



# **Small Turbo-generator for DG & Hybrids**

Rolls-Royce / DOE contract DE-FC26-00NT40914

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# **Fuel Cell Hybrids: Market Assessment**

Resource Dynamics Corp. / DOE Contract via R-R

**Presentation to DOE Turbine Power Systems Conference  
Feb 25-27, 2002**

**Presented By: Bob Moritz, Allison Advanced Development Company**



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# Input to Market Assessment

Inputs from US industry/agency “averaged”:-

**Base (soon)**

**Near future**

**2010+**

	Skid cost	Install cost	O&M cost	Effy to electricity
Recip				
Turbine		<b>6 sizes 0.2 - 50 MW</b>		
ATS or CC				
Fuel Cell				
Hybrid				

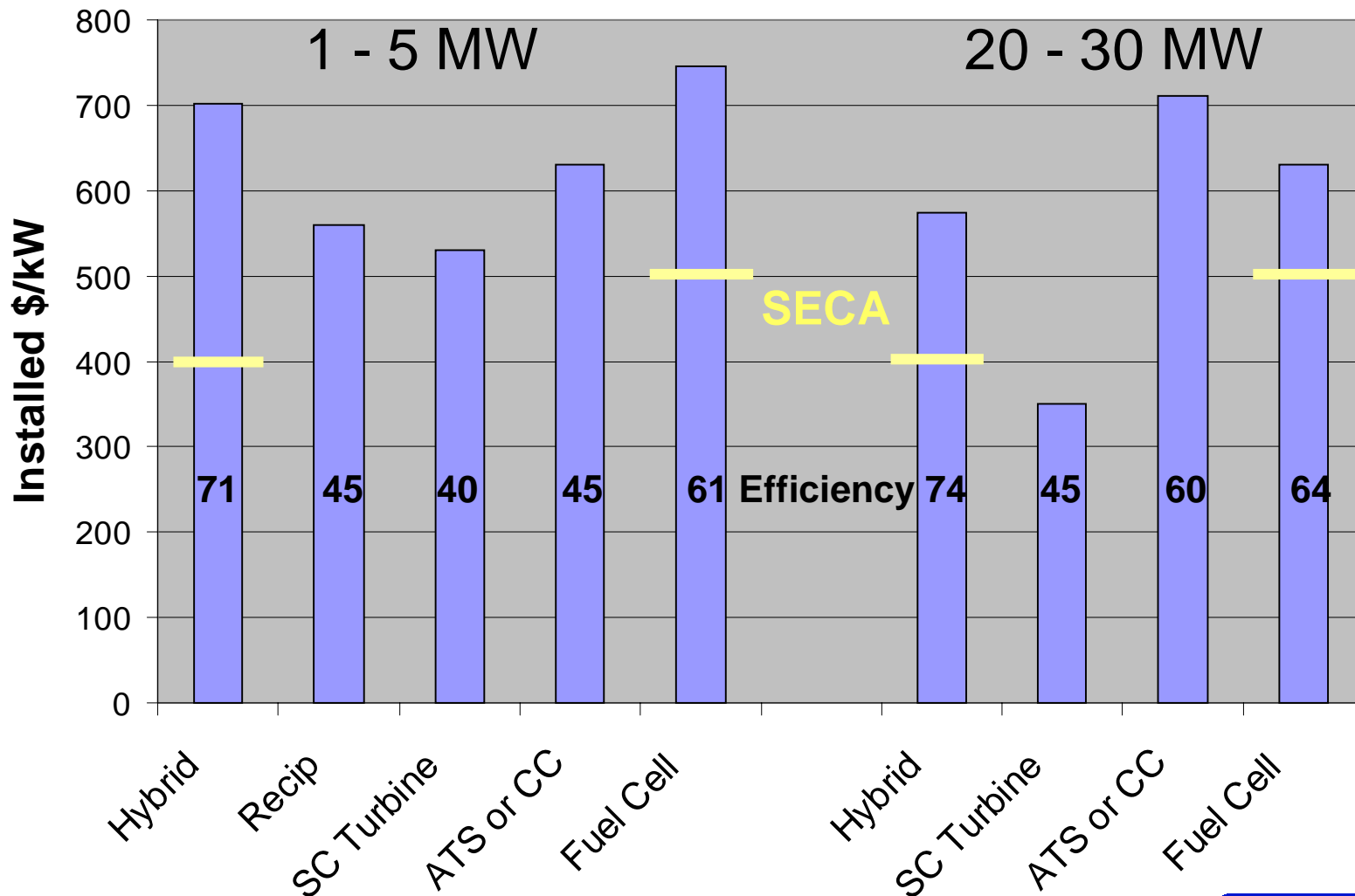
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# Cost indications used for study



