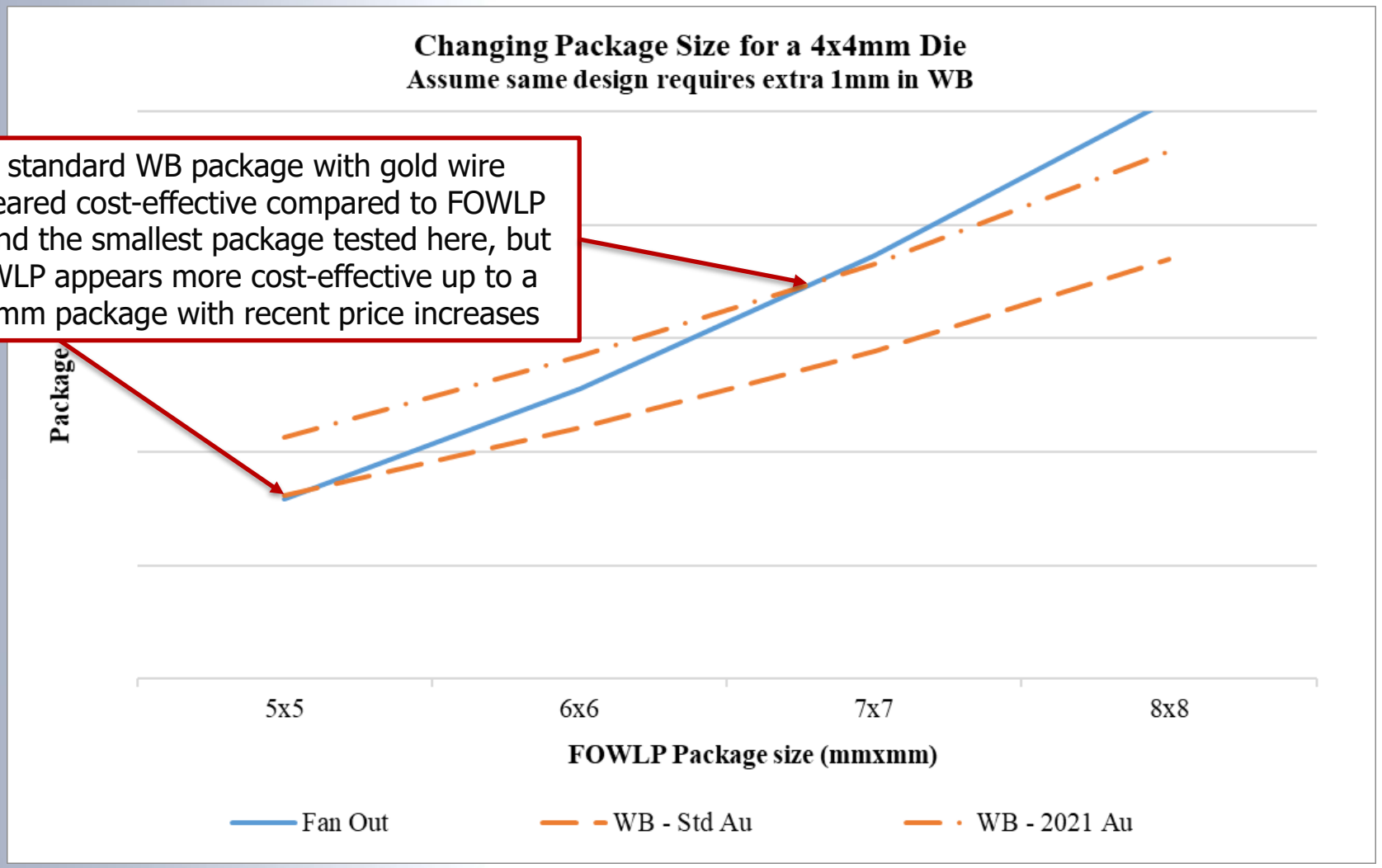
Changing Package Size: WB vs FOWLP



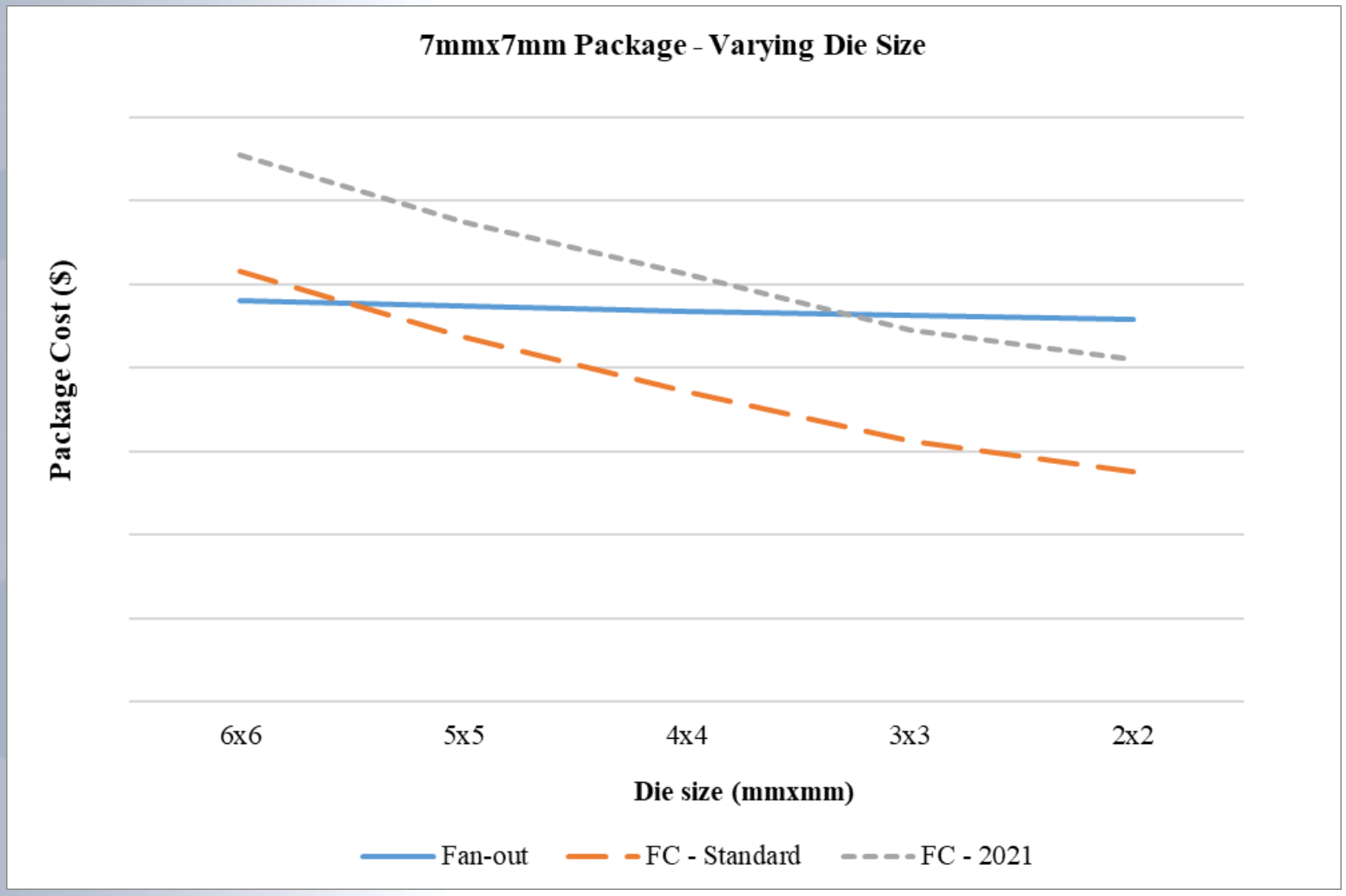
