#### **Buildings for Sustainable Energy**











Vítor Leal Cambridge | 2011.05.26



#### **Buildings for Sustainable Energy**

#### Vítor Leal<sup>1</sup>

<sup>1</sup> Faculdade de Engenharia da Universidade do Porto

Buildings represent about 40% of the demand of primary energy and about 60% of the consumption of electricity in developed countries. It was therefore realized long ago that they are a key-piece of Energy Systems, and difference types of programs or regulations to drive them towards energy efficiency have been implemented, with the equilibrium point being determined by both cost-effectiveness considerations and by cultural (mis)perception of the issue. Recent time however added complexity to the topic, as the miniaturization and cost reduction of local energy "production" allow a second way to mitigate the impact of buildings in the energy systems. Furthermore, the "demand efficiency" and the ""local generation" paths can be combined in a multitude of ways, whose optimum is significantly context-dependent. The frontline of research in buildings has therefore moved from its physics to system analysis, first of the building as systems on their own, but also on how buildings interact with the "whole" energy system. Examples of this are the research on how much building energy load can be eliminated or be made flexible at cost-effective levels, as well as which doses of incentives, positive or negative, are effective to drive consumers to system-friendly options.

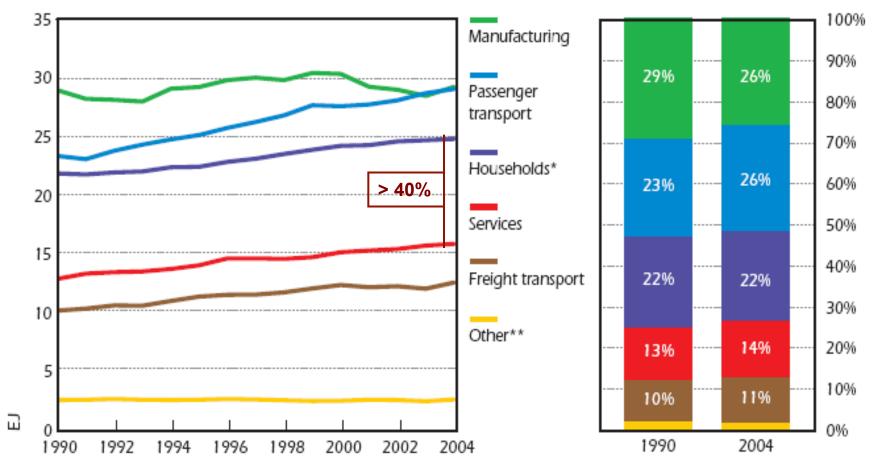




## Buildings in the Energy System

#### **Final Energy**

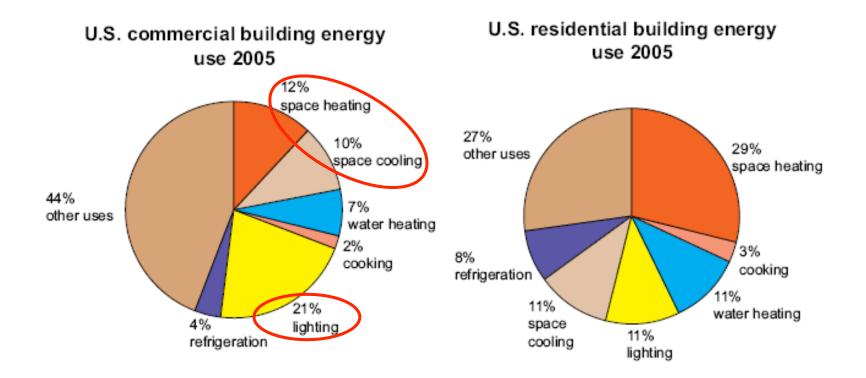
Total Final Energy Consumption in the non-residential building sector, IEA 14



Source: European Commission, 2008 - Energy and Transport , Trends to 2030 – update 2007; Universidate do Porto A 2007 - Energy Use in the New Millennium, Trends in IEA countries; Mckinsey & Company , 20 Sobal Ecology Menhand Growth: The Energy Productivity Opportunity