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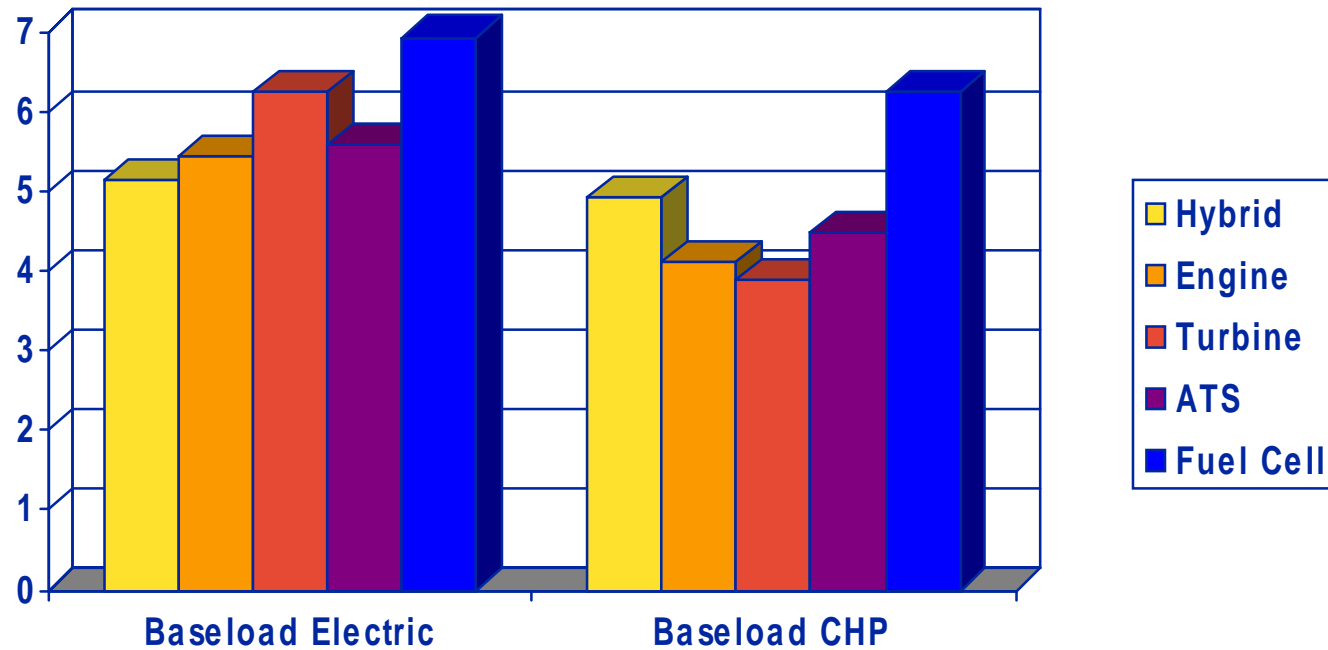


# Hybrid cycle CoE does not beat turbine CHP

2010+ 1-5 MW units



Cost of Electricity  
cents / kW-hr





# Market assessment parameters

- Customers
  - Municipal
  - Commercial buildings & aggregations (100)
  - Industries & aggregations (10)
  - Rural electrical cooperatives
- Plant competition
  - Turbines, Recips ...
  - The grid, by region ..... grid support may be an opportunity
- Site considerations
  - Fuel & grid availability
  - Industry type & size
  - No credit given for low emissions or low cost permitting