Changing Package Size: WB vs FOWLP



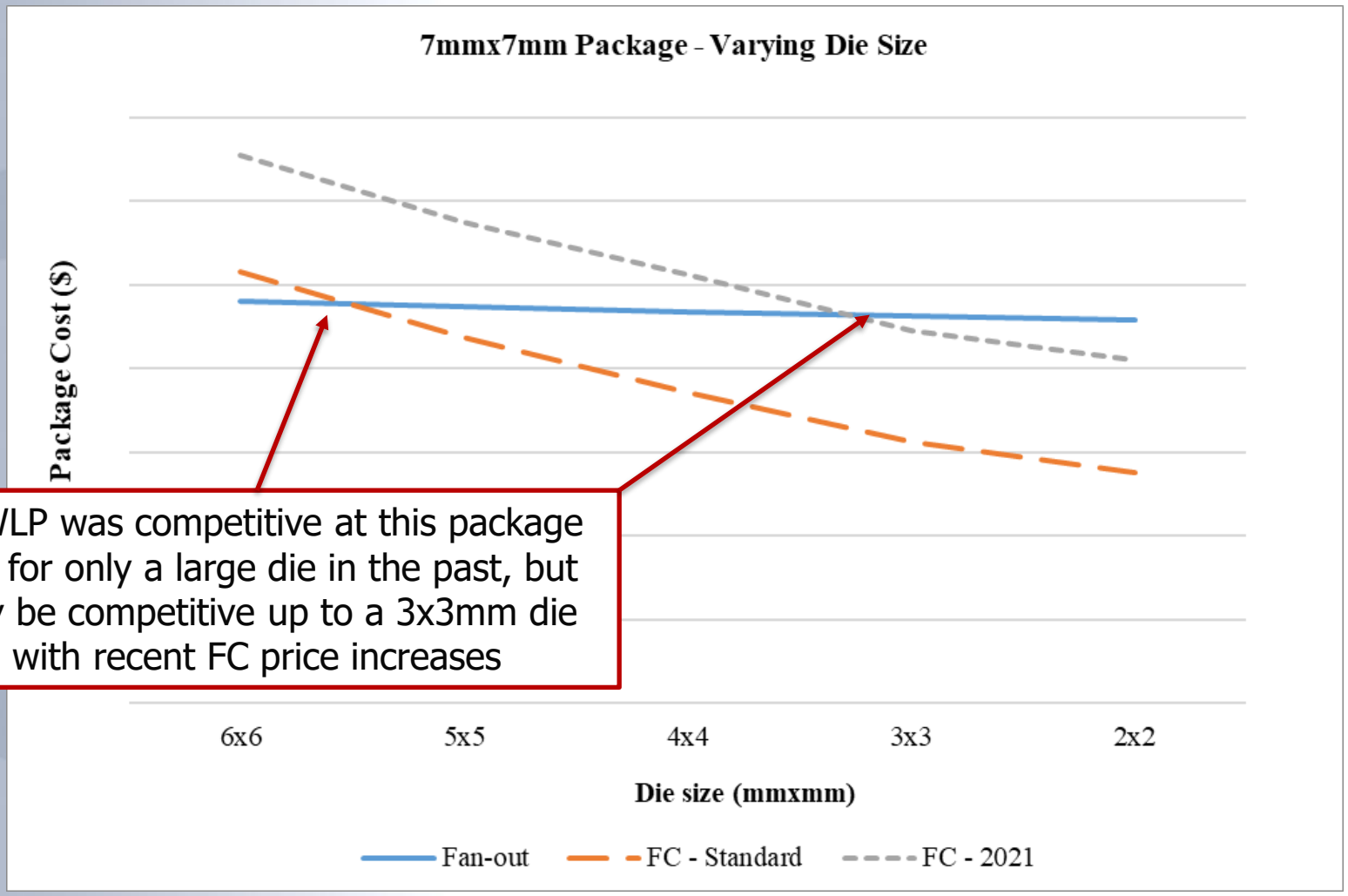
Changing Package Size: WB vs FOWLP