#### ENERGY USES (USA)



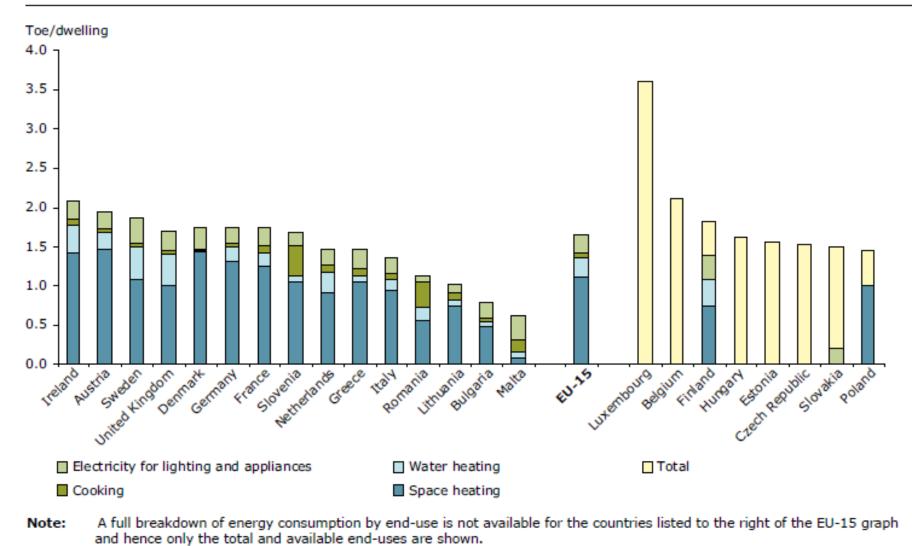
Comparison of the energy use (final energy) in commercial and residential sector (USA), in 2005. Source: M. Levine





#### **ENERGY END-USES IN RESIDENTIAL BUILDINGS EU**

#### Figure 6.2 Energy consumption by end use per dwelling, 2005



Source: Odyssee.

North Street

Source: EEA 2008

а

# Research related Heating, Cooling & time-agreggated energy balance





## Research related to Heating and Cooling

- Thermal characterization of materials
- Requirements for Human Comfort
- Manual calculation of Heating and Cooling Loads
- Accounting for Thermal Inertia
- Thermal characterization of building components
- Human requirements for Indoor Air Quality / Ventilation
- Analysis and design of Natural Ventilation
- Analysis and design of Daylighting
- Dynamic Simulation
- Efficiency of HVAC equipments
- Building-integrated Renewables



TIME



## **Policy Action**

- Requirements for thermal insulation
- Requirements for Ventilation
- Thermal Performance
- Energy Performance [EPBD]
- Certification and Labelling
- Regular inspections and energy audits
- Promotion / Enforcement of profitable EE measures [incl/ existing buildings]
- PassivHouse
- Net-zero Energy Buildings





TIME

#### Recast EPBD (1):

- The 'Stick-Carrot-Tambourine' approach
- 1) The 'Stick': Performance Requirements
- All new build "<u>nearly-zero energy buildings</u>" as of 2020 (public sector: 2018). Remaining energy need mainly covered by renewables
- b) Minimum energy performance requirements for <u>all</u> existing buildings that undergo an <u>energy relevant</u> renovation
- c) <u>Level of minimum energy performance requirements</u> for new buildings (until 2020) and renovations: <u>Benchmarking</u> to achieve cost-optimal levels
- Requirement for min. energy performance levels for <u>technical building systems</u> when installed, replaced or upgraded



0/10

http://www.buildup.eu/system/files/content/ELSEBERGER%20Presentation%20From%20recast%20to%20reality%20CoR%20EUSEW%2023032010.pdf

#### Recast EPBD (2): The 'Stick-Carrot-Tambourine' approach

- 2) The 'Carrot': Financing
- a) Stimulating financing mechanisms for energy efficiency investments
- b) Assessment of appropriateness & best practices of fin. instruments
- 3) The 'Tambourine': Information
- a) Strengthening the <u>role and the quality of energy</u> <u>performance certificates</u> – i.a. by quality checks & use of performance indicator in all advertisements
- b) Strengthening the <u>role and the quality</u> of Heating and AC system <u>inspections</u>
- c) Display of EP Certificates in public buildings