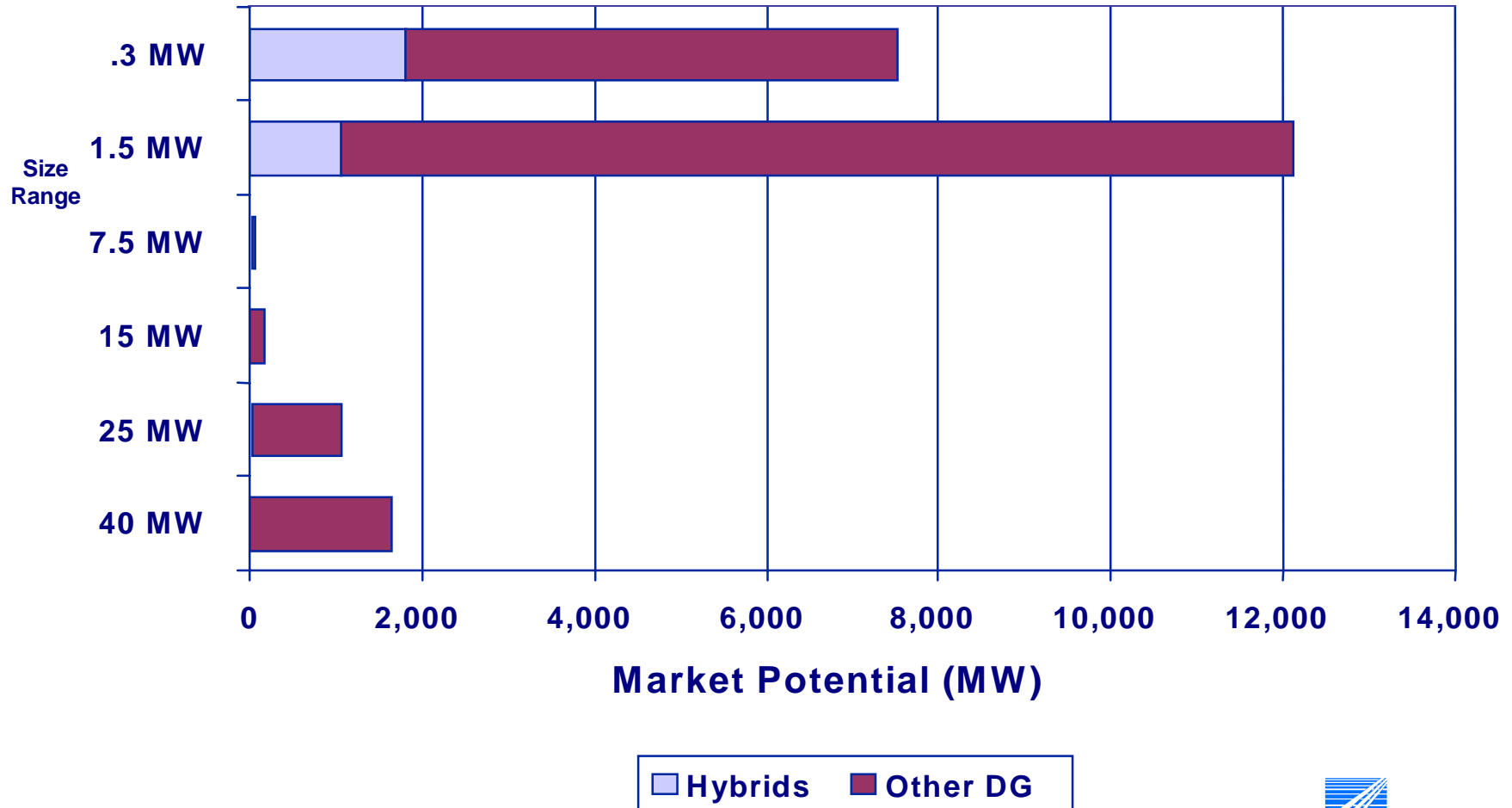
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# Single-facility DG will support small hybrids' launch