Changing Die Size: FC vs FOWLP



Changing Die Size: FC vs FOWLP

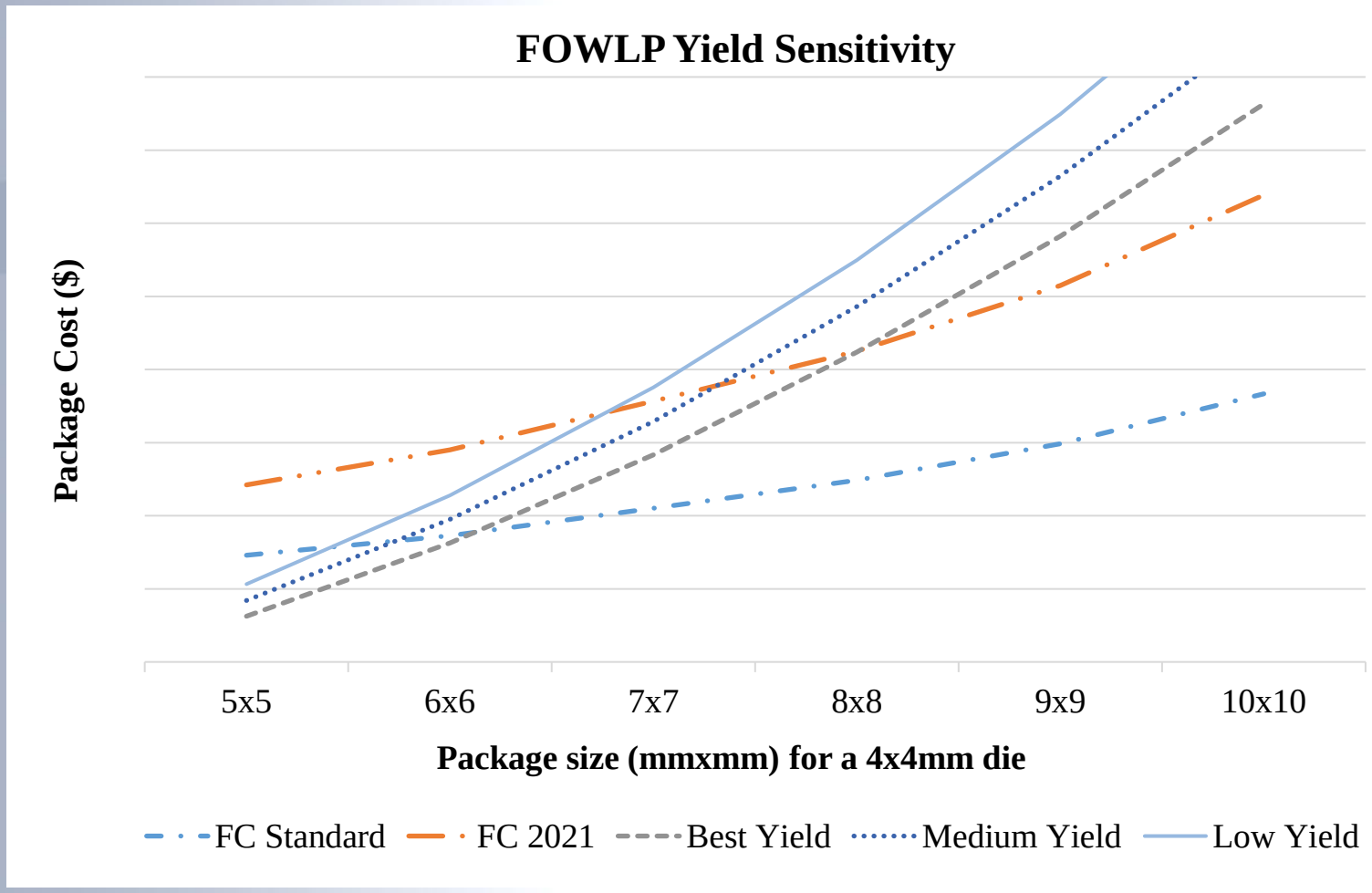


FOWLP was competitive at this package size for only a large die in the past, but may be competitive up to a 3x3mm die with recent FC price increases