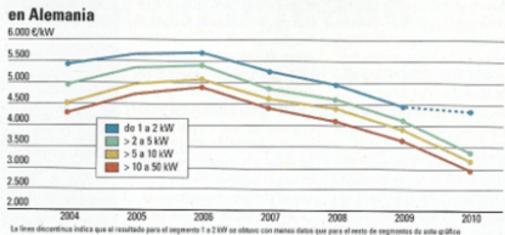


#### Renewable E. Technologies for Building Integration

- Solar Thermal
- Photovoltaics
- Wind Turbines
- Micro-CHP

- Maturation of Technology
- Increasing energy prices change context

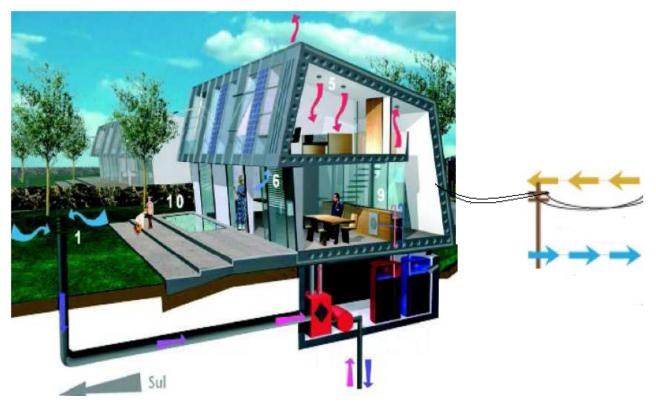






## Net-Zero Energy Buildings

 A Net-Zero Energy Building (NZEB) is a building that includes microgeneration and is bidirectionally connected to the grid so that it produces as much energy as it uses when measured on site on a annual basis











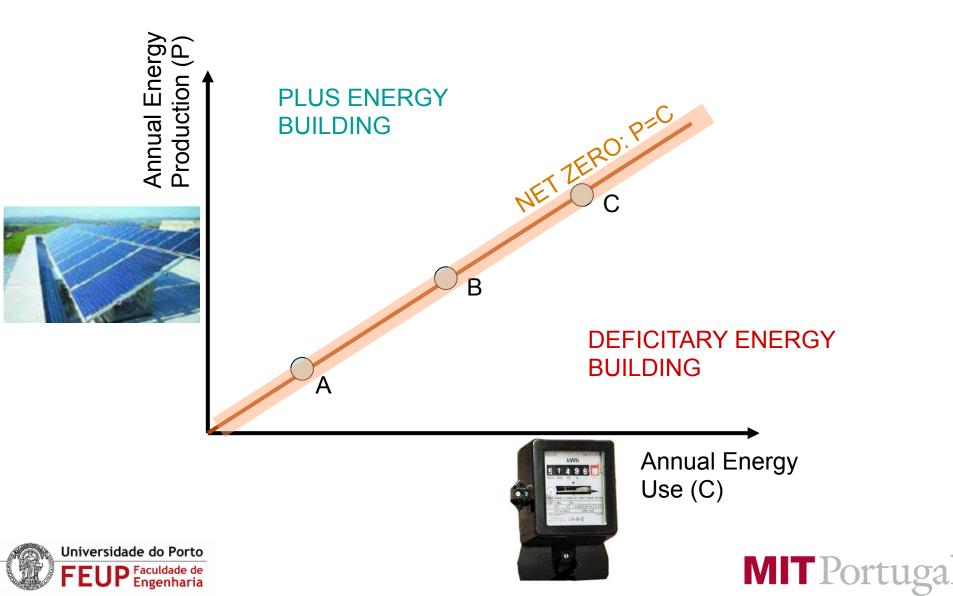


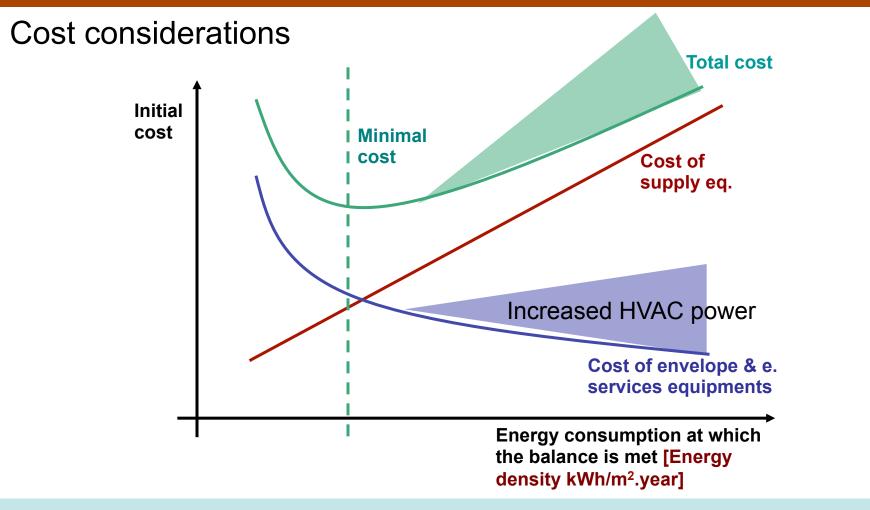
- It is proven that they can be built !
- So what now ?