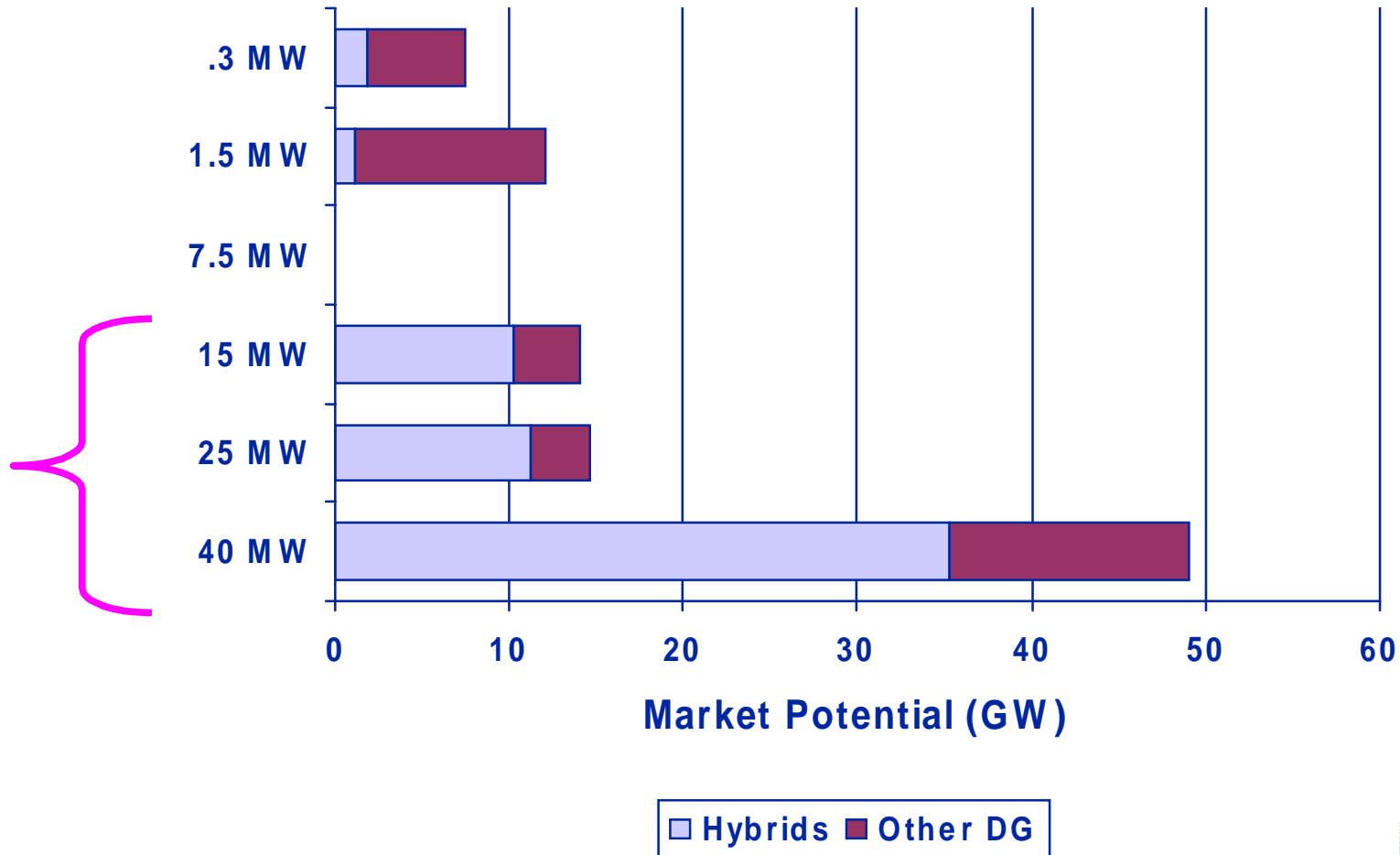
2010+ standard

## “Other DG” includes turbo-generators



# Larger hybrids DG potential by aggregation

2010+ standard





# Need for a fuel-cell turbo-generator



- Early SOFC hybrid market will be primarily 1-3 MW range
  - n x10 kW class hybrids need prior volume production to achieve right price
- Turbo output 200kW - 600kW at FCH turbine temperature
  - if single module
  - SECA fuel cell hybrid system module is expected to be smaller
- Pressure ratio > micro-turbine (DOE FCH study program)
- Not with a free power turbine (optimum flow control)
- MTBF >> 8000 hours (to retain adequate FCH availability)
- Prefer oil-free and direct drive alternator (DDA) “one-piece”
  - like some micro-turbines