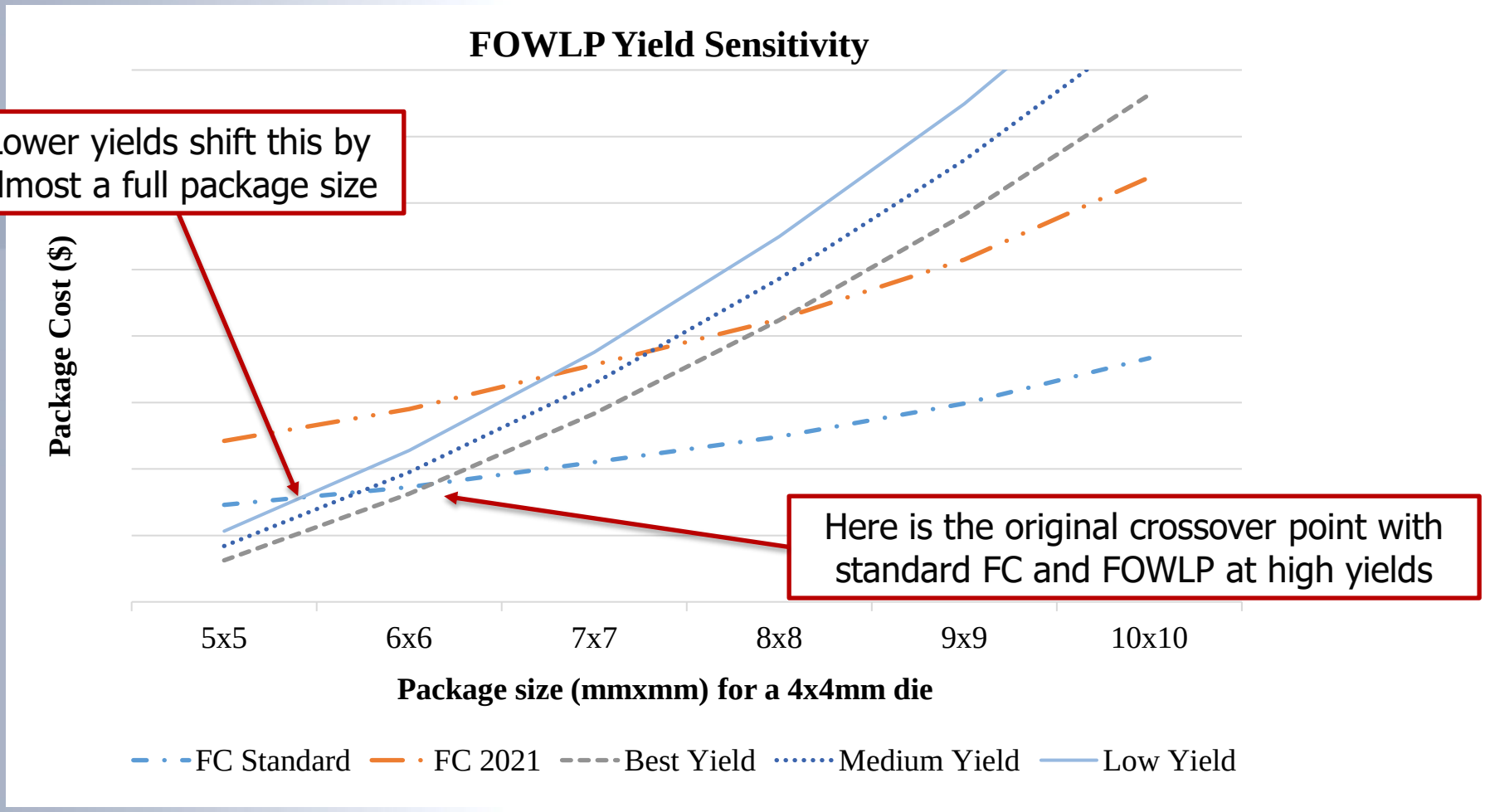
Changing Yield: FC vs FOWLP

- **Yield is an important component of cost**
- **FOWLP cost model considers defect density, not a set yield number (like assuming all packages, regardless of size, have a 99% yield)**
  - Upcoming charts are labelled low, medium, and high yield, since we can't label them with a specific yield number
- **Following charts assume a $1 die is being packaged in all cases**