## Net Zero Energy Building Concept





The point at which the minimal cost is met must depend significantly on the local climate – No "one size fits all" solution



#### DesignTool Interface

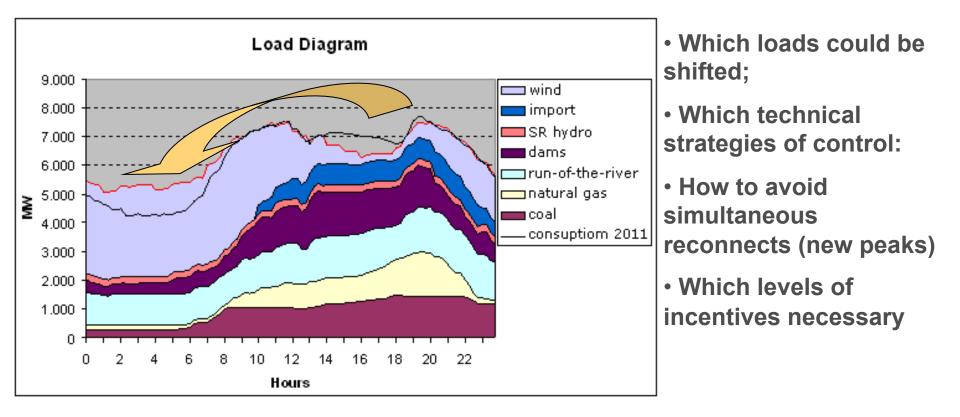
- Location	Equipment		- Outputs
Country Portugal	Heating Equipment Furnace or Boiler (non condensing)	Type of Lighting Non efficient	Energy Outputs
City Porto 🗸	Furnace or Boiler( condensing)	Efficient (50%)	Final Energy needs (KWh/year)
Pono	HP (air source)	Ultra efficient(100%)	Value Calculate
	HP (geothermal)		
- Envelope	Electric radiator		Primary Energy Needs (kgoe/year
- Building Geometry	AC system (conventional)		Value Calculate
	AC system (class A)	Microgeneration Information	
Useful Area (m^2) Value Inertia Low Addium	- User Defined	T Type of Equipment PV high efficiency	CO2 emissions (kgoe/year)
Shape Factor Value High 👻		PV regular efficiency	Value Calculate
	Type of Fuel consumed Gas 🔹	Small Wind Turbine	Calculate
Insulation		Mix of PV and Small Wind Turbine	I Microgeneration Energy output
	Efficiency or COP (%) Value	Solar Collector	PV module Power (W)
Insulation Level > 15 cm  About 0 are		Mix of PV and Small Wind Turbine	PV module Power (vv)
About 8 cm About 3 cm	Primary energy factor (kgoe/KWh) Value	and Solar Collector	Value Calculate
About 3 cm High V		Green electricity from network	Number of PV modules
	Cooling Equipment AC system (conventional)		Value Calculate
- Window Description	AC system (class A)	Roof Area (m <sup>2</sup> ) Value	Calculate
Window Type Single-glazed Clear (Aluminium)	None 👻	Evtra Free Onep Shace Area (m^2) Value	Wind Turbine Power (W)
Window Type Single-glazed Clear (Aluminium) Single-glazed clear (Aluminium with thermal break		Extra Free Open Space Area (m^2) Value	Value Calculate
Double-glazed Clear (Aluminium)	User Defined	Site Description	Number of Small Wind Turbines
Double-glazed clear(Aluminium with thermal break	Type of Fuel consumed Electricity	Rural	Value Calculate
Double glazed, low-e (Al)		Medium 👻	
Double glazed, low-e (AI with thermal break))	Efficiency or COP (%) Value		Solar Collector Power (VV)
Triple-glazed Clear (Aluminium)			Value Calculate
Triple-glazed clear(Aluminium with thermal break	Primary energy factor (kgoe/KWh) Value		Microgeneration
Triple glazed, lo w-e (Al) Triple glazed, lo w-e (Al with thermal break))		Price of Electricity sold to the grid (€kWh) Value	Energy Output (KWh/yr)
	DHW Equipment HP Water Heater		
Shading-		Cost of Electricity taken from the grid (€kWh) Value	Value Calculate
Shading Inside	Conventional Water Heater Conventional Water Heater (Tank Boiler(condensing)		
Outside	Boiler( condensing)	- Best Solution Design Strategy	- Economic predictions
None 👻		According to: C Energy Needs (KWh/year)	Initial Cost (€)
	Una Defined		Value Calculate
	User Defined	O Initial Cost (€)	
Type of Ventilation Natural	Type of Fuel consumed Electricity 💌	○ Life Cycle Cost (€)	Maintenance Cost (€per year)
Mechanical without HR		©	Value Calculate
Mechanical with HR	Efficiency or COP (%) Value		Payback Period(years)
H ybrid 🔻	Primary energy factor (kgoe/KWh)	Find	
	Primary energy factor (kgoe/KVVh) Value		Value Calculate