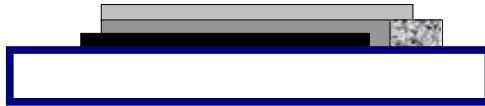
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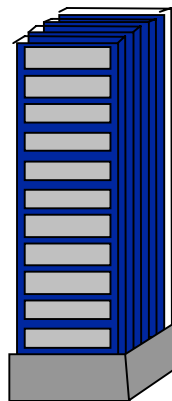
# Unit build-up from 1 Watt to 1 MW



Cell  
1 W

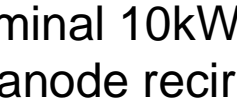
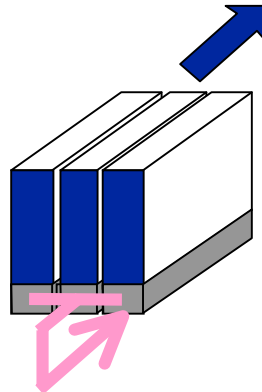


**Module**  
» 40 cells  
» 50W



**Bundle**  
» 12 modules  
» 500W

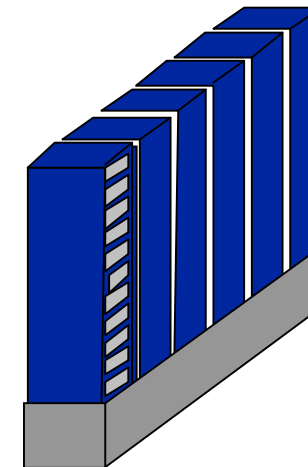
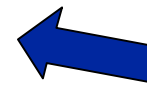
**Stack Block**  
» 3 strips  
» nominal 10kW  
with anode recirculation



**Pressurized 1 MW stack assembly**  
» 80 stack blocks

or

**SECA 50 kW module?**  
» 4 stack blocks



**Strip**  
» 6 bundles  
» 3kW



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# Commercial & development units



- Volvo VT600: aggressive PR 8.9, right size bracket, needs oil-free bearings & DDA “one-piece”
- P&WC ST5: right PR, right size bracket, oil-free but has free power turbine
- Capstone™ micro-turbine: neat design, oil-free & DDA but low PR & size << 1 MW flow
- Small aero-engines: have free power turbine



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# Design features

- Compound bearing system for minimum risk, low loss
  - AMBs at one or two cool stations, give levitation at all times. Favor Calnetix™
  - AMB also sets impeller axial clearance, sensed at impeller
  - Air bearing, at hot station by turbine, enhances system stiffness.
  - Maybe air journal bearing at cool end as well
- 2-stage axial turbine about 3% better  $\eta$  than radial
  - Weight & space occupied quite similar to radial.
- Self-pumped air-cooled stator for PM alternator
  - No added moving parts. <2% parasitic loss
- 34,000 RPM alternator lower cost than 3600 RPM
  - Partly compensates for power conditioning costs
- PR=7.5 has good  $\eta$  & long life using low cost alloys
  - Steel impeller, cast turbine blisks similar to model 250
- Genset cost very competitive



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## Integration with fuel cell

- Avoid ducting external to pressure vessel
  - Simplifies, e.g. No need for pressure-balanced bellows
- Capacity of TG set to supply stack in one PV
- Mounted on PV like a turbocharger on recip engine
- No combustor required for base-load plant
- Black-start capability aided by combustor
  - Probably not a feature of market entry product