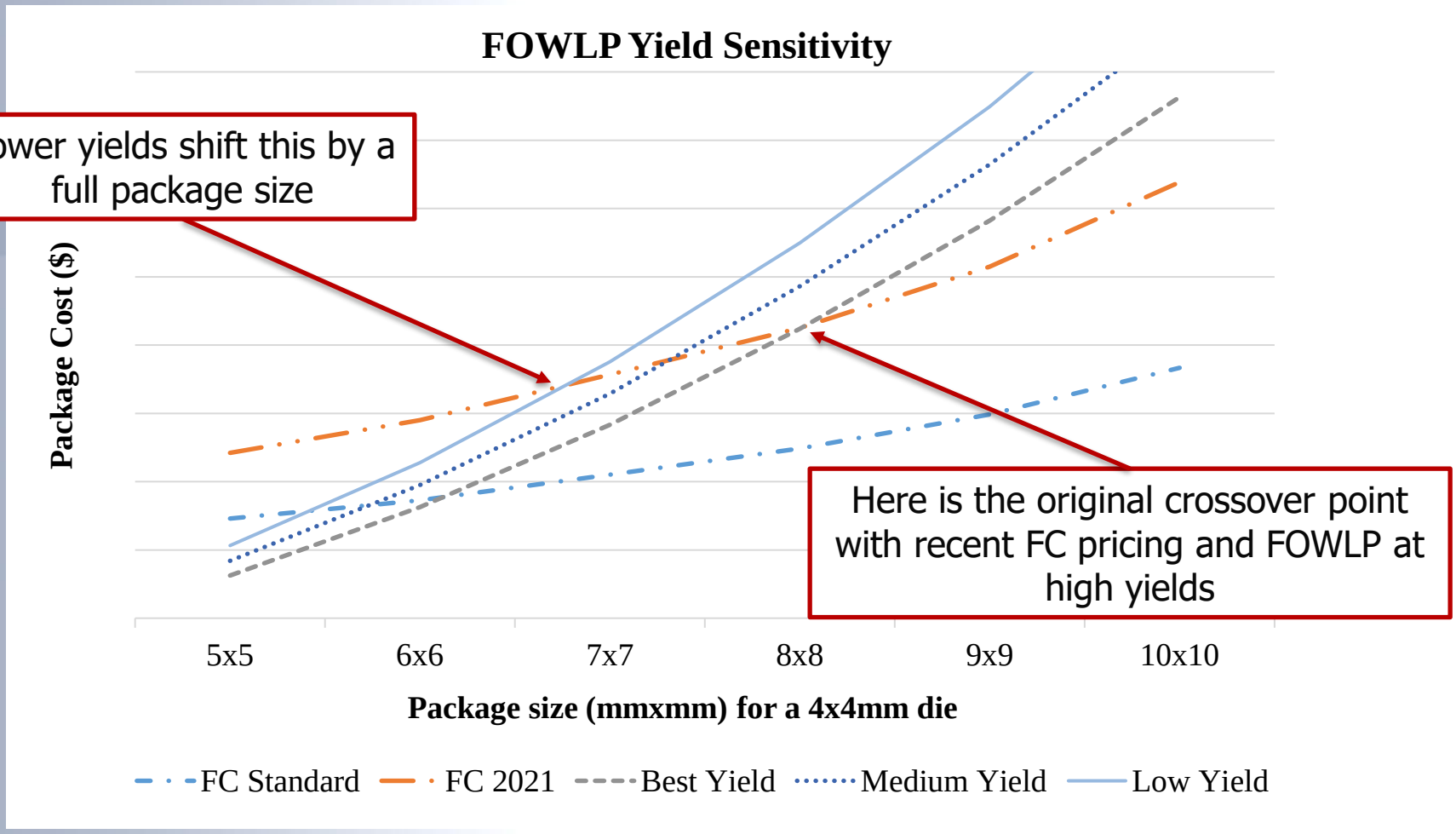
Changing FOWLP Yield: FC vs FOWLP



Changing FOWLP Yield: FC vs FOWLP



Changing FOWLP Yield: FC vs FOWLP



SUMMARY

Summary

- **FOWLP, FC, and WB packages have different cost drivers**
- **Selecting the right package for a design is already complex**
  - Supply chain issues further complicate this decision
- **Pricing changes driven by the pandemic make FOWLP appear cost-effective versus mature technologies in more scenarios than before**
- **Yield considerations can also shift the cost-effectiveness of FOWLP, regardless of whether we're considering old or recent pricing**