# Helping the Electric Grid





# Limitting [Deferring ?] the investments in generation and transmission infrasctructure

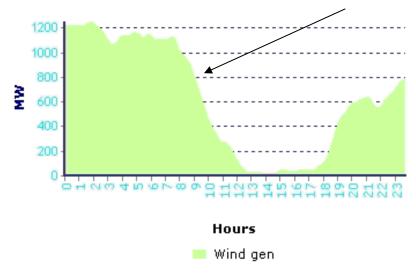






#### Enabling the integration of more Renewable E.

- Large scale wind generation deployment requires either central storage management or active load management (increasing consumption):
  - To increase load
  - To deal with reserves management



Wind Generation of 14 th February 2007 Source: REN (Portuguese TSO); http://ww.ren.pt

Storage or consumption is needed Load Diagram 9.000 🗆 wind 8.000 import 🛯 SR hydro 7.000 ∎dams 6.000 run-of-the-river ⊐natural gas 5.000 Š ∎coal 4.000 consuptiom 2011 3.000 2.000 1.000 n 10 12 14 16 18 20 22 Hours

> Prospective generation allocation in a winter windy wet day (2011)

In a wider perspective: to adapt the load to the supply interests [technical or economic or both] FEUP Faculdade de Engenharia

Slide authorship Prof. Peças Lopes / INESCPorto



#### On-site vs. Off-site offset for NZEBs

Universidade do Porto

Ε

UP Faculdade de Engenharia



Technology	Scenario	Levelized Cost* (€/kWh)
Micro PV	1, 2, 3	0.32
Micro Wind	4, 5, 6	0.21
Macro PV	7	0.20
Macro Wind (1500h)	8	0.07
Macro Wind (2500h)	9	0.04

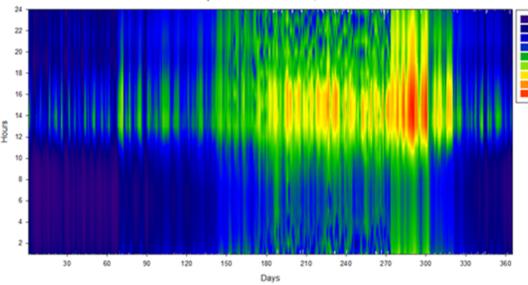
# Social / Behavioral issues





#### Resilience to Fuel Poverty

Temperatura do ar - Versão 3, Maia.