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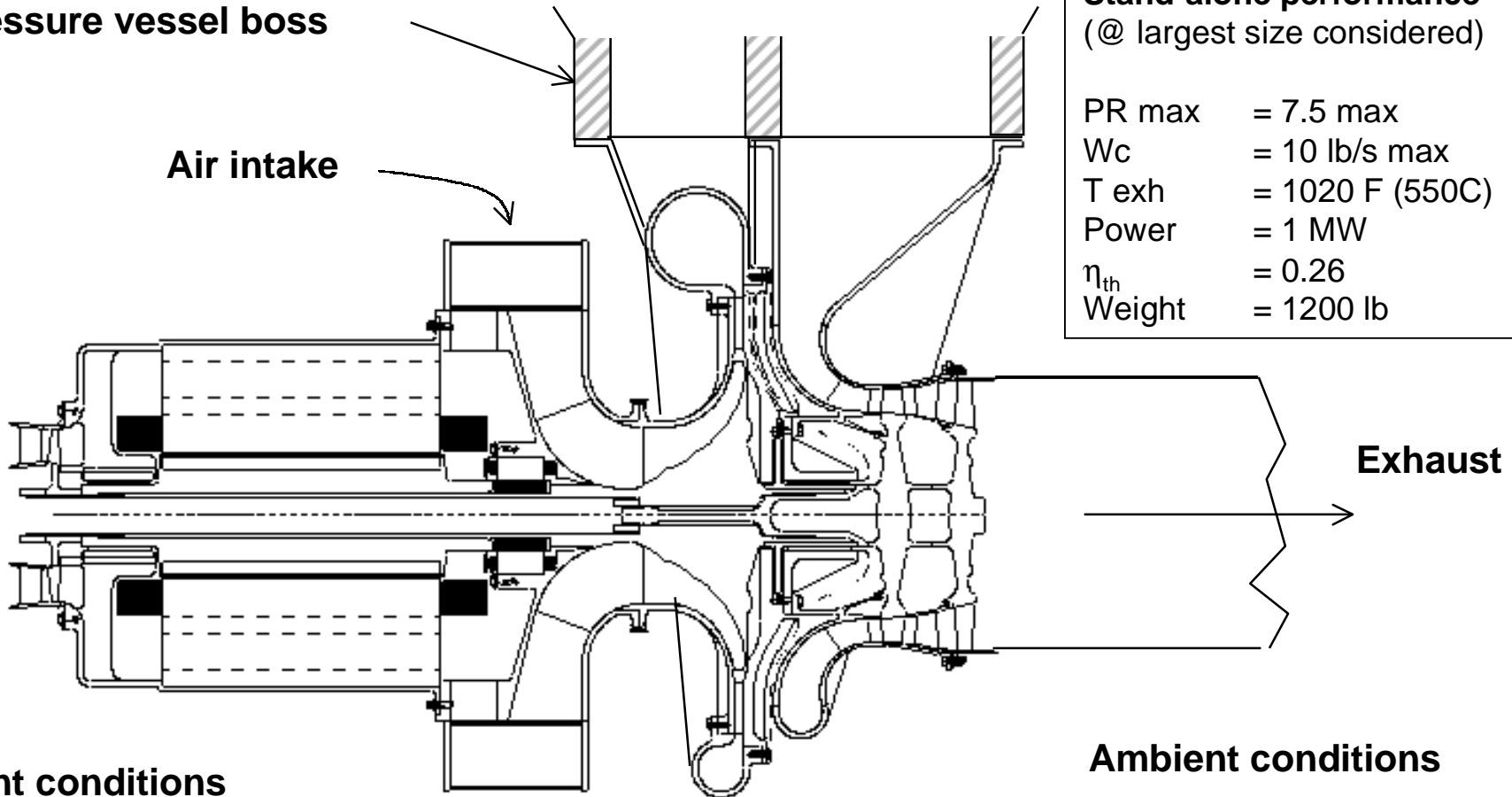


# Medium pressure ratio turbo-generator Fuel Cell Hybrid configuration



Mounted like a turbo-charger  
on pressure vessel boss

Air intake



**Stand-alone performance**  
(@ largest size considered)

PR max	= 7.5 max
Wc	= 10 lb/s max
T exh	= 1020 F (550C)
Power	= 1 MW
$\eta_{th}$	= 0.26
Weight	= 1200 lb

Exhaust

Ambient conditions

Ambient conditions



# Fuel cells will take over



- But some applications will take a little longer



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