#### ÍPSILON | GUIA DO LAZER | CINECARTAZ | INIMIGO PÚBLICO



Peter Cook "Portugal merece mais do que uma arquitectura cool"

Portugal é um dos países da UE onde mais se morre de frio

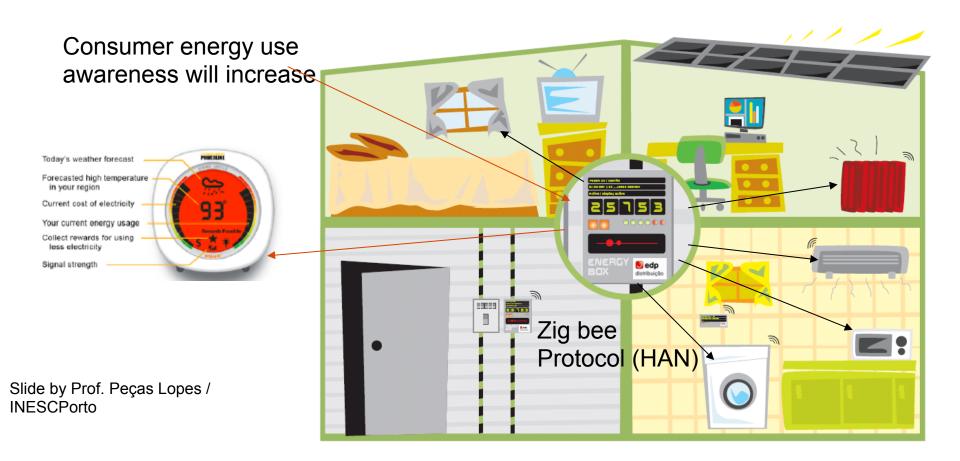
15.02.2010 - 12:53 Por Lusa





A falta de condições de isolamento das habitações poderá ter estado ontem na origem da morte de quatro idosos em Lisboa (Adriano Miranda (arquivo))

## Behaviors & attitudes incl/ Smartmetering

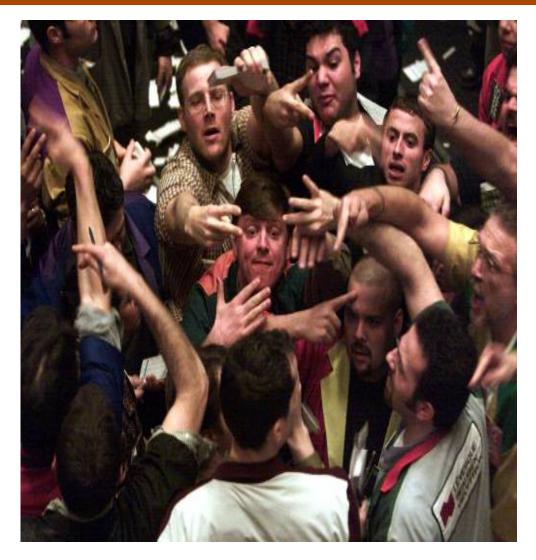


- Which information are users sentitive to ?
- Which incentives necessary to achieve a behavioral reaction ?





## Dynamizing the Local Economy







**MIT** Portugal



#### Role in Whole-Energy-System transformation

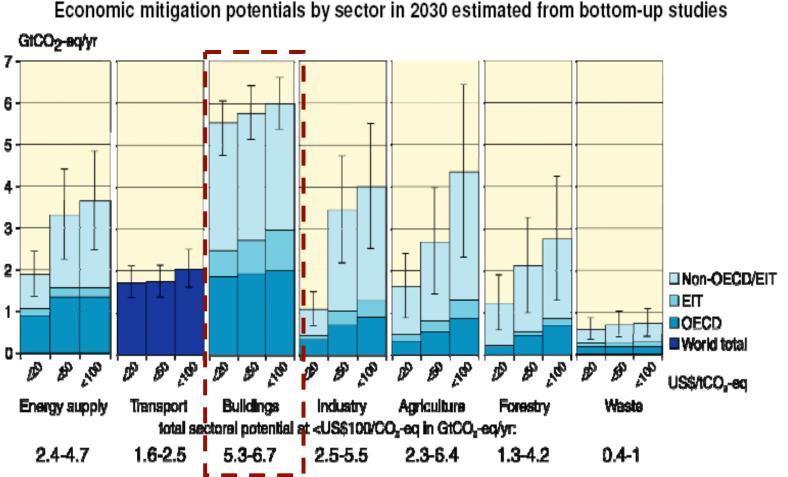


Figure 4.2. Estimated economic mitigation potential by sector and region using technologies and practices expected to be available in 2030. The potentials do not include non-technical options such as lifestyle changes. {WGIII Figure SPM.6}





# Thank